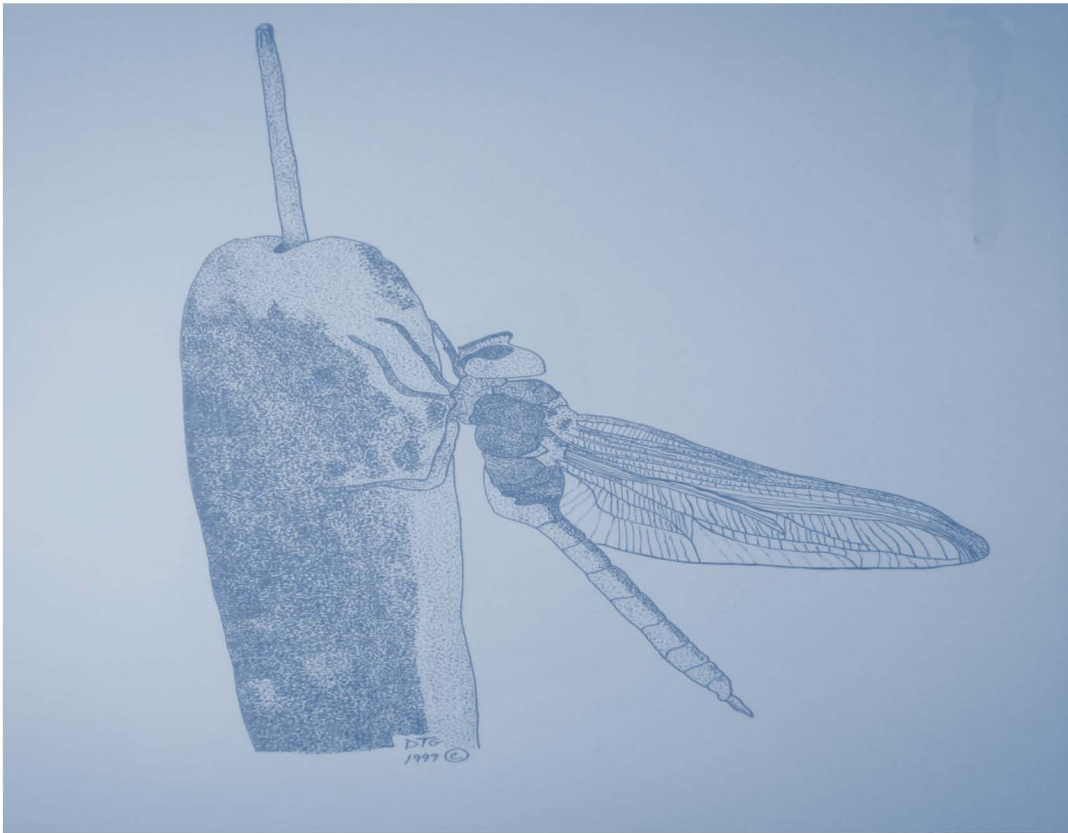


Science Education



in the Face of Social Change



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Image on the cover was drawn by Professor Daniel Gerber, Department of Biology, the University of Wisconsin - LaCrosse.

Most of the articles in this issue were amongst those presented at the Second World Conference of New Trends in Science Education that was held in Cracow, Poland from 2-5 July 2013. The host organizer of the conference was International Union of Biological Sciences' Commission for Biological Education (IUBS-CBE) Executive Committee Member Professor Katarzyna Potyrala, Pedagogical University of Cracow (Uniwersytet Pedagogiczny w Krakowie), Department of Science Education, Communication and Mediation, Podbrzezie 3, 31-054 Cracow, Poland. The theme of this conference was Science Education in the Face of Social Change. In addition to her affiliation with IUBS CBE, Professor Potyrala is a member of the European Commission on Community Research and Development Information Service. As she and Alicja Walosik have written: "Education must constantly be adapted to new needs. Educational tasks determine new styles of teachers' work and also their competencies, showing that the effects of the course of didactic process depend on the teacher's awareness to a large extent, way of understanding of the school's reality and the students themselves. Currently media are ever-present. Mass media and hypermedia shape new patterns and new values. In [this conference, we asked speakers to] attempt to answer the question: "What kind of biology teachers' competence is necessary in connection with the social changes?"

Education for Sustainable Development in the Programmes of Study for Natural Sciences

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The occurrences of global problems connected with environmental risks pose new challenges and increased demands for contemporary science. In order to prevent these problems more attention should be paid to the process of education within the field of sustainable development at higher education institutions. These education centres instruct students on the basis of research and accumulated knowledge, therefore their main objective should be to develop ecological awareness and ethics in the society. Higher education institutions are being expected to develop interdisciplinary forms of education related to ethical sensitization, which would prepare the society to solve problems related to sustainable development. The UN designated the years 2005 – 2014 “The Decade of Education for Sustainable Development”. The aim of this project is to implement the rules of sustainable development at higher education institutions, realized, in part, by creating new degree courses and subjects that tackle these issues. The idea of sustainable development and related matters are particularly visible within the fields of natural sciences, technical sciences, as well as agricultural, forest and veterinary sciences. The National Qualifications Framework published by the Ministry of Science and Higher Education encompasses guidelines as to the programmes of study for particular degree courses, however, each institution is given autonomy in creating their own educational programmes. The aim of this theoretical analysis and research is to obtain information about the opportunities to implement Education for Sustainable Development in the natural sciences at the Pedagogical University of Cracow, and to gain knowledge about the degree to which students are prepared to tackle the issue of sustainable development. For sustainable development at the higher education level, there is still no comprehensive vision as to the implementation of the assumptions of sustainable development in the basic subjects, degree-related subjects and or the specializations.

Keywords: higher education, sustainable development, natural sciences programmes

Występowanie globalnych problemów dotyczących zagrożeń środowiskowych stawia przed współczesną nauką nowe zadania i rosnące wymagania. W celu przeciwdziałania tym problemom, należy położyć większy nacisk na proces kształcenia w zakresie zrównoważonego rozwoju na uczelniach wyższych. Wyższe uczelnie kształcą studentów w oparciu o prowadzone badania i posiadaną wiedzę, dlatego ich głównym zadaniem powinno być kształtowanie świadomości i etyki ekologicznej w społeczeństwie. Coraz bardziej oczekuje się od nich rozwijania interdyscyplinarnych form kształcenia w połączeniu z uwrażliwianiem etycznym, które przygotowywałyby społeczeństwo do rozwiązywania problemów związanych ze zrównoważonym rozwojem. Lata 2005 - 2014 zostały ogłoszone przez ONZ „Dekadą Edukacji dla Zrównoważonego Rozwoju”. Idei tej przyświeca cel wdrażania na uczelniach zasad zrównoważonego rozwoju, co jest realizowane m.in. poprzez tworzenie nowych kierunków studiów i przedmiotów podejmujących tę tematykę. Termin zrównoważonego rozwoju oraz zagadnienia z nim związane występują szczególnie w obszarze nauk przyrodniczych, technicznych oraz nauk rolniczych, leśnych i weterynaryjnych. Krajowe Ramy Kwalifikacji wydane przez MNiSW zawierają wytyczne dotyczące programów kształcenia na poszczególnych kierunkach w szkołach wyższych, jednakże oprócz zawartych w Ramach zapisów, uczelnia ma pełną autonomię w zakresie tworzenia programów kształcenia. Celem podjętych analiz teoretycznych i badań jest uzyskanie informacji o możliwości realizacji założeń Edukacji dla Zrównoważonego Rozwoju w programach kształcenia kierunków przyrodniczych na Uniwersytecie Pedagogicznym oraz o stopniu przygotowania studentów do realizacji zagadnień zrównoważonego rozwoju. Mimo wielu realnych postępów w edukacji dla zrównoważonego rozwoju na poziomie wyższym, nadal nie ma kompleksowej wizji uwzględniania założeń zrównoważonego rozwoju w grupach przedmiotów podstawowych, kierunkowych, a także w ramach specjalności, poprzez które można docierać z wiedzą o zrównoważonym rozwoju do wszystkich studentów.

Introduction

Sustainable development constitutes a great challenge for the process of influencing the awareness of various groups in the society. There is a need for optimal didactic and educational solutions, encompassing educational aims and content as well as forms and methods of teaching that would prepare pupils for active participation in everyday life facing challenges of the contemporary world. Challenges result from the escalation of various social, economic, political and environmental processes that have been taking place at the global and

regional scale, and from the threats they bring about. They include: the negative changes in the natural environment, social and economic crises, globalization consequences, technological and IT progress, the growing significance of environmental knowledge in solving global problems, and decreases of interest in environmental sciences among the youth. Additionally, there is a lack of social recognition of the importance of environmental education and, finally, difficulties in describing the scope of environmental knowledge necessary for the

contemporary societies. In the course of their studies students at higher education institutions become acquainted with the above problems while studying various subjects. Most of the time, however, there is not enough opportunity for them to take a broad view of these complex processes. As teachers, however, they will be required to teach pupils to experience the world in a holistic way and practise problem-based thinking which takes into consideration the influence of various factors on the processes they learn about. Given the lack of integration between particular higher education courses, there is a growing need to present students and teachers with views on social, economic and environmental problems, as seen from the point of view of teaching and didactics. And, to acquaint them with the often contradictory general pedagogical and didactic paradigms, theories and suggestions for practical solutions. It is therefore necessary to prepare students to analyse critically the reports and prognoses pertaining to the state of the natural environment, economy or education. It is also necessary to present the links existing between the processes of education of teachers of Natural Sciences and Biology, and the process of teaching and learning.

The reforms of the educational system pose new challenges for the schools as they modify simultaneously educational aims, tasks, content as well as methods of teaching and pedagogical care. These changes, accompanied by the growing expectations of society with respect to education, broaden the functions of schools and the tasks of teachers in the process of preparing pupils for partaking in social life.

In their everyday life, young people might either contribute to or – quite the opposite –

detach themselves from the ideas and assumptions of sustainable development. It depends to a great measure on the everyday environment in which they are brought up and function within, and the relevant models of behaviour passed on to them.

Since the birth of the concept of sustainable development, education has been perceived as the key ingredient for its achievement. The obligations to implement education for sustainable development (ESD), made at the international forum, contain advice as to the aims, tasks, methods as well as groups and areas of influence. At present, the realization of ESD should be based on guidelines proposed in “The Decade of Education for Sustainable Development” (2005-2014), and on the Strategy for Education for Sustainable Development (2008) of the United Nations Economic Commission for Europe. Particularly important, for the implementation of sustainable development, are the schools and universities.

The issues relating to environmental protection and management in the context of sustainable development constitute nowadays one of the main areas of interest for the society, science and education. National policies perceive environmental education as one of the main methods of implementing sustainable development of the society and economy. The level of environmental awareness in the society is a condition for the acceptance of such policies. It would be difficult to imagine active participation of the society even in the best-prepared programmes if the way for it has not been paved by the earlier process of education (Rybska, 2010).

Ecological and environmental education is a concept of education and pedagogical

instruction conducted in the spirit of respect for the natural environment and assumes managing social opinions about the surrounding environment. It requires sensitizing people to the environmental problems, looking for the causes of these problems, and envisaging the results of activities leading to the degradation of natural environment.

Ecological education encompasses a broad spectrum of teaching methods and educational content. Its aim is to integrate various subjects and specialties. Apart from supplying knowledge about the natural environment, ecological education aims to influence and develop universal capabilities for undertaking common initiatives at the levels of school, district, regional government and region. Ecological education implies full participation of students and members of the local society in conducting projects, which leads to undertaking practical activities for the benefit of the environment.

An important role in the process of ecological education is played by teachers whose aim is to build a system of values in which the natural environment is an overriding objective. Teachers should motivate pupils to undertake activities beneficial for the environment; they should also become leaders of pro-ecological activities in schools and in the local society.

Educational policy formation is scarred by a dilemma which is difficult to solve. On one hand, there are overloaded educational programmes and there is massive knowledge to be transmitted. On the other hand, is the necessity to prevent the ecological crisis which threatens our civilization. The proofs of which are quoted by various scholars

warning against ecological catastrophes (e.g. Al. Gore, 1997; Biernacki, *et al.*, 2009). It is expected that the level of environmental threats can be lowered by increasing the knowledge and ecological awareness of various social groups. This idea constitutes the basis for implementation of necessary knowledge about the environment and about managing its resources.

Education is perceived as a necessary condition for the implementation of sustainable development. The overriding aim of the schools and universities is to support comprehensive development of their learners and to prepare them for functioning in the contemporary world.

The Strategy of Education for Sustainable Development (2008), describes specific aims, points out tasks and provides guidelines ensuring that ESD implementation is successful in all indicated areas of influence. The main recommendation of the strategy is to include the theme of sustainable development in educational programmes at all levels of the educational system.

If the ESD is to become a part of the programme of changes towards a more sustainable society, it requires research and cooperation of a wide range of agents. The outcome of research should be made public and implemented in various elements of the educational system and put into practical use. Education for sustainable development should be implemented by means of including topics related to SD in all school subjects; it should enable the acquisition of relevant experiences in the course of learning as an outcome of active participation in SD and compliance with its guidelines.

Ecological education and education for sustainable development should mostly utilize active methods of teaching which boost learners' activity, increase the efficiency of teaching and learning, enable the development of creative thinking, and are conducive to active involvement in the issues. One of the main elements of ecological education should be a particular focus on bringing up future generations in the spirit of respect for natural environment and consideration for sustainable development. Therefore, the framework of ecological education should include interdisciplinary education. Such perception of education for sustainable development will enable the implementation of the following aims:

- Develop an awareness and raise interest in the interconnected nature of economic, social, political and ecological issues;
- Enable everyone to acquire knowledge and life skills as necessary for the improvement of the state of the environment;
- Create new role models and influence opinions, values, views of individuals and societies, taking into consideration the care for the quality of the environment.

Ecological education is described as one of the basic elements of the "National Environmental Policy of the State", alongside the legal and administrative instruments, systems of control and monitoring, and scientific research (Papuziński, 2000; Kostecka, 2009; Borys, 2010). At the beginning of the twenty-first century, the ecological policy of Poland must be able to meet the challenges brought by the new political, social and economic situation. We need to face challenges which

result from national and global advancements in science and technology. One of the aims of the ecological policy is to develop ecological awareness of various groups of the society, as well as to increase their active participation in specific activities undertaken for the benefit of the environment and in activities which enhance the overall effectiveness of pro-environmental initiatives.

The "National Environmental Policy of the State" is implemented by: The creation of legal and material conditions for the participation of individual citizens, social groups and non-governmental organizations in the process of shaping a model of sustainable development; The simultaneous development of ecological education, raising ecological awareness and sensitizing the public to issues concerning ecology; and The creation of new code of ethics regarding our behaviour towards the environment ("National Environmental Policy of the State", 2008). Another document which identifies and ranks the main aims of ecological education and indicates opportunities for their implementation is the "National Strategy of Ecological Education". The introductory part of the document presents ecological education as an international obligation and explains the status, significance and aims of the strategy itself. One part draws attention to the significance of the concept of sustainable development: *The need to implement eco-development, understood as an entirety of harmonious activities of an individual who utilizes natural resources in a rational, responsible and sustainable way, is currently an urgent issue worthy to be elevated above all divisions* ("National Strategy of Ecological Education", 2001). At the same time, ecological education is

identified as an important element of civic education conducive to the development of a society that accepts the rules of sustainable development, is able to assess environmental risks and can partake in decision-making processes. The basic aims enumerated in the strategy pertaining directly to education are:

- Promotion of the concept of balanced development in all spheres of life, taking into consideration the workplace and free-time activities, i.e. permanent ecological education of all social groups;
- Implementation of ecological education as interdisciplinary education at all levels of formal and non-formal education;
- Development of ecological education programmes at the levels of voivodships, powiats and local government units as a form of expansion of the “National Strategy of Ecological Education” (2001);
- Promotion of the guidelines of ecological didactics and ecological education (“National Strategy of Ecological Education” 2001, p. 10).

Higher education institutions in Poland base their teaching on the National Qualifications Framework published by the Ministry of Science and Higher Education. It comprises general guidelines as to the programmes of study for particular degree courses in higher education institutions; however, apart from the guidelines, each higher education centre is given autonomy in creating their own educational programmes.

The document is very general. However, it also contains passages pertaining to education for sustainable development which is implemented in only a few degree

courses. It is worrying that there are no national standards imposing the requirement for education for sustainable development to be a part of all higher education courses.

The National Qualifications Framework requires students to gain knowledge and skills relating to sustainable development only in the case of:

- natural sciences (*The Resolution of the Minister of Science and Higher Education of 2 November 2011 on the National Qualifications Framework for Higher Education*).
- agricultural sciences, forest sciences and veterinary sciences (*The Resolution of the Minister of Science and Higher Education of 2 November 2011 on the National Qualifications Framework for Higher Education*).

The aim of this paper is to present and analyse the preliminary results of a Questionnaire administered to students of degree courses in natural sciences: *Biology, Chemistry and Environmental Protection*.

The research aimed to:

- assess students’ comprehension of the concept of sustainable development, its significance and aims,
- assess students’ involvement in implementing the principles of sustainable development in everyday life,
- obtain information allowing for modification of programmes of study.

In developing the survey Questionnaire it was assumed that students studying Biology, Chemistry and Environmental Protection should possess at least basic knowledge about sustainable development, its significance, as well as about the interrelations between natural environment, society and economy. An in-depth analysis of the educational content of the environment-related subjects within the framework of the above courses allowed for identifying issues relating to sustainable development. Most of the content, however, only indirectly related to sustainable development which means that the implementation of knowledge related to this issue is to a great extent dependent on the authors of educational programmes for these subjects and on the academic teachers themselves. The courses which educate future teachers require only the achievement of social competencies, and the problem of sustainable development is treated in a very superficial way – mainly as professional self-development and lifelong learning.

Main research problem

Are the students of degree courses in natural sciences prepared to implement the elements of sustainable development? To what extent?

Specific research problems

1) Can students of natural sciences degree courses correctly interpret the definition of sustainable development?

2) Do they know the assumptions of "sustainable development" and implement them in everyday activities undertaken for the benefit of the local environment?

3) What are the sources that students use mostly for gathering information about "sustainable development"?

4) Do environment-related classes (conducted within the framework natural sciences degree courses) tackle issues pertaining, among others, to economic development, social problems in the world, human rights, rational production, and consumption which does not pose risks to the environment?

5) Do the courses under research promote such values as, for example, respect for the environment, health, cultural tolerance, peace and safety?

In order to assess the level of knowledge about sustainable development among students a diagnostic poll method was used. The research method used was a questionnaire.

The research was conducted from January to March 2013. It included 73 students of full-time degree courses in natural sciences (26 students of Environmental Protection, 26 students of Biology and 22 students of Chemistry) studying at the Pedagogical University of Krakow.

Table I. Data about the respondents

Data about the respondents	Degree courses					
	Biology		Chemistry		Environmental Protection	
	N	%	N	%	N	%
Women	25	96	19	88	20	77
Men	1	4	3	12	6	23

The choice of students of natural sciences courses was dictated by an attempt to measure the knowledge about environment-related conditioning factors of sustainable development among young people who connect their professional career with environmental knowledge, managing and protecting the natural environment, and the relations between people, natural environment and economy. Understanding the level of students' knowledge about the issue allowed us to modify and amplify the educational programmes of subjects taught within the framework of the above courses.

Results

The first question in the questionnaire pertained to the knowledge of the concept of "sustainable development". The analysis of the results obtained allows for drawing a conclusion that not all of the students of the three courses under research knew the term "sustainable development" (Table II).

The highest number of correct answers was given by students of Environmental Protection (19 respondents out of 26, or

73%). According to most of these students, sustainable development connects economic development with respect for natural environment and with social development, creating better perspectives for future generations. Such a definition, widely used today, was formulated in 1987 in the report of the World Commission on Environment and Development also known as the "Brundtland Commission Report."

Correct (or almost correct) definitions of sustainable development were given in greatest numbers by the students in the third year of Environmental Protection. The least correct definitions of "sustainable development" were given by students in Biology – only half of the respondents gave correct answers.

The next question required the students to describe the circumstances in which they had encountered for the first time the concept of "sustainable development". It was an open question. The results can be grouped into five categories (Table III).

Table II. Understanding the term "sustainable development"

Understanding the term "sustainable development"	Degree Courses					
	Biology		Chemistry		Environmental Protection	
	N	%	N	%	N	%
Correct definition	13	50	13	59	19	73
Incorrect definition	13	50	9	41	7	27

Table III. Educational stage/situations in which respondents encountered for the first time the term "sustainable development".

<i>SITUATIONS IN WHICH STUDENTS OBTAINED INFORMATION ABOUT SUSTAINABLE DEVELOPMENT</i>	DEGREE COURSES					
	Biology		Chemistry		Environmental Protection	
	N	%	N	%	N	%
Upper secondary school – subject: Biology	3	11	-	-	12	46
Upper secondary school – subject: Geography	2	8	8	36	4	15
Didactic classes within the framework of the degree courses	18	69	7	32	10	38
Personal research	1	4	7	32	-	-
Lower secondary school - subject: Introduction to Entrepreneurship	2	8	-	-	-	-

The knowledge about “sustainable development” was obtained by the students in various situations and at various educational stages. In most cases, information on the subject was gained in upper secondary schools during Biology and Geography classes (for respondents studying Environmental Protection and Chemistry). On the other hand, the respondents studying Biology pointed out classes within the framework of their degree course as the main source of information about sustainable development (69% of the respondents). In the case of students of Environmental Protection and Chemistry, the classes were listed on the second position. A large number of students answered also that they had become familiar with the concept of sustainable development only during their studies while studying subjects such as “Ecology” and “Environmental Protection Law” (38% of Environmental Protection students and 32 % of Chemistry students). 32% of Chemistry students indicated their personal research as a source of information about SD. Among the respondents who studied Biology and Environmental Protection, the number of persons indicating their individual research as the source of information about SD was respectively negligible (one respondent) or equal to zero.

The fundamental document relevant for the dissemination of the idea of stable and sustainable development and environmental education is Agenda 21 – a global action plan for sustainable development into the 21st century. It contains basic guidelines pertaining to the management and protection of the human natural environment, focusing on its numerous social and economic conditioning factors, protection of natural resources and rational management of these

resources in order to assure stable and sustainable development. Agenda 21 comprises four parts. The first part is devoted to social and economic issues. The second and most lengthy part describes the problems of protection and management of natural resources from the point of view of eco-development. The third part of the document is devoted to the roles of main social groups and the necessity to increase their participation in the implementation of Agenda 21. The last part of the document pertains to the opportunities for implementation of particular tasks and recommendations. Agenda 21 constitutes the basis for undertaking activities, marking out aims and ways of behaving, accordingly to local problems and conditions, possibilities and priorities of particular states, albeit in accordance with the declaration undertaken in Rio de Janeiro relating to natural environments and development. The Polish version of Agenda 21 was published in 1993 in the volume, “Final Documents of the UN Conference on Environment and Development.” Our Questionnaire requested the respondents to describe the significance and essence of that document, in particular for the activities undertaken for the sake of sustainable development (Table IV). Among Biology students, 73% of the respondents correctly identified the Agenda 21 document as a global programme for sustainable development. Most of the Environmental Protection students (58%) were aware of the fact that the above document was passed and implemented, whereas 42% of students of that course defined incorrectly the significance of the discussed document. Students of Chemistry presented a very limited knowledge about the document (only 41% of them gave correct descriptions).

Table IV. Knowledge about the significance of Agenda 21.

WHAT IS AGENDA 21?	DEGREE COURSE					
	Biology		Chemistry		Environmental Protection	
	N	%	N	%	N	%
Global action plan for sustainable development into the 21st century	19	73	9	41	15	58
Environmental protection act	5	19	6	27	6	24
Economic and development programme of the UN	2	8	7	32	5	18

Table V. Spheres of sustainable development

SPHERES OF SUSTAINABLE DEVELOPMENT	DEGREE COURSES					
	Biology		Chemistry		Environmental Protection	
	N	%	N	%	N	%
Economic development	12	46	9	41	24	92
Health care	24	92	14	64	12	46
Protection of natural environment and resources	25	96	20	91	26	100
Social development	15	58	16	73	18	69
Sex equality	7	27	5	23	0	0

Environmental protection problems are a result of the development of industry, advancements of technology and changes in lifestyle, which do not always compliant

with nature. As with every type of problem, an action strategy arises. In this case, its aim is to stop the process of degradation and prevent its negative consequences. In order

to attain a fully sustainable model of life one has to be aware of and be ready to implement on an everyday basis, the principles of “sustainable development”. It is therefore related to specific tasks in various spheres of life: economy, health care, environment, social existence and sex equality.

The next item in the Questionnaire pertained to the selection of the three most significant spheres of sustainable development, according to the students’ own opinions (Table V).

The responses indicate that the environmental aspect of sustainable development was by far the most popular (96% of Biology students, 91% of Chemistry students and 100% of Environmental Protection students) followed by economic development in the context of equal division of profits (92% of Environmental Protection students) (Table 5). The choice was very apt and in line with the main assumptions of the report, “Our Common Future” of the World Commission on Environment and Development of 1987.

The next question in the Questionnaire pertained to the sources from which the respondents gained knowledge about sustainable development. It was an open question. The respondents mostly indicated as the sources: literature, academic course books, popular-scientific journals, the Internet, classes within the framework of their degree courses, and the Environmental

Protection Law. The source which proved most popular among the students of Environmental Protection and Chemistry was the Internet. It was chosen by 100% of the students of Environmental Protection and 92% of the students in Chemistry. 69% of the Biology students stated that they do not look for information about sustainable development. The Internet was listed in the second position (27% of responses). As to other sources of information about SD, most of the students of Environmental Protection (62%) and Chemistry (72%) indicated using literature, academic course books and journals to broaden their knowledge about sustainable development. The respondents studying Biology rarely used other sources of information (7% indicated television and classes within the framework of their course).

The Questionnaire also included a question about what issues relating to sustainable development are discussed during environment-related classes within the respondents’ degree courses. The issues pertained, among others, to economic development, global social problems, human rights, sustainable production of goods, and consumptions that cause no threats to the environment. In case of all three researched degree courses (Biology, Chemistry and Environmental Protection) the classes tackled problems which related directly or indirectly to the concept and assumptions of sustainable development. The results are presented in Figures 1, 2, & 3.

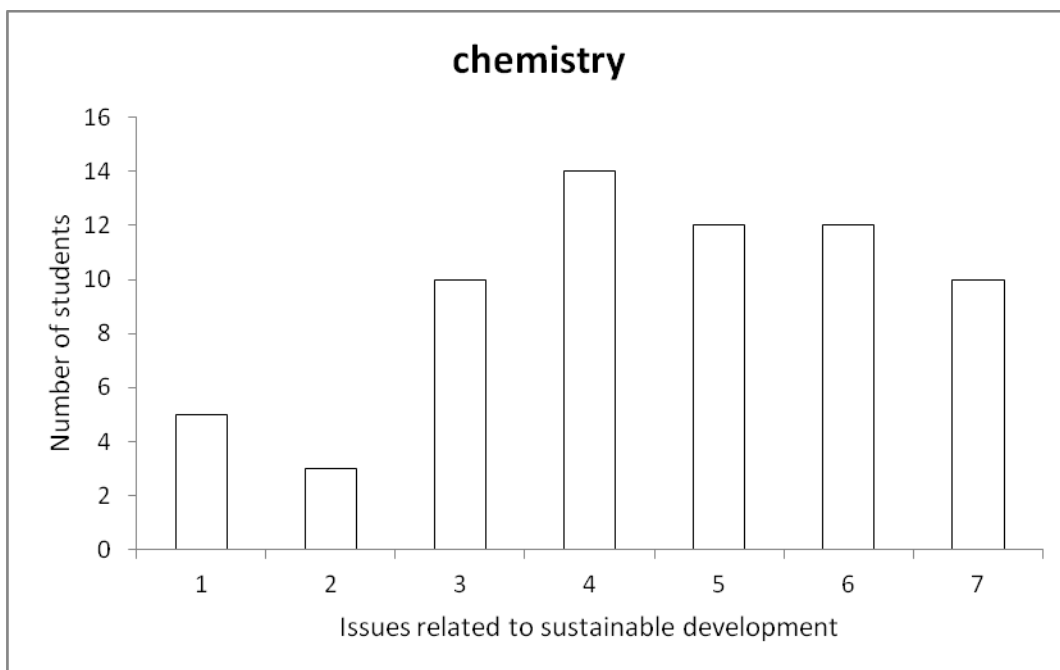


Figure 1. Number of Chemistry students who indicated that various issues (related to the seven categories listed below) occurred during the course of their studies.

Meaning of numbers 1-7 that are marked on Figure 1

- 1 - Economic development which does not cause environmental pollution
- 2 - Social problems in the world – poverty, famine, epidemics
- 3 - Observing human rights
- 4 - Modern technologies
- 5 - Problems related to natural environment
- 6 - Responsibility for the degradation of the environment
- 7 - Rational production and consumption that does not pose risks to the environment

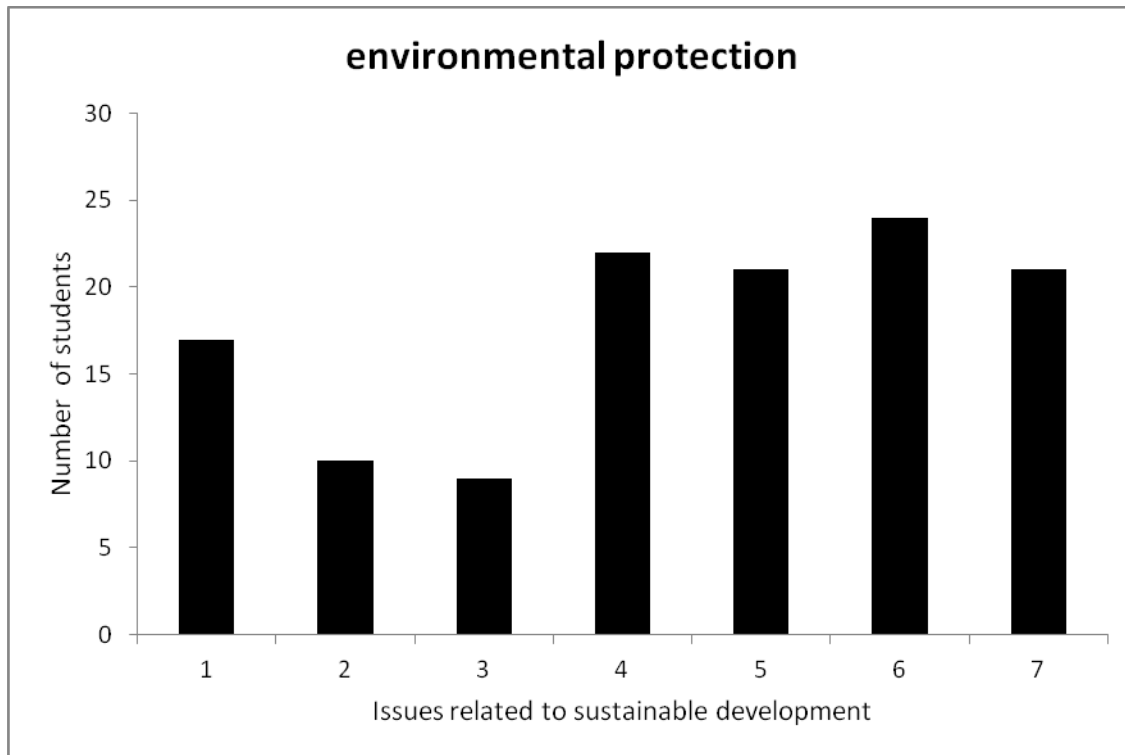


Figure 2. Number of Environmental Protection students who indicated that various issues (related to seven categories) occurred during the course of their studies. The meaning of numbers 1-7 that are marked on Figure 2 are explained under Figure 1.

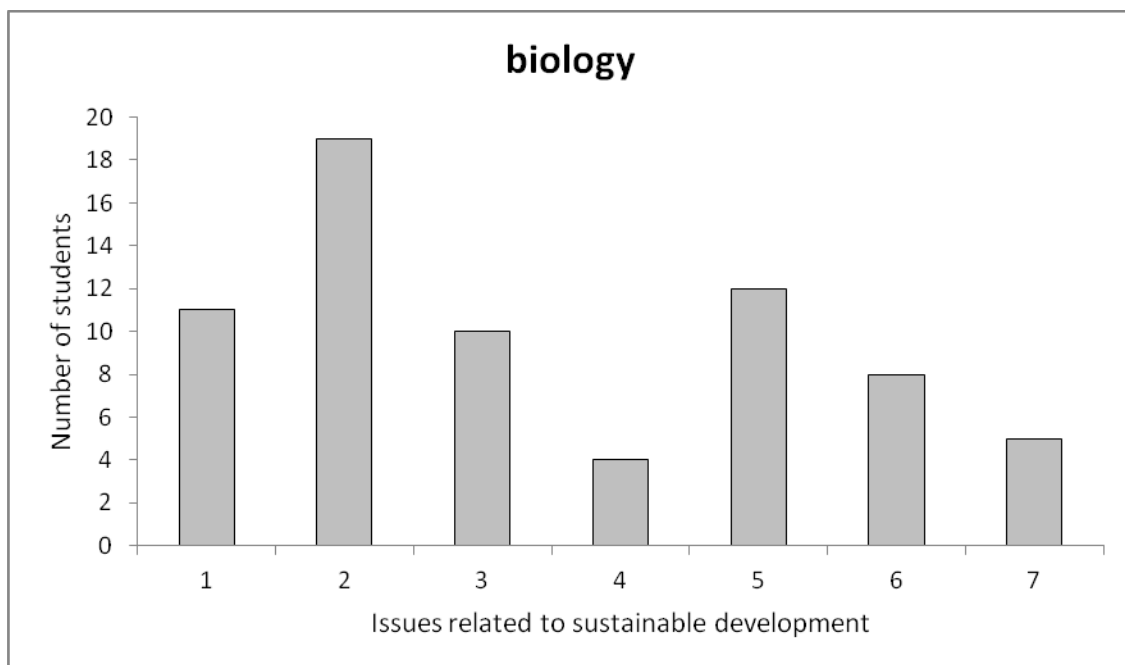


Figure 3. Number of Biology students who indicated that various issues (related to seven categories) occurred during the course of their studies. The meanings of numbers 1-7 that are marked on Figure 3 are explained under Figure 1.

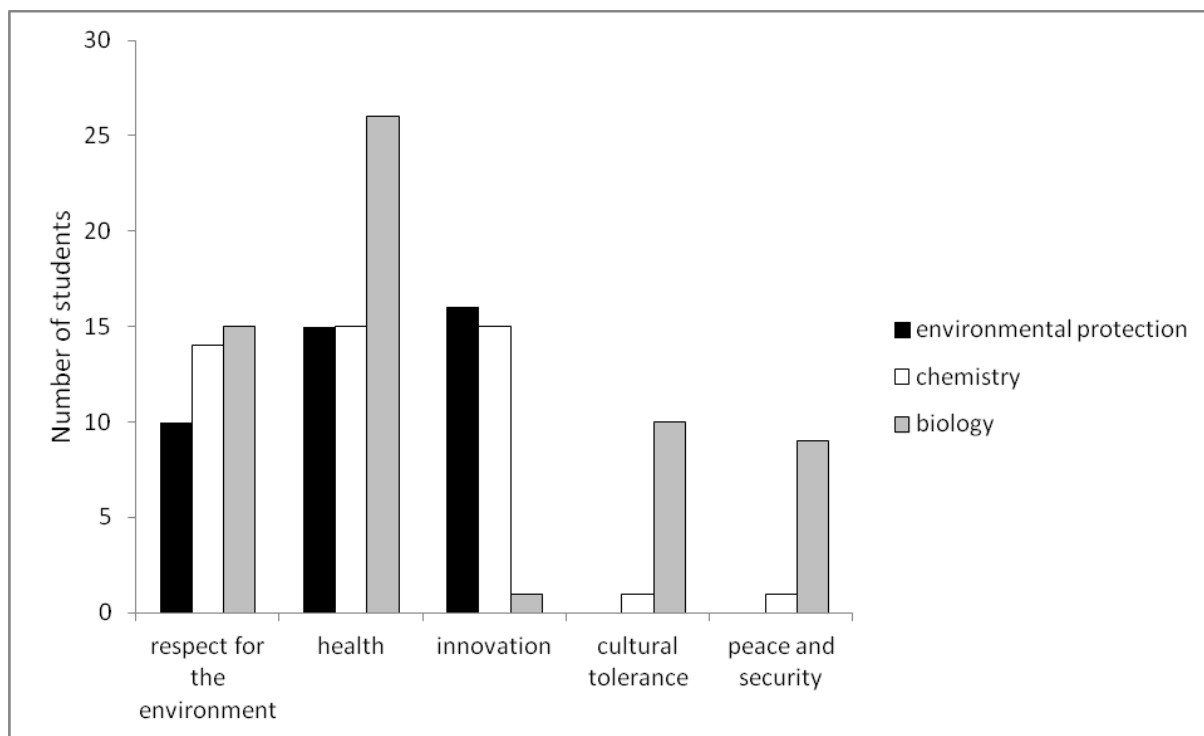


Figure 4. Responses of students of Environmental Protection, Chemistry and Biology to the question: Do environment-related subjects/classes within the framework of your degree course promote the following values? (five categories presented in the diagram on Y axis).

The last question in the Questionnaire was: Do natural sciences degree courses promote values such as: respect for the environment, health, cultural tolerance, innovation, and peace and safety? The answers indicate that all three courses mostly include in their programmes content related to respect for the environment and health (Figure 4). While studying their subjects, the students of Chemistry and Environmental Protection often encountered issues relating to innovation, but rarely those pertaining to cultural tolerance or peace and security. With respect to the last three categories the results for Biology were different: very little attention was devoted to innovation, whereas issues such as cultural tolerance and peace and security were mentioned.

Summary and discussion on the results

The idea of sustainable development is very difficult to implement in the current economic and social circumstances (Kostecka, 2008). Therefore, it is very important to learn about the reasons for which each of us would be ready to take the challenge to implement the rules of sustainable development in everyday life. The motives that make us respect and accept these rules are important. Basic limitations in implementing the concepts of sustainable development occur mostly at the level of popularizing the ideas and aims of SD in the environmental, economic and social context. In spite of the abundance of potential sources of information about the SD, the key role is still played by the didactic process. Many respondents indicated that they

actively pursue information in the Internet, television, and popular-scientific literature.

This is confirmed by other research which says that “an important element of education and ecological upbringing is the non-formal ecological education. Popularizing knowledge about environmental processes and their influence upon social life, and, promoting knowledge about environmental protection is pursued by making available many sources of pro-environmental information. The highest impact is achieved by the mass media, such as television, radio and daily press” (Nowak & Żeber Dzikowska, 2002). According to the document, “Report on Education for Sustainable Development (ESD) in Poland, Final Report” (2012) there are numerous internet platforms containing and promoting materials, scenarios and teaching aids for teaching about SD (interactive maps, films, presentations, tests). They provide information about training and e-learning courses, which are increasingly popular among teachers. According to the report, only 14% of school and academic teachers and 7% of pupils and students admitted that these platforms and the Internet are used in their institutions for teaching about SD.

An important element in the implementation of sustainable development is Agenda 21 as indicated in the research by Fleszar (1998): “The assumptions of Agenda 21 should be implemented in practice. The move from theory to practice should be the aim for all: teachers, pupils, students, as well as for parents and children.”

The results indicate little awareness of the significance and potential opportunities for implementing the rules of Agenda 21 due to lack of knowledge about this document:

73% of Biology students are aware of its existence; 42% of the Environmental Protection students described the significance of the document incorrectly. Most of the students of Environmental Protection (73%) knew the term “sustainable development”. This was most probably the result of the fact that they had studied the following subjects within their degree course: General Ecology, Legal Basis of Environmental Protection, Basics of Environmental Management, Ecological Education, Economic Basis of Environmental Protection and Analysis of Chemical Threats to the Environment. Therefore, they had had a chance to learn about SD and the conditions for implementing SD as a challenge for current and future generations, focusing in particular on eco-development at the local and regional levels. However, is the correct understanding of the term “sustainable development” equivalent to being aware of the fact that the Constitution of the Republic of Poland contains a passage pertaining to sustainable development? This information is very important as the Constitution is a supreme act of law which governs social life and therefore its knowledge is very useful for implementing pro-environmental actions.

Knowledge about the idea, concepts and aims of sustainable development is usually gained by the learners in upper secondary schools. At the level of primary and lower secondary schools, the term is not known to the pupils. This is inconsequent with the assumptions of the core curriculum for lower secondary schools (2009) according to which Biology education should promote knowledge about sustainable development and should constitute the foundation for learning about relations within the environment while realising the programme

related to ecology. The report on ESD in Poland (2012), mentioned earlier, indicates that 29% of teachers in primary and lower secondary schools and 33% of teachers in upper secondary schools claim that they are obliged to implement education for sustainable development in accordance with the guidelines contained in the core curricula. Lower secondary pupils should also learn about eco-development issues while discussing “Global and local environmental problems”. These issues pertain to global warming and actions aimed at preventing environmental pollution, like recycling, managing dangerous waste, and the rational use of water and energy resources. The aim of geographical education in lower secondary schools (according to the core curriculum) is to prepare pupils to discover relations and connections in the natural environment, economy and social life. Focus is placed on developing responsibility for the natural and cultural environment, being aware of one’s own identity and introducing respect for other nations and social groups.

Academic teachers who educate students in natural sciences degree courses are particularly obliged to implement the guidelines of sustainable development and include them in teaching programmes. This is congruent with the results of the report on ESD in Poland (2012).

The level of preparation of students to implement the elements of sustainable development is inadequate. It is worth adding that after obtaining BA degrees, students of Biology and Chemistry can practice teach. Therefore, for a number of respondents, it is the end of their university education. The results indicated that not many students are interested in broadening

their knowledge about SD by individual research so it can be assumed that they will not include it as a part of their professional self-development.

The programme of study for Environmental Protection degree course does contain subjects which tackle issues related to SD. Students learn, among others, about types of anthropogenic impact on the natural environment, methods of preventing synanthropic changes in environmental systems, planning sustainable development of urbanised and rural areas, methods and techniques of protecting biological diversity, changes to and degradation of water resources and their reclamation, civil engineering, systems and neutralisation of sewage, materials utilized in environmental protection, and modern material technologies. As indicated by the students, the assumptions of sustainable development in the context of economy, environment and social life are implemented in a greater number of subjects within the Environmental Protection course compared to the Chemistry and Biology courses (the subjects include: Water and Wind Energy, Global and Local Threats to Natural Environment, Environmental Protection, Economy of the Environment, Legal Basis of Environmental Protection, Parasitology, Environmental Monitoring, Economy of Natural Resources).

The report on ESD in Poland (2012) points out the idea that sustainable development is becoming more and more popular. Recent years have brought significant advancements in the implementation of sustainable development. The society is more ready to practice pro-environmental and pro-health behaviour. Ecology and healthy lifestyles are becoming fashionable, particularly

among young people. Behaviour characterized by too much focus on consumption is criticised and ignorance towards the environment causes indignation. It can be suspected that educational activities which raise awareness about sustainable development have been conducive to the creation of such trends.

One of the aims of our research was to obtain information which would allow us to modify the educational programmes for the natural sciences degree courses with respect to knowledge about sustainable development. Our most important suggestion for education is to include the concept of sustainable development in the educational programmes at all levels of education. Specific attention should be devoted to the programmes used for educating future teachers. Students should gain comprehensive knowledge about the most current programs of action to influence socio-economic progress and simultaneously preserve social and economic balance taking also into consideration protection of environment and health. According to the Strategy for Education for Sustainable Development, which is a response to and form of implementing The Decade of Education for Sustainable Development, teaching programmes should take account of local, regional and national conditions, global context, and achieve balance between global and local processes. They should also diversify focus on particular aspects of sustainable development, take into consideration the meaning of the concept of "sustainable development," and contain aims which encompass knowledge, skills, comprehension, attitudes and values. They should include content relating to the environment, economy and social life; be characterised by an integrated approach to

the problem of sustainable development; tackle key problems associated with the reduction of poverty, human rights, responsibility for the local environment, justice, safety, health, sex equality, and cultural tolerance. It is also necessary to include local communities in the didactic process and consider international cooperation while implementing educational programmes. Students should be encouraged to enter into social dialogue. Particular attention should be paid to raising awareness with respect to sustainable development not only among students but also among academic teachers. Similar conclusions are drawn by Grodzińska- Jurczak, *et al.* (2010). It is worth implementing innovative strategies, methods, forms and projects stimulating students to active participation and mutual cooperation. Properly executed education can increase the chances for success.

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Research conducted by Dr. Alicja Walosik, PhD centres around problems relating to ecological and environmental education at all levels of education. She is also interested in the

environmental awareness of young people and activities undertaken by them for the purpose of sustainable development. She focuses further on the environmental and biological education in the context of the requirements of knowledge-based society as well as on the role and tasks of education in the process of European integration. Numerous works of Dr. A Walosik, PhD are devoted to the didactics at higher education institutions, education of teachers, and development of their professional competences in the context of new educational tasks.



Elzbieta Rozej-Pabijan, PhD

I'm an ecologist, my scientific interests focus on two major areas. The first is dedicated to human driven changes in the environment, particularly:

biodiversity loss,

causes and consequences of pollinator declines and impact of alien and/or invasive plant and animal species on local fauna. One thing is to study human impact on the environment and discover how apparently small changes can pose a threat to the functioning of ecosystems. Another thing is to share this scientific knowledge and help other people to understand how we influence the environment and that we can change a lot. Therefore my second area of interest is informal ecological education and the popularization of biological knowledge. This is reflected in many workshops that I have participated in and lectures organized mainly for children, concerning little known aspects of the biology of insects and bats. What an inspiring experience it is to see amazement on the faces of students and to answer their surprising questions!

Learning, Complexity and Conceptions: New Tools for a New Society

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The ecosystem is the result of epistemological concepts, starting from the "economy of nature" until Tansley and his analysis on the synthesis of the various ecological concepts. To understand ecosystems and to be able to take action, one should take into account the complexity of interactions and feedbacks involved in the organization and dynamics of the ecosystem. The concept of complexity is not new, Pascal (1669) emphasized the need to link things in order to understand them by saying *Flame cannot exist without air; therefore to understand the one, we must understand the other...* Today complexity has invaded our daily lives and our learning methods have to adapt. Describing and understanding this complexity cannot be done without a comprehensive approach called a "systemic approach". It depends on the conceptions of teachers about the system concept. A new pedagogical culture of research should enable new forms of learning in our society where science and citizenship are inseparable. My research analyzed the conceptions of Tunisian biology (SVT) teachers to find out to what extent they could be "favorable" or "unfavorable" to learning these complex concepts. De Rosnay (1975) considers that a "systemic approach is based on the concept of system" and suggests structural and functional elements to describe and understand the systems. The introduction of the systemic approach in teaching should be part of a pedagogical strategy aimed at training teachers to achieve the learning objectives of complex concepts. Initiating teachers and students to systemic thinking and proposing learning activities based on this approach could lead to making new pedagogical choices. The study of interactions, feedbacks and ecosystem dynamics, should help learners develop new skills to cope with the complexity that characterizes various aspects of our society today.

Keywords: Ecosystem, complexity, systems approach, teacher training.

La notion d'écosystème est l'aboutissement épistémologique des concepts, depuis « l'économie de la nature » de Linné, jusqu'à Tansley et son essai de synthèse des différentes notions écologiques. Comprendre et agir sur les écosystèmes devraient tenir compte des interactions et des rétroactions qui interviennent dans la dynamique et l'organisation de l'écosystème, bref, de ce nouvel aspect qui est la complexité. Le concept de complexité n'est pas récent, Pascal (1669) soulignait la nécessité de relier pour comprendre en disant « *la flamme ne subsiste point sans l'air : donc, pour connaître l'un, il faut connaître l'autre* ». Aujourd'hui la complexité a envahie notre vie quotidienne et nos modes d'apprentissage doivent s'y adapter. Décrire et comprendre cette complexité ne peut se faire sans une approche globale dite « approche systémique ».

Cette approche est souvent confrontée aux conceptions des enseignants à propos de la notion de système. Une nouvelle culture pédagogique de recherche des liens devrait permettre de nouvelles formes d'apprentissage dans notre société où science et citoyenneté sont indissociables. Cette recherche analyse les conceptions d'enseignants tunisiens de SVT pour voir dans quelles mesures, elles peuvent être « favorables » ou « défavorables » à l'apprentissage des concepts dits complexes. De Rosnay (1975) considère que « *l'approche systémique s'appuie sur la notion de système* » et suggère des éléments structurels et des éléments fonctionnels pour décrire et comprendre les systèmes.

Introduire la systémique comme démarche d'enseignement devrait s'inscrire dans une stratégie didactique pour la formation des enseignants en vue d'atteindre les objectifs d'apprentissage des concepts complexes. Initier les enseignants et les apprenants à la systémique et proposer des activités d'apprentissage par cette démarche, pourraient servir de guide pour de nouveaux choix pédagogiques.

La recherche des interactions, des rétroactions et la dynamique de l'écosystème, devront servir à développer de nouvelles compétences chez les apprenants pour affronter la complexité qui envahie divers aspects de notre société aujourd'hui.

Mots-clés: Écosystème, complexité, conception, approche systémique, apprentissage

Introduction

Our primary focus is concerned with the Biosphere, a concept related to our planet, taking into account the impact of environmental crises both at the qualitative and quantitative levels, and to encourage reflection on our relationship with the biosphere. This means trying to understand the complexity of systemic ecology, building on the concept of system, on modeling and on the Conceptogram as a tool, not as a simple conceptual representation, but as a tool used to identify the interactions and feedback associated with this complexity.

In the field of education, teaching ecology should lead students to appropriating this approach. The didactic approach able to achieve this goal is the systematic approach. But shouldn't we first prove the relationship between global and systemic ecology? Is it possible to consider ecology as an example for the systemic approach? Can we develop educational resources for learning about complexity? Does our "conception" of the system allow us to accede to this way of thinking?

The birth of a complex ecosystem concept

De Rosnay (1994), states that "ecology is an integrative concept, a way of thinking that materializes today global eruption of systemic education, industry and politics." Some experts, including Acot (1988), consider that Linnaeus assumed the relationship between the living and the environment in terms of distribution and equilibration of providential living on the surface of the globe, that is to say, a system of nature based on the balance of existing species.

Deléage (2001) places this in a global context and considers that "in science, biogeography, the Darwinian theory of evolution and geochemistry laid the foundation for a holistic approach to the planet before the concept of a biosphere is formulated in the twentieth century. To Deléage, Humboldt sought to understand the overall logic of the geographical distribution of species. Darwin stated, on the one hand, the 'seniority' of the Earth and the modification of organisms and, secondly, the multiplication of species by speciation. Finally, it is through natural selection that the accumulation of successive changes in the process of evolution occurred.

With Lavoisier's chemical insights, geochemistry permitted us to know the chemical processes on the surface of the Earth in ancient agricultural systems, the nutrients removed by harvesting are recycled on site by the rural population. Today, with industrialization and urbanization, nutrients are accumulated in the cities as waste. These human activities cannot be overlooked in our relationship with the environment as our survival depends on a sustainable biosphere. The late nineteenth century, the Darwinian current that we can consider as participating in the birth of ecology and even "Darwinism considered as an ecological theory of evolution of species", even though Darwin speaks of "the place of the animal in nature "to describe the concept of ecological niche, this could" leave the blur around the concept of species. "

The first time that the idea of the unity of the living world was formulated, was when Suess proposed the notion of a "biosphere."

Möbius (1877) speaks of "biocenosis" about the life of a species and its evolution, which depend on all the other species that live in the same environment. Intraspecific and interspecific interactions, feedback, and regulation, are factors that describe Biodiversity as a global "system. Systematically, exploring how environmental action, from a physiological point of view, acts on the organs of plants, French Schimper concludes that, "the close relationship between the character of vegetation conditions and extreme climates is revealed by the most obvious adaptation"

The idea of the global system and flow

This global view is reinforced in modern ecology with the work of Vernadsky which provides a synthetic picture of the movement of elements through organic and inorganic matter on the surface of the globe, saying that:

"it is certain that the manifestations of life produce a profound disturbance in the chemical reactions on earth crust [...] we know that there is a huge amount of chemical elements in the biosphere, through the living matter subject to other chemical processes, than they would have suffered, if there was no life on earth."

This illustrates the exchange of matter and energy and highlights the scale of the biosphere.

As part of his work on vegetation dynamics, Clements states that "vegetation is essentially dynamic," but because it reacts strongly on habitat, it shows a tendency to become static. He enunciates, in other words, a fundamental concept in ecology: the homeostasis of ecosystems and their tendency to change and remain in equilibrium. Tansley, meanwhile, is engaged

in a "real epistemological analysis of ecology, opting instead to talk about the ecological system or ecosystem."

On the basis of these notions, Tansley notices the absence of the physical factors of the environment. He offers a broader and more comprehensive approach, including living beings and external conditions, while also being influenced by physical systems, Tansley stipulates this idea:

"if the organization of the elements of a system fails, no system can be built or a system is dispersed in its early stages. There is actually a kind of natural selection of systems in their early stages, and those that can reach the most stable balance survive the longest. [...] A similar idea has been largely developed by Hume and even Lucretius."

The approach of Tansley is qualitative; it is primarily concerned with vegetation. Two streams of research emerged, the study of animal populations and energy approach, led to the birth of a theory of ecosystems.

If the study of Möbius on oysters opened the door "to applied and most focused researches," Forbes' work has focused on insect pests, that can cause extensive damage to agriculture, in Midwest lakes, in the State of Illinois.

Research problem: complexity and logic systems in ecology

De Rosnay (1998) points out the common characteristics of complex systems and considers them applicable "in the world of biology, economics or ecology."

Using these characteristics, De Rosnay (1998) provides a number of examples of complex systems. Systemic visions enable

us to apply use systems logic. We present the example of ecosystem by De Rosnay described as:

“a fairly simple system, a symbiosis between the animal world and the vegetal world: some need others and some are regulated in relation to each other. There is an "economy" of the ecosystem. One could say that ecology is the economy of nature, while the economy is the ecology of the societal system”

The analogy with the notion of system in ecology is not new. The systematic classification of the vegetable kingdom, established by Linnaeus (1749) gave rise to the "sexual system" Lamarck (1802) calls for not only the determination of the species, but to get into " the knowledge of the origin, relationships and mode of existence of all natural productions “chemical accounting”. Lavoisier (1893) had introduced, the idea of" elements transfer "between the three kingdoms of nature. Speaking about botanical geography, Humboldt (1817) suggests looking for "general theory" to "secure the influence of disturbing factors."

The elements of this "system" begin to appear. Lecoq (1854) launched the concept of the *station* to determine the influence of physical factors in the distribution of plants. With the theory of Darwinian evolution (Principles, 1832), new concepts appear in the relations between the living and the environment: regulation and balance. Möbius (1877) introduced the idea of feedback in the functioning of the whole natural system. His idea, which came from the depletion of oysters in Schleswig-Holstein, is that "we cannot understand the abundance or scarcity of a species only through its fertility rate [...], without taking

into account all the other species that live in the same environment, which feed on or compete with, and he proposes the term biocenosis to name this set of elements "Drouin (1993).

Cowles (1899) introduced the concept of model to describe and analyze the evolution undergone by the sandy shore dunes of Lake Michigan near Chicago. He offers a succession process to model the overall system of plant formations. This model is used to determine the interrelationships between formations. Lotka and Volterra with (1925 - 1935), changes in numbers of animal populations have been described with mathematical models. The economic challenge and the search for profitability are new factors imposed by humans in the natural system.

These interactions between living things and the environment is a source of regulation. In the 1980s, working on Westbroeck unicellular alga, *Emiliana huxleyi*, argues that "the physical, chemical and biological soil interacts strongly and, whether by accident or on purpose, modifies each other's collective destiny." The role of living beings, including man, in control of their own environment, is thus reported, our relationship with nature is to rethink the sum of our regulatory activities to strengthen short, our future depend heavily on this regulation.

This global vision that began long ago, culminating with a fundamental concept, which includes all ecological concepts: ecosystem Tansley (1935). It is now proposed that we rather speak about ecological system or ecosystem that "includes organisms and physical factors of the environment" Drouin (1993).

Drouin (1993) adds that Tansley states that "the term ecosystem is to be considered in the sense of physics. The ecosystem may well take place in a system that starts with the atom and agglomerate to the scale of the universe. The systemic approach is none other than this global macroscopic vision of the ecosystem according to De Rosnay (1975). It helps to conceptualize the ecosystem, the model for understanding reality, clarifying its components, searching interrelationships and feedback, allowing it to maintain balance and to regulate its environment with which it exchanges the energy and matter.

Concepts that underlie the ecosystem, its dynamics, its self-organization, represent its complexity. Teaching learners about the ecosystem seems complicated. Motivating young people to behave environmentally (insert a reference to socio-cultural values) is another degree of difficulty, starting with understanding the environment, its challenges regarding a "rational management" and sustainable resources. It is the same applies for teaching complex ecological concepts like ecosystem, according to the systemic approach.

Tools and educational resources are important for the training of teachers on this new approach. A problem remains unanswered: to what extent teachers' conceptions can influence educational choices? How can it take into account the views of learners in the learning process, to integrate a stable and sustainable learning process?

Analysis of the conceptions of teachers

Our research participants were two groups of Tunisian teachers of Science of Life and Earth (SVT). They were in charge of

teaching the concept of ecosystem to second-year secondary school students (16-18 years). We collected data through questionnaires, a pre-test and a post-test and an interview. This work was carried out during the years 2008/2009 and 2009/2010.

The questionnaires consisted of questions related to the notion of system; a training session was carried out with each group, just after the pre-test. It is based on the foundations, didactic inputs through a study and discussion of case studies of the systemic approach. We asked the teachers involved to apply the systemic approach to teach the ecosystem, a teaching form was provided at the end of the post-test, meant to describe the educational tool chosen to teach the ecosystem, in order to identify the degree of apprehension of the systemic approach as a didactic teaching approach.

The questionnaires used

The questionnaires consist of four groups of questions:

1. A system consists of interacting elements. What is a system for you? Examples of systems? How does a system work? What are the types of interactions in a system? What is the relationship between the parts and the system?
2. A system is connected to its environment: What are the nature, extent and density of exchanges? What are the sensors used? Are there any boundaries between a system and its environment?
3. The system responds to disturbances it receives from its environment. Do the disturbances affect the structure of the system? If so, how? If not, why?

4. In the post-test questionnaire we added the following questions:

What is a systemic approach for you?

How is it different from the so-called classical approach?

Educational fact sheets

To analyze teachers' pedagogical choices, we proposed teaching notes, including four categories of questions:

1. which of the following pedagogical tools have you used in the classroom to teach the concept of ecosystem?

- A concept map or Conceptogramme
- A study prepared by each student on a topic chosen in advance
- A field trip with the class
- A-class discussion topic from a particular document
- Another tool – describe

2. Describe the benefits of educational tools that you used in the classroom: how have they helped students to understand the ecosystem, network of relationships between components, the hierarchy of relationships, the exchange with the environment etc..?

3. Can you describe the contributions of conceptogrammes compared to other educational tools in teaching ecological

concepts?

4. Which teaching tools do you think allowed you to teach ecological concepts successfully according to the systemic approach?

Educational tool selected:

Justify your choice:

Interviews were held with some teachers, three from each group, and the questions were taken either from the pre-test or the post-test.

Analysis of teachers' conceptions

In our analytical framework, we have taken into account the approach of De Rosnay (1975) which reported the description and understanding of the concept of a system according to structural aspects, relating to the constituent elements as functional aspects, resulting in interactions and feedbacks. Structural elements consist of a border or boundary elements or components of a system, the tanks are used to store materials, energy and information that pass through the system, and communication networks ensure traffic flow. Functional aspects include streams of flows, decision centers, response times and feedback loops.

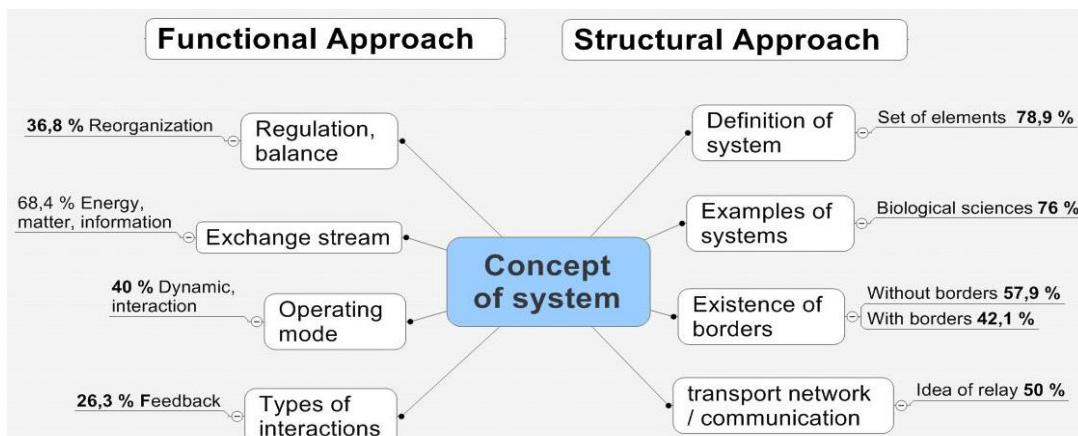


Figure 1: Responses to the questionnaire pre-test group 2008/2009

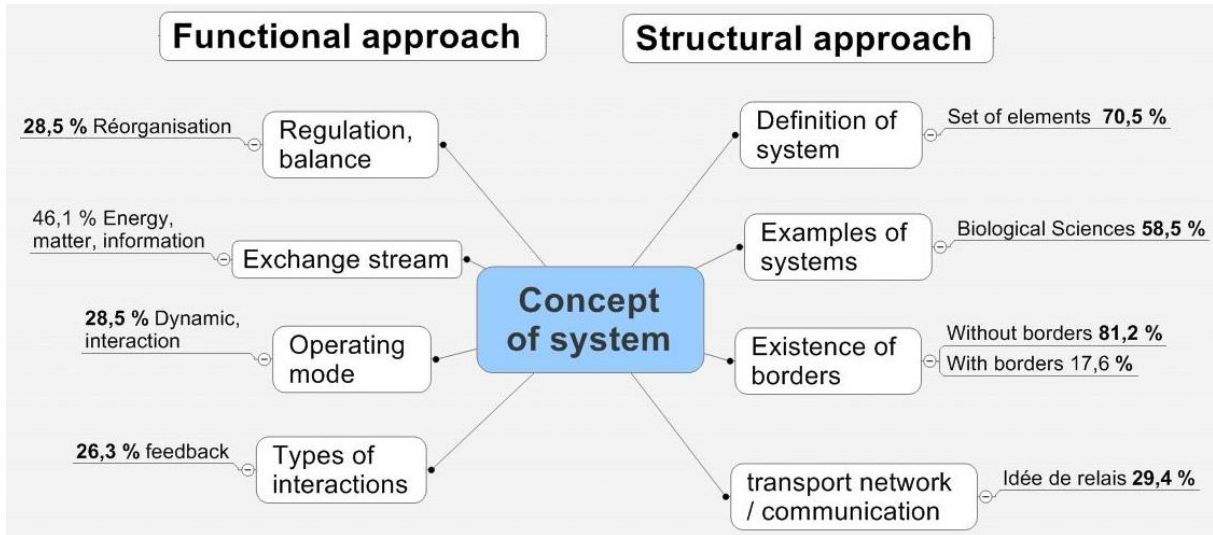


Figure 2: Responses to the questionnaire pre-test group 2009/2010

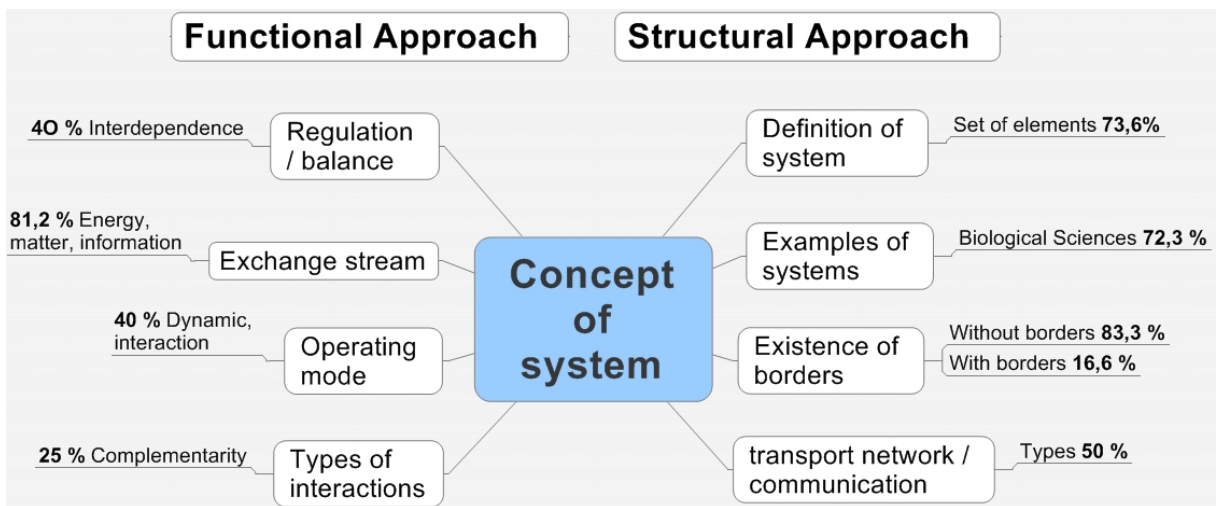


Figure 3: Responses to the questionnaire post-test group 2008/2009

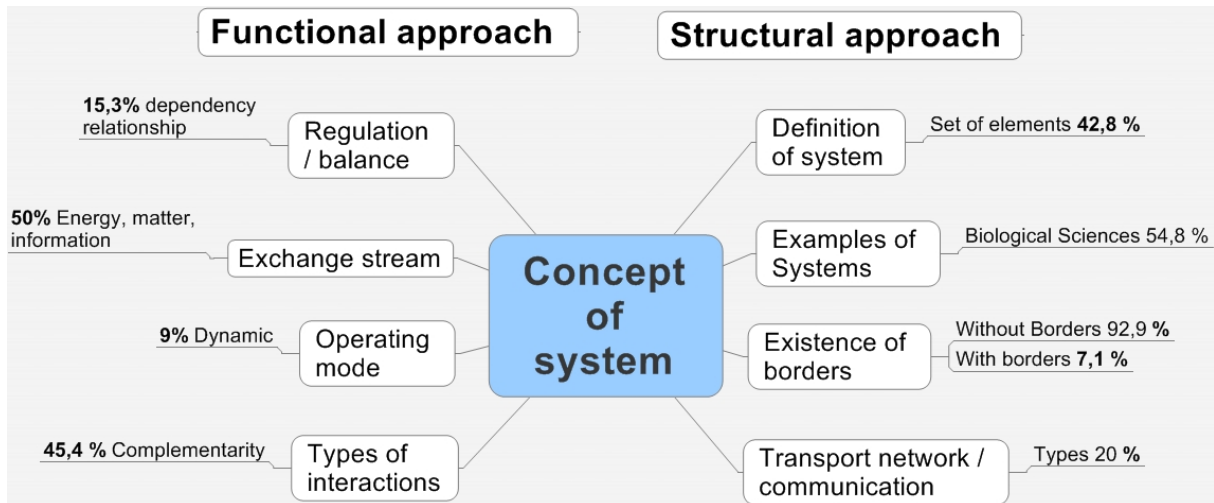


Figure 4: Responses to the questionnaire post-test group 2009/2010

Based on responses to the questionnaires, we can identify the following aspects of the pre-test: the structural approach is favored such as the composition of the system, its operation in terms of complementarity, the presence or absence of boundaries between the system and its environment, and a communication network characterizes conceptions of most teachers participating in this research. Double responses, the lack of answers to some questions, convey ambiguity and reflect the need for a new vision of the complexity of concept system.

Although present in some of the responses, the functional approach to the notion of system in terms of flows, decision-making centers, spatio-temporal dynamics and feedback loops, does not reflect a distinct aspect of the teachers concept system. Some properties emergent of the systems are absent (reorganization, dynamics, exchange flows, full spectrum). Sometimes they are expressed in different ways while staying away from the functional approach (as a source of feedback regulation, relationship

between the parts and the system, importance and density of exchanges for the survival of the system, and a system regulation due to the disturbances of the environment and the concept of reorganization).

The didactic approach is in line with the "professionalism" of teachers of SVT. When we refer to the notion of system and the fact that they can draw an analogy with the ecosystem. This mode of reasoning is deficient when its reference to the ecosystem cannot be justified. We found out when questions are related to the functional approach systems (as in the case of the types of interactions, relationships between the parts and the system of exchange and the possibility of changing structures following disturbances), that teachers do not offer answers, or simply justifications that express the contradictions but they sometimes even deliver double and contradictory answers.

We noticed that some of the teachers sometimes gave different responses to the questionnaire and the interview. However,

with the second group, the responses reflected a certain "trend" toward answers and justifications reflecting a way of thinking that takes into account the functional aspect of the systems. Teacher training on the systems approach could facilitate understanding of the complexity of systems and the development of its emergent properties.

In the case of replies to the post-test, we noticed a change in teachers' responses in favor of the functional aspects of systems. This was in terms of examples of areas covered by the system, the types of interactions and relations between the parts and the system, exchange flows, control mode and system dynamics.

One aspect of this change is that there is a possibility that the teacher is convinced by the dual approach to the systems and may adhere to this way of thinking;

The other side is reflected in the answers that continue to express the vagueness, ambiguity, and the change may not be sustainable and it needs to be strengthened.

The major difficulty lies in the ability of teachers to implement this approach and allow learners to achieve this change in their way of thinking.

Sustainability of a change for the functional approach of the system requires reinforcement of related concepts and training in didactic approaches promoting a way of thinking that captures the complexity and highlights of the emergent properties of systems.

We chose to add two questions to the post-test, to summarize teachers' views on the

systemic approach and basically its differences with the so-called classical or analytical methods. Although rates reflect a trend in the proposals, the most important is what the systemic approach as a tool, can offer.

In our analysis, we first examined the answers to question 10. The notions of "dissociation" of "limited analysis" and "dissociation analysis" constitute the foundation of the analytical approach. Our way of thinking is "familiar" with this approach; the school has become so accustomed to this and teaching practices strongly impregnated with it, that these constitute barriers to new practice.

This analytical approach may be "insufficient" sometimes, so some teachers believe it "does not address the complexity." The systemic approach could "meet" the need and act where the analytical approach stops.

The concepts expressed in "global vision", "network" and "complexity" are the tools of the systemic approach for the first two concepts, and the outcome of this approach for the third concept.

We are still far from the conceptual framework and epistemological considerations that could make us discover the contributions of the analytical approach in the history of science, but also its limitations given the rediscovery of complexity. The systemic approach is certainly not a panacea, but it is thought to rearrange the logic of the system, not to seek the truth but to examine the possibility to capture a new methodology, new tools and techniques to address the complexity and lead to new forms of learning.

The analysis of records reflecting the educational choices related to the teaching

of the ecosystem concept reveals the 'benefits' as expressed by teachers.

Table 1: Summary of Benefits offered by teachers about teaching tools valid for systemic approach group 2008/2009.

Selected tools	Benefits expressed
Concept map	Use of ICT Enables visualization
Field Trip	Enables observation, comparison and study To see impact on environment To initiate research spirit To develop conceptogrammes Entertainment
Class debate	To enhance critical thinking To foster reasoning
Other tools	To allow visualization, use of ICT, interactive whiteboard

Concept maps, a technique used in systemic analysis, are not often chosen, which could lead to a blur in the overall conception of the systemic approach in its theoretical framework, methodology and techniques of representation. The use of this pedagogical tool does not seem to be clear for teachers: the practical approach to achieving this type of card, its connection with the issue taught, research of the possible interactions between the concepts, and the evaluation of knowledge through this tool. It should be included in the programs (i.e., objectives, approach) and embodied in the teaching aids (textbooks, teaching materials, training sessions, etc.).

Benefits expressed in the second group are more in line with the systemic approach:

Table 2: Summary of Benefits offered by teachers about teaching tools valid for systemic approach group 2009/2010.

Tools selected	Benefits expressed
Conceptual Card	Searching interdependencies, links
Field Trip	Promoting experimentation, observation and sampling Developing conceptogrammes Promoting preservation Allowing the change of attitude
Study carried out by students	Enhancing the spirit of debate enabling accountability
Other tools	Promoting visualization tools Promoting a global vision

In this group, the benefits seem to fit more with the systemic approach, based on the answers, concept maps allow "research links and interdependencies" and field trips can be used to "create the conceptogrammes." While 9 teachers have made field trips to teach the ecosystem, only 5 said that they are an efficient tool for teaching the systemic approach.

Among the 8 teachers who considered that the outputs of the field trip are the most valuable tool for the systemic approach, three have not tried them. The benefits are rather theoretical for them. Four teachers tried the tool "field trip" but this tool, according to them, does not seem effective to the systemic approach.

Conclusion

- Responses to the pre-test questionnaires highlight the influence of specialization of teachers in their references to the notion of system, and difficulty for them to imagine this concept in various fields such as economics, sociology, urban planning, etc.
- The vagueness and ambiguity arise when we place ourselves in the register of common knowledge on the system: borders, exchange, regulation and dynamics. The identification of these conceptions of knowledge, is fairly easy especially if the teacher has to answer questions about nature, size and density of exchanges or regulation of the system to disturbances it receives from its environment;
- Difficulties arise also when imagining "leaking" borders playing

the role of limits, but at the same time allowing exchanges between the system and its environment;

- Training on systemic and its foundations, offers teachers a new way of reflection on the systems and the possibility of expanding the scope of this concept in various fields. A new way of thinking is now possible, based on the search of links, feedback and the concept of "all" characteristic of the systems.
- Despite the difficulties mentioned, a timid change in conceptions appears in the post-test questions, with regard to the definition of the system, its mode of operation, types of interaction between the components and the borders. The spatio-temporal or dynamic evolution, the reorganization of the system in relation to disturbances and exchange flows represent concepts and practice that are difficult for teachers to imagine using in various fields. These are factors that we refer to as "adverse" to the apprehension of complexity. We note this difficulty in the descriptive notes where the teacher's choice of classical approach methods still prevails, despite our request to apply the systemic approach in teaching the concept of ecosystem.

We also recall that the pedagogical guidelines each teacher is required to apply leave no freedom for teachers to try such an approach outside the research setting.

Expanding this research to other groups of teachers could reveal details of the concepts and modes of reasoning of each, but could also contribute to spreading this approach as much as possible. We propose that teaching or learning in a broad sense, according to the systemic approach, should be reflected in the learning objectives, in real schemes and clearly stated in formal programs, providing educational resources to teachers.



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The Universal Dimension of Natural Sciences Education

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Abstract: In Europe, following the steady progress of globalization, there are many problems and challenges. Those facing education are numerous, difficult to standardize, and, in many ways contingent. The European Union has prepared a strategy "Europe 2020," for smart, sustainable development which lays out five long-range goals: employment, research, poverty reduction and climate and energy. This program requires good social foundations of education. These can be created by developing transferable core competencies for education, which has been set by the Council of Europe. The key competences are considered essential skills for young Europeans not only in modern times, but also for the future. The Council of Europe Report "Developing Key Competences at School in Europe and Opportunities for Policy" recognizes key achievements and challenges related to the development of key competencies in schools in Europe. Progress has been made relating to the implementation of competence in school curricula and other educational regulations. This is also a matter of exact and natural sciences. Of the 37 countries in the report, 19 have national strategies to promote key competences in general education (primary and secondary) which take into account the proposals of the Council of Europe. Countries that have reformed their programs have adopted an approach based on learning outcomes. These programs include a description of the messages that a student should have and the skills that should be mastered in the different stages of learning. In the natural sciences, one common key competency for students is scientific reasoning. The speech will be discussed with the possibility of their universality.

Key words: sciences education, universalization, knowledge and skills of students

Abstrakt : W Europie obserwuje się ciągły postęp globalizacji, istnieje wiele problemów i wyzwań. Stojące przed kształceniem są liczne, trudne do ujednoczenia i wielorako uwarunkowane. Unia Europejska przygotowała strategię „Europa 2020”-na rzecz inteligentnego i zrównoważonego rozwoju. Wytyczono pięć dalekosiężnych celów w dziedzinach: zatrudnienie, badania naukowe, ograniczenie ubóstwa oraz w zakresie klimatu i energii. Program ten wymaga dobrych społecznych podstaw edukacyjnych. Mogą być tworzone przez rozwijanie uniwersalnych dla edukacji kompetencji kluczowych, które wyznaczyła Rada Europy. Za kompetencje kluczowe uznawane są umiejętności niezbędne dla młodych Europejczyków nie tylko na czasy współczesne ,ale także dla przyszłości. W raporcie Rady Europy „ Rozwijanie kompetencji kluczowych w szkołach w Europie i możliwości tworzenia polityki edukacyjnej ”[Developing Key Competences at School in Europe and Oportunities for Policy] wybrano najważniejsze osiągnięcia i wyzwania odnoszące się do rozwijania kompetencji kluczowych w szkołach w Europie, odnotowano postęp odnoszący się do wprowadzania kompetencji do programów nauczania i innych regulacji edukacyjnych. Odnosi się to również do kompetencji dotyczących nauk ścisłych i przyrodniczych. Z 37. krajów przedstawionych w raporcie 19 krajów wprowadziło strategie krajowe promujące kompetencje kluczowe w kształceniu ogólnym (szkolnictwo podstawowe i średnie) uwzględniające propozycje Rady Europy. Kraje, które zreformowały swoje programy przyjęły podejście oparte na efektach nauczania. Programy te zawierają opis wiadomości jakie uczeń powinien posiadać i umiejętności, które powinien mieć opanowane w poszczególnych etapach nauki. W naukach przyrodniczych za wspólne kompetencje kluczowe dla uczniów w krajach europejskich uznaje się rozumowanie naukowe. W wystąpieniu omówione z beda możliwości ich uniwersalizacji.

Education for the future

Europe is undergoing a continuous progress of globalization, which generates different problems and challenges. Those facing education are numerous, difficult to unify and variously conditioned. The European Union has come up with a strategy “Europe 2020” for sensible and balanced development. Five long-term goals have been distinguished: employment, scientific research, decrease of poverty, climate, and energy. This program requires good social educational background. They may be created by development of universal educational key competences, as indicated by the European Council. The key competences are skills that are necessary for young Europeans not only at present but also for the future. Those competences recommended by the European Council for all the European Union include:

1. an ability to communicate in one’s mother tongue
 2. communication in foreign languages
 3. mathematical and basic scientific-technical competences [also resulting from science and natural sciences education]
 4. computer (digital) literacy
 5. social and citizenship competences
 6. business initiative basics
 7. readiness to life-long learning
 8. Cultural awareness and expression
- <http://eacea.ec.europa.eu/education/eu-ridice/thematic_studies_en.php>
<<http://eur-lex.europa.eu>>

The European Council’s report “Developing Key Competences at School in Europe and Opportunities for Policy”, including the most significant achievements and challenges, recognizes certain progress in the introduction of the competences into syllabuses and other educational regulations. It also refers to competences in science and biology. 19 of

the 37 countries presented in the report have introduced state strategies promoting key competences in general education (primary and secondary education), corresponding to the suggestions of the European Council. Those countries have transformed their syllabuses and acquired an attitude based on academic results. These syllabuses include a description of knowledge that a student should attain or skills he should possess at different stages of education.

In certain countries attainment measures have been matched to the competences. They serve as a ready-made tool for teachers to assess students’ performance and acquired competences.

Key competences include basic abilities and overall skills. The competences are measured by test exams arranged on average 3 to 11 times throughout the obligatory education cycle [11 exams in Denmark]. They usually concern two basic subjects: mother tongue and math. In some countries exams also include foreign languages and sciences. Exam results often determine the future academic career of a student. They are used for various purposes e.g.: to control realization of standards and competences, to inform students and their parents about any progress, to evaluate schools and teachers’ performance, to make improvements in education, to create syllabuses, to improve teachers’ training. (Euridice, 2009)

The testing style is often criticized by teachers and parents. Those criticisms are based on the assumption that assessment should take place in different forms with various tools. The exams do not show most students’ achievements, do not regard their physical condition on the exam day, nor their ability to concentrate in the situation of exam stress. In Poland, education exams

are basic assessment tools from early primary school to A'levels finishing secondary school education. According to EU recommendations, standardized assessment has been introduced in Poland: internal and external exams. Evaluation of school performance is based on external test results, while university entrance exams are dropped.

New syllabus basics have been prepared according to the above-mentioned principles. They were introduced in 2009 by an act of the Minister of National Education. Syllabus basics include: educational aims, general requirements, which can be referred to the key competences and teaching contents, i.e. particular requirements.

Biological education starts at kindergarten, then continues in the years 1-3 of primary school as an integrated subject of wildlife, and in the years 4-6 it is divided into biology, geography, chemistry and physics as separate subjects. Thus divided subjects are later taught in junior and senior high school. However, in senior high school integrated education is on again, thus the subject of wildlife is introduced.

Edward Rydygier (2012), in evaluating the reform of education in Poland, in its psycho-social aspect, claims that “the assumed by its creators benefits of the reform did not meet reality. The loss consists in intellectual degradation of students and increasing functional illiteracy” resulting from the wrong profiling of education from senior high school to university studies [natural sciences university, pedagogical university, humanistic university...]

The Lifelong Learning Program (2007-2013) is crucial in European education. “The aim of the program is to develop and

support exchange, cooperation and flexibility between education and training systems, so that they become a quality model according to the Lisbon strategy. Thus it contributes to community development of the society based on advanced knowledge, with constant economic progress, more workplaces and better ones, and more social coherence.” Natural sciences education should be implemented on every level of education and included in UN and UNESCO programs. The program “Education for Everyone”, the aim of which is providing educational basics for everyone concerns: literacy, arithmetic abilities, expressing thoughts, problem solving and creating appropriate attitudes <www.unesco.org.pl>. Particularly precious are its natural sciences elements that are common in Europe, such as: preservation of bio-diversity [ecosystems, species, genes], development aiming at a balanced future [creating ethics and social and ecologically friendly attitudes], and research analysis [at higher levels of academic training]. While the programs are rather general, educational systems in individual countries are detailed and adjusted to various purposes.

It is precision that is required from natural science competences that are universal for the future of Europe, according to PISA research results. They show a wide range of students' levels. What measures should be taken to decrease the discrepancy? Apparently, raising natural sciences achievements, saving their universality.

Reasoning in natural sciences – PISA research

European countries participate in the Program for International Student Assessment (PISA) coordinated by OECD.

PISA research is based on the assumption that natural science reasoning means:

*knowledge and ability to use it in asking questions, knowledge acquisition, explanation of phenomena, forming conclusions both about scientific issues and those loosely connected with sciences.

*scientific reasoning consists in understanding scientific characteristics as a sort of intellectual activity, and comprehension of rules according to which research is carried out and conclusions are made. (Nowak at www.zedn.edu.pl)

PISA research results are supposed to answer the following questions: to what extent is youth prepared to take up the challenges of the future? Can young people effectively analyze, reason and express their thoughts clearly? Are they ready to continue their learning ability for lifetime? How do we create syllabuses and education systems in order to help them at that? How can we make their career prospects more equal by means of education?

Within the natural sciences, the research is concerned with capacity for reasoning. 6 levels of abilities were distinguished. Following are 3 levels in an abbreviated form:

Level 6 the highest

“Students can always define, explain and apply natural science knowledge and academic reasoning in various complex situations in life... associate different sources of information to justify their decisions...”

Level 5

“Students can define scientific elements, in various complex situations in life... they can compare and evaluate adequate scientific evidence to react to situations

they face. They are able to give explanations based on evidence and arguments as a result of critical analysis.”

Level 4

“Students can work efficiently in situations and with issues that may include clear phenomena demanding drawing conclusions about the role of science or technology... They are capable of thinking over their actions and expressing their decisions, using academic knowledge and scientific evidence.

Subsequent PISA research results confirm that the level of key competences in the natural sciences is growing. In 2006, Poland was in the 23rd position gaining 498 points, while in the year 2009 they were in 19th position with 508 points. This score is close to the average results of students in OECD countries.

In search of effective strategies for natural sciences education

Universality in education is a pursuit of creating unity of a sort – wholeness, working out a complete model of attitudes based on acquisition of specific key competences for the human being to function in the contemporary world.

The trend towards united Europe generates a necessity for changes in natural sciences education to meet common challenges manifested in the pursuit of care for nature in general, and its protection and proper use by all European countries, in particular.

As indicated by PISA research, significant differences result from various models of natural sciences education and utmost care to prepare the whole system of biological education. Not all the countries pay enough attention to the role of natural sciences education in the development of human personality, creating attitudes for

modernization of one's own country and preservation of wildlife. There are discrepancies in syllabus contents, the form of education systems, the number of hours devoted to the subject education. In certain countries apart from the teacher leading a lesson or extra classes, there are technicians-lab workers hired to help prepare didactic aids necessary for doing experiments. In other countries, particularly in Eastern Europe, there are no proper conditions for students to get high achievements, though requirements are high, both for teachers and students. High number of students in a class makes it impossible to do experiments. Lessons are carried out by means of verbal delivery as a prevailing method and are based on its strategy of projects [wrongly called the method of projects].

According to a PISA research report by E. Norkowska for the year 2006, 62% of Polish students declare that they have never or hardly ever carried out lab experiments during lessons. It is only 27% for France and on average 32% in OECD countries. <www.dodn.wroclaw.pl>

In many European countries including Poland, discussions are held concerning the effectiveness of education. On occasion of various exams, it is indicated that because of evaluation and forming school ratings after exams, teachers mainly teach how to pass exams, i.e., they highlight techniques of filling in tests, and mechanical memorization of necessary content to gain the highest score. Apparently, 25% of correct answers are randomly marked. Hence the need to work out such methods of assessment that would stimulate teachers to implement key competences associated with science reasoning. It seems vital to prepare teachers and to give them appropriate conditions to apply methods based on the constructivist cycle of inquiry

[IBSE]. (Linn *et al*, 2004) This model, based on project strategies, includes the following stages of science inquiry: engage – explore – explain – extend - evaluate. (Llewellyn, 2002; Euridice/thematic_studies_en.php). D. Cichy distinguishes the following stages of a project: the choice of a research problem, defining the targets, preparation of the program and the schedule, realization of the project, project evaluation and presentation of the project. (Hauke & zu Belzen Umpeier, 2012)

This education strategy is applied in Poland under the wrong name of “problem method.” The name has been registered in education documents. In Poland, projects are realized regionally, locally, carried out at one school, or individually, and conducted by a team or one student.

Natural sciences education should have a common foundation not only with reference to key competences, but also in terms of training, the use of progress in pedagogical studies, and the introduction of the knowledge into school practices. The report, “Key Competences Development at Schools in Europe” indicates that in order to meet these requirements it is necessary to unify science education in terms of pursuing the following science competences:

- *comprehension of basic phenomena occurring in natural environment, both natural and of antropogenic origin;
- *critical thinking – fact evaluation, skeptical attitude to rising issues, ideas and arguments;
- *recognition of cognitive limitation of natural sciences;
- *interpretation and practical usage of research results.

These key competences should be acquired by students in science education mainly by scientific investigation/discovery. (Llewellyn, 2002)

Didactics are searching for new strategies and science education methods that would raise students achievements and trigger their motivation and attitudes towards environment, environmental culture and balanced development. Hauke Hellwig and Annette Umpeier zu Belzen, based on research, have worked out eight didactic concepts of environmental biological education and balanced development. The new concepts demand a change of teachers' thinking and a competency-based teaching-learning process. <Euridice/thematic_studies_en.php>

Ulrich Katmann is working on a reconstruction model for science subjects. The model consists of connection of theory and practice and their positive influence on the teaching-learning process. (Hauke & zu Belzen Umpeier, 2012)

Katarzyna Potyrała is carrying out research on appropriate implementation of information technologies in the process of education and digitization of school. (Potyrała, 2012)

Summing up and conclusions

Undoubtedly, natural sciences didactics is undergoing a crisis, which is manifested in:

- *axiological mess
- *poor communication between pedagogy and didactics revealing by insufficient transformation and no consensus.

In the IBSE project (Inquiry Based Science Education) for physics teaching, the authors suggest a constructivist investigation cycle. Following Linn, Davis & Bell (2004), they assume that "scientific investigation is an intentional process denoting problem diagnosing, critical analysis of experiments and finding alternative solutions, research planning, testing hypotheses, searching for

information, model construction, friendly debates and formulating coherent arguments." Accepting this definition in didactics of biological and environmental subjects may be a step towards global consensus in the area of European didactics of natural sciences. Yet, even if we have a different attitude, we have to accept the achievements of natural science subject didactics, according to which science teaching is based on research methods depending on scientific reasoning.

There is a need to further develop research and teachers' training on every level. Moreover, in European dimension there is a need to:

- *realize European regulation concerning environmental competences mainly referring to academic reasoning and the use of various media
- *create European didactic research teams
- *draw special attention to education for balanced development – motivate and create attitudes both among students and teachers
- *appeal to ministerial authorities about the significance of environmental subjects and creation of conditions for modern education.

I believe the conclusions from this conference will inspire teachers, pedagogical scientists, didactics and authorities to positive actions concerning European environmental education.

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The act of the Minister of National Education from 23rd December 2008 referring to the syllabus basics of pre-school and general education in different kinds of schools published on 15th January 2009 in the Acts Manual nr 4, paragraph 17, with later amendments.



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Municipal Waste Management and Life Quality: Sustainable Development of Local Communities in Małopolska and Podkarpacie

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The modern educational system in addition to the traditional formal education focuses on enabling individuals and social groups in the various forms of school education. These forms have been increasingly used in the activities of local government units, including the environment issues. In most cases, these are organized on a small, but effective, scale, because they are planned for a specific audience and a specific problem-oriented theme. A choice of methods to carry out these activities often depends on local governments, who possess the best knowledge about the specifics of the area. Greater opportunities for the implementation of environmental tasks occur through associations of boroughs. Municipalities may apply for joint domestic and international infrastructure project financing important for each municipality belonging to the association of local authorities. In Poland, there are currently 35 associations of municipalities, for which the first priority is the implementation of tasks in order to improve the quality of the natural environment and implement the principles of sustainable development, including municipal waste management. This paper examines the involvement of municipalities - members of associations in improving the quality of local environment, and thus increase the quality of life of local communities. Based on data for two rapidly acting associations (Związek Gmin Górnej Raby i Krakowa in Malopolska voivodship and Związek Gmin Dorzecza Wisłoki in Podkarpacie voivodship), we exemplify two different natural environments, different activities, forms of information and education to improve the efforts, in terms of the local natural environment as undertaken by local government units.

Keywords: municipal waste management, associations of municipalities, sustainable development

Współczesny system edukacyjny oprócz tradycyjnej edukacji formalnej stawia na włączanie jednostek i grup społecznych w różne formy edukacji pozaszkolnej. Formy te coraz powszechniej stosowane są w działaniach jednostek samorządu terytorialnego, w tym na rzecz środowiska naturalnego. W większości przypadków są to działania organizowane na małą skalę, ale skuteczne, bo zaplanowane dla konkretnej grupy odbiorców i zorientowane na określony problem tematyczny. Dobór metod do prowadzenia niniejszych działań zależy najczęściej od samorządów lokalnych, posiadających najlepszą wiedzę o specyfice danego obszaru. Większe możliwości na realizację postawionych sobie zadań środowiskowych i większe szanse na powodzenie ich przeprowadzenia mają gminy zrzeszone w związkach gmin. Gminy te mogą występować o wspólne projekty infrastrukturalne z funduszy krajowych i zagranicznych na finansowanie działań ważnych z punktu widzenia każdej gminy należącej do danego związku gmin. W Polsce obecnie istnieje 35 komunalnych związków gmin, dla który podstawowym priorytetem jest realizacja zadań międzygminnych w celu poprawy stanu środowiska przyrodniczego i wdrożenia zasad zrównoważonego rozwoju, w tym gospodarki odpadami komunalnymi. Niniejsza praca bada zaangażowanie gmin zrzeszonych w związki gmin komunalnych w działania na rzecz poprawy stanu lokalnego środowiska przyrodniczego, a przez to poprawy jakości życia lokalnych społeczności. Na podstawie analizy danych zastanych do badań włączono prężnie działający Związek Gmin Dorzecza Górnej Raby i Krakowa z województwa małopolskiego oraz Związek Gmin Dorzecza Wisłoki z województwa podkarpackiego stanowiące przykład działań na rzecz lokalnego środowiska przyrodniczego. Jest to ewaluacja różnych działań i form informacyjno-edukacyjnych na rzecz poprawy lokalnego środowiska przyrodniczego podejmowanych przez jednostki samorządu terytorialnego.

Słowa kluczowe: gospodarka odpadami komunalnymi, związki gmin, zrównoważony rozwój

Introduction

According to the amendment to the Polish waste legislation, which has been executed since January 1, 2013, the local governments became responsible for municipal waste in their areas. At the same time, policy makers became responsible for developing waste management plans. The search for new solutions to the problems of waste, is in line with the principles of sustainable development as defined by the following policy guidelines of the European Union. EU Framework Directive defines the hierarchy of methods for how waste is to be managed (Fig. 1).

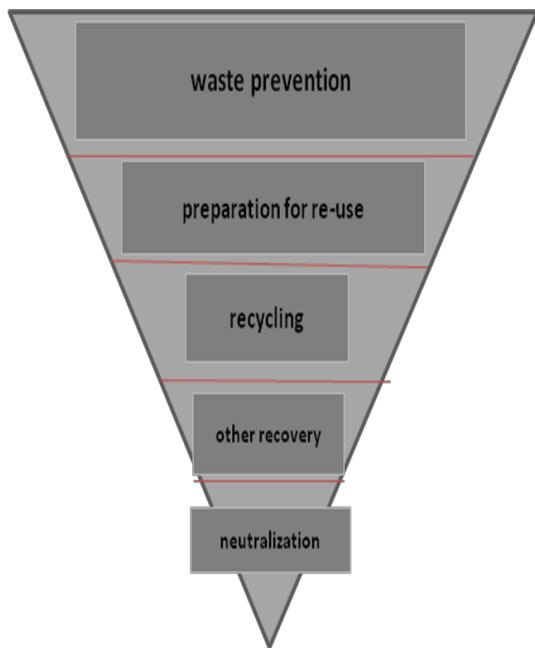


Figure 1. The waste utilization hierarchy (the development of their own based on Ernst & Young, 2011)

The EU Member States wishing to follow this scheme must provide appropriate national regulations regarding waste management and organize a complex system of waste collection and disposal. In Poland, the changes in the waste law introduced in 1.01.2012, includes this scheme for

sustainable development policy. Municipalities are obliged by the end of 2020, to reduce by at least 50%, municipal waste such as paper, metal, plastic and glass by re-using and recycling.

To achieve these goals, municipalities need, as defined in the Act of July 2011, to maintain cleanliness and order in municipalities, and through other acts, to conduct information and educational activities in the field of waste management, to various groups of the public. (Dz.U., 2011 No. 152, item. 897).

A survey developed for the Ministry of the Environment (2011) shows that not all residents have had a chance to join the system of selective collection of waste. In 2008, just 23% of municipalities have not conducted, or carried on a limited scale, such activities. Creating the conditions for the selective collection and reception of waste should be carried out in conjunction with activities related to raising public awareness. Informing the local community about the principles and forms of collecting various types of waste can be a task of municipalities, conducted individually or jointly with other municipalities, as part of the municipal associations.

An association of municipalities is created by local municipalities, under the provisions of the Act of 8 March 1990, and the Local Government, to undertake joint public activities including improvement of the natural environment. Municipalities are eligible to apply for joint projects, with domestic and foreign funds, to finance activities of importance to each municipality belonging to the Association. In Poland, there are 35 municipal associations of municipalities, for which the priority is the implementation of incentives in order to improve the environment and implement the

principles of sustainable development, including waste management.

The activities of local governance

Our study included the rapidly developing Związek Gmin Dorzecza Górnej Raby i Krakowa in Malopolska voivodship, and, Związek Gmin Dorzecza Wisłoki in Podkarpace voivodship. Based on an analysis of our data, we present examples of various activities, forms of information and education to improve the local environment as undertaken by these local government units (Grodzińska-Jurczak *et al.*, 2006; 2010; 2011).

Using qualitative research, and in-depth analysis of the problem, we selected municipalities from two associations of Carpathian municipalities. We conclude that the actions taken by small municipalities are rather ineffective. The activities planned by a number of municipalities have possibly a greater chance of success both in achieving educational results, and, obtaining funding from external resources.

The involvement of communities in efforts to improve their local environment, and thus improve the quality of life, is significantly dependent on information and education campaigns. Various forms of extracurricular activities, including information and education campaigns, have been increasingly used in the activities of local governments, and these have included a focus on the environment (Nieszporek and Grodzińska-Jurczak, 2013). Well-planned activities are effective because they are targeted to a specific audience (Heberlein, 2012). Although there is no doubt that local communities involvement in waste management is crucial, its effectiveness depends mainly on the type and methods of communication used. More inquisitive

approaches, rather than traditionally common public hearings, have proved to be effective in leading to social acceptability of the proposed new policy (Timlett and Williams, 2011).

The effectiveness of the action taken in connection with the EU requirements, in the field of waste management, depends not only on the business industry and infrastructure, but also, to a large extent, on individual consumers. The effectiveness of waste separation depends on the degree to which there is public acceptance of the waste policy (Laurian and Shaw, 2009). In addition, public engagement in specific solutions and effective participation is reliant on good information and ease of use. The key to success is to change social behavior, which should be accompanied by not only the appropriate information campaign, but also the development of a system for collection of various types of waste. A range of external variables (i.e., financial incentives, availability of good information, and the organisation of a local infrastructure for separate collection) (De Young, 1989; Judge and Becker, 1993), relating to environment, can resume the adoption of the principles of rational waste management (Fenech, 2002; Shaw and Maynard, 2008).

Local human development

Thanks to the support of the European Union, funding disparities between regions is reduced. "National Human Development Report. Regional and local development "(2012) analyzes local development in terms of health, education and wealth of the inhabitants. For the analysis, the local index of social development (Local Human Development Index - LHDI) was used. This enables us to study socio-economic development at the national level. In

particular, we can analyze public policies that focus on the development of human and social capital, and sustainable development at the regional level, innovation, and, improving the quality of life. The basic unit of analysis is the development of the local district.

In order to determine the coefficient on education (EI), we assumed that the national gymnasium test, particularly its' key - science part, could be compared on a national scale.

In our report, the welfare index (WI) indicates the amount of taxable income,

income from agriculture, the total expenditure on social assistance, and, other tasks of social policy (e.g. family policy), which were included in the budgets of local (municipal and county) government. However, the health factor (HI) is calculated as the average life expectancy of a newborn, and the number of deaths due to cancer and cardiovascular disease.

Surveyed municipalities are in the four counties Podkarpacie and five counties Małopolska. Indicators of social development of these districts are shown in Figure 2.

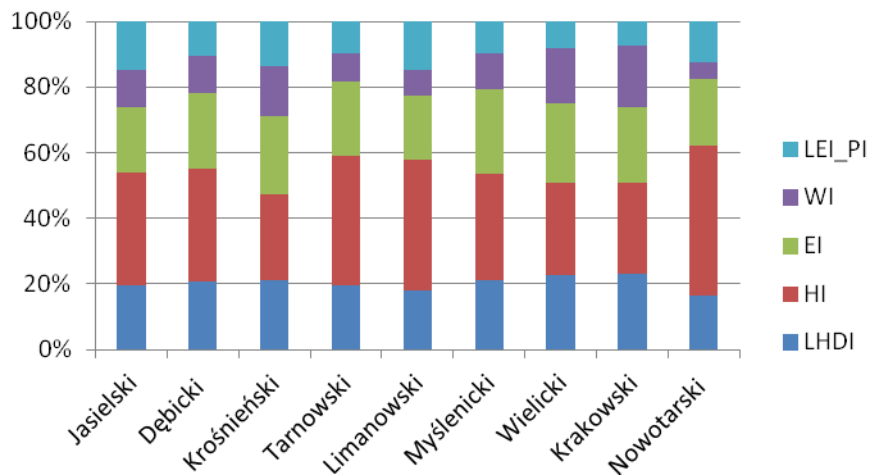


Figure 2 Local Social Development (National Human Development Report Poland 2012):

LHDl – Local Human Development Index
HI – Health Index
EI – Education Index
WI – Welfare Index
LEI_{PI} – Local Expenditures Index Policy Input

A nationwide poll by TNS Poland showed that 69% of respondents believe that municipalities do not lead promotional and educational activities on the management of waste (Figure 3). These studies support our conclusions based on the analysis of in-depth interviews in the surveyed municipalities of Lesser Poland and Subcarpathian province. When asked about the causes of not selecting the wastes the most frequent answer was a lack of bins in the area. For the same reasons, nearly 60% of people in TNS Poland, in 2012, and 11% of the population in Jaslo, did not, in fact, separate wastes.

However, nearly one-fourth of the respondents by TNS Poland (29%) indicated a lack of space at home as a main reason for no separation. Accordingly, in Jaslo the lack of space in the house was identified by 11% of respondents. The results show that the main barrier to waste sorting was due to external causes, mainly the lack of adequate infrastructure. Satisfactory is that this infrastructure slowly, but steadily is getting better.

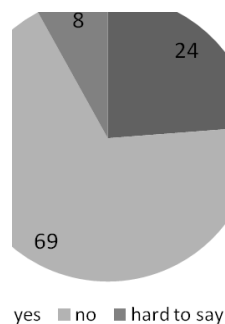


Figure 3. In the last year, said (a) you (i) carried out by the municipality of information and education on the proper management of waste? (TNS, 2012).

On the basis of the study of selected communities in the Carpathian region, it can be said that information and education activities, organized on a small scale, are effective, because they are usually targeted to a specific audience and a specific problem-oriented theme. The choice of methods to carry out these actions depends mostly on local governments, which have the best knowledge about the specifics of the area. Information and education campaigns in the management of municipal waste can bring good results when they are engaged in. There is a huge effect of educational information campaigns when they are conducted in schools. Knowledge is conveyed not only to students, but also to their families, and a joint participation in ongoing projects results in promising effects.

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Ustawa z dnia 8 marca 1990 r. o samorządzie gminnym (Dz.U. z 2001 nr 142 poz. 1591, brzmienie od 15 lutego 2013).



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Nature of Science and Science Education: Missing Connections and Potential Interdisciplinary Links

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Science education research and policy has advocated that a scientifically literate individual should have some knowledge of and about science. Although science is deemed important as an educational outcome, there is no uniform agreement among the different stakeholders about what constitutes science and what therefore should be included in educational settings. Some philosophers of science have emphasized that there is no precise definition of science due to the complexity of the enterprise while some science educators have been involved in discussions around a consensus view on nature of science (NOS). That view has the following list of tenets: scientific knowledge is tentative, empirically based, subjective (theory-laden), partly the product of human inference, imagination, and creativity, socially and culturally embedded; observations are different from inferences; and scientific theories and laws are different from each other and have distinct functions. These tenets have been based on a series of empirical studies conducted in the last two decades or so mainly aiming at characterizing students' and teachers' views on NOS, as well as at proposing and validating an adequate instrument to support and assess such characterizations. Since 2011, some criticisms have emerged from both science education and philosophy of science communities about the characterization of NOS. This paper traces some of the key aspects of these recent debates and provides an alternative way forward with a particular emphasis on the role of interdisciplinary investigations in characterizing science. In so doing, the argument will be presented that NOS needs to be reconceptualised for the purposes of science teaching and learning.

Key words: science education, NOS, students and teachers

Introduction

In recent years, there has been a great deal of focus on the teaching and learning of nature of science (Abd-El-Khalick, Bell, & Lederman, 1998; Alters, 1997; AAAS, 1990; Bartholomew, DfE, 2012; Eastwood et al., 2012; Flick & Lederman, 2006; Hogan, 2000; McComas & Olson, 1998; NRC, 2012; Smith & Scharmann, 1999; Teaching and Learning Research Programme, 2006). The significance of science is reflected in many official documents of countries from all over the

world (ACARA, 2010; AAAS, 1990; McComas & Olson, 1998; NRC, 2012; QCA, 2007). The authors of such documents and papers claim that one of the key outcomes of knowledge about nature of science is that judgments about scientific discoveries and applications can be scrutinized and evaluated (Hogan, 2000).

Although science is deemed important as an educational value, there is no uniform agreement among the different stakeholders about what constitutes science and what

therefore should be included in educational settings. Whilst some philosophers of science have emphasized the disunity of science view, according to which “science is a multifaceted enterprise for which no satisfying definition that encompasses it in its entirety is likely to be found” (van Dick, 2011, p. 1087), some science educators have been involved in intense discussions around forming a consensus view on nature of science. A particular aspect of this debate involves the role of interdisciplinary characterisations of the nature of science. “Science Studies”, the interdisciplinary set of investigations on the nature of science, are contributing to the aim of informing science education of the foundational perspectives from a range of disciplines, including cognitive science, philosophy of science, artificial intelligence and sociology of science (Duschl, Erduran, Grady, & Rudolph, 2006). Various science studies characterizations are conceptually related, but historically distinct and have different lines of research. Namely, they go by: “Socio-Scientific Issues” (SSI) (e.g. Sadler, 2011; Zeidler, Sadler, Simmons, & Howes, 2005), “Science-Technology-Society-Environment” (STSE) (e.g. Aikenhead, 2003; Gaskell, 1982; Yager, 1996), “History, Philosophy and Sociology of Science” (HPS) (e.g. Matthews, 1991), and “Nature of Science” (NOS) (e.g. Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). They argue for situating science in its historical, socio-political, economic and cultural contexts for educational purposes.

There are at least two key rationales for interrogating the intersection of NOS with interdisciplinary accounts. The first concerns the grounding of knowledge in science education in relevant bodies of knowledge that concerns the characterisation of science itself. Given the focus on ‘science’ in “science education”, it is entirely appropriate

to investigate what (if any) features of science should be infused in science education, both in terms of theoretical framing of science but also in terms of the practical implications for science teaching and learning. The second rationale is related to the potential reverse relationship of the contributions of science education research to perspectives on Science Studies. Given that the establishment and the maintenance of the scientific enterprise rely on the production of scientists through the education system, it is conceivable that science education knowledge can and should inform arguments in Science Studies as well.

An implicit goal underlying the inclusion of interdisciplinary perspectives in science education is the notion that scientists and the public alike should possess scientific literacy. Here ‘literacy’ is not meant in a generic sense. Rather, “scientific literacy for all” is a theme that has been advocated in science education research (e.g. Brown, Reveles & Kelly, 2005; Gott & Roberts, 2004; Holbrook & Rannikmae, 2009; Laugksch, 2000; Lemke, 2004; Norris & Phillips, 2003), and, international policy initiatives (National Research Council, 1996; OECD, 2006) quite explicitly and strongly in recent years. Numerous curricula in the world have already embraced and promote the teaching and learning of “scientific literacy” in schooling. For instance, Erduran and Wong (2013) have conducted a comparative study of science curricula in England and Hong Kong for their coverage of themes related to scientific literacy. Roberts (2007) distinguished two visions of scientific literacy. Vision 1 describes an understanding of the enterprise and epistemology of science and could be considered as what the public should know about the science used by society. Vision I surfaced in 1985 with the beginning of AAAS *Project 2061*. The project’s

Benchmarks for Science Literacy and *Atlas of Science Literacy* have influenced the thinking of educationalists in the USA and worldwide. The notion of “science as economic enterprise” is consistent with Vision 1 scientific literacy. Here the goal for science teaching and learning would entail the articulation of the economics that drive, shape, hinder or enable scientific inquiry. Vision 2 involves understanding the world as a scientist would, i.e. being able to offer explanations and hypotheses about the world. Generating theories and knowledge claims are seen as the key activities of science.

In this paper, I will trace a set of ideas with the aim of engaging in the debates in Science Studies so as to investigate the potential interactions that might exist with science education. For example, I will review some of our work on the implications of economics of science (Erduran & Mugaloglu, 2012).

The predominant definition of the NOS in the empirical studies on teachers’ and students’ perceptions of science have relied on the characterization of science primarily relative to the cognitive, epistemic and social aspects of science, and have been limited in terms of their conceptualizations of science from broader perspectives (e.g. Allchin, 2011) including economics of science. Let us consider the collective set of learning goals for understanding the NOS advanced, explicitly and in a particular sense, by the key proponents of this area of research in science education (Lederman, *et al.*, 2002; McComas, 1998):

- (a) Tentativeness of Scientific Knowledge: Scientific knowledge is both tentative and durable;
- (b) Observations and Inferences: Science is based on both observations and

inferences. Both observations and inferences are guided by scientists' prior knowledge and perspectives of current science;

(c) Subjectivity and Objectivity in Science: Science aims to be objective and precise, but subjectivity in science is unavoidable;

(d) Creativity and Rationality in Science: Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world;

(e) Social and Cultural Embeddedness in Science: Science is part of social and cultural traditions. As a human endeavour, science is influenced by the society and culture in which it is practiced;

(f) Scientific Theories and Laws: Both scientific laws and theories are subject to change. Scientific laws describe generalized relationships, observed or perceived, of natural phenomena under certain conditions;

(g) Scientific Methods: There is no single universal step-by-step scientific method that all scientists follow. Scientists investigate research questions with prior knowledge, perseverance, and creativity.

Even at such propositional characterisation of NOS, it can be argued that this characterisation of science is quite limited. Take for instance, 5 of the 7 statements: (a), (b), (c), (f) and (g) which all imply primarily an epistemological grounding, namely the emphasis on the nature of scientific knowledge and knowledge production procedures. The remaining elements, (c) and (d) are mainly concerned with the cognitive, social and cultural features of science, all rather broad and lacking sufficient detail to differentiate the nuances that, for instance,

differentiate branches of science. Take, for instance, the arguments for the role of ‘classification’ in science. From a NOS perspective, classification would be presented as a process that scientists use in order to understand the world. It would potentially be considered a component of (g) above. However, the articulation of ‘classification’ in philosophy of science (e.g., Bryant, 2001) illustrates the complexity in the ways in which different branches of science use classifications. While classification may be prevalent in science, the particular ways in which it is instantiated in different disciplines (e.g., elements in chemistry, species in biology) are nuanced illustrating the domain-specific ways of reasoning. Discipline specific philosophies of science have documented other aspects of scientific knowledge that portray variations in conceptualisation. For example, the concept of ‘laws’ can have very different meanings in chemistry versus physics (Christie & Christie, 2000). If we consider the articulation of the disciplinary variations and specifications of the epistemological (e.g., Scerri & McIntyre, 1997) as well as the cultural and social practices (e.g., Knorr-Cetina, 1999) of different sciences, the NOS framework above falls short of meaningful grounding of science in authentic (and not overgeneralised) aspects. One could indeed query, the nature of *which* science NOS characterisations capture in the first place? Whilst our reference mainly concerns the variation in the sciences from an epistemological perspective (e.g., Scerri & McIntyre, 1997), we shall see in subsequent sections that there are also variations in the economics-related practices of science as well. For instance, we will illustrate how the molecular biology and biotechnology fields have been prone in particular ways to the commodification of scientific knowledge.

One of course could argue that NOS needs to be framed for educational purposes in a rather broad sense, given the developmental, curricular and pedagogical constraints that NOS will face in schooling. In other words, whilst the researchers in science education might acknowledge the nuances in the disciplinary variations in science, it may not be practically plausible to import these features for schooling purposes. Considering the abundant literature on children’s difficulties with science (e.g. Driver, *et al.*, 1996), the argument could go that a broad and underspecified NOS is what is needed in education. The alternative educational imperative is that learning is a situated activity (e.g., Lave & Wenger, 1991), and it is only through the nuanced practices of science that learning will be meaningfully situated.

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Beliefs of Pre-Service Chemistry Teachers on the Use of Visualizations in Teaching in Two Countries: Brazil and Portugal

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The beliefs of preservice chemistry teachers, from Brazil and Portugal, on the use of visual tools in teaching chemistry, which have been introduced increasingly in the areas of teaching/learning in these two countries were investigated through qualitative research. We began this work with a brief theoretical debate about the nature of scientific knowledge and its forms of representation, followed by the initial training of the chemistry teacher. The analysis of questionnaires submitted to these students showed great similarities regarding ideas about using these tools, because in general there is a lack of questioning that leads to superficial and naive views on the subject, as well as possible misconceptions.

(Português): Nesta pesquisa qualitativa, foram investigadas as concepções de professores em formação inicial no Brasil e Portugal à respeito do uso de ferramentas visuais no ensino de química, as quais têm sido introduzidas crescentemente nas áreas de ensino/aprendizagem nos dois países dentro dos últimos anos. Inicia-se o trabalho com um breve debate teórico à respeito da natureza do conhecimento científico e suas formas de representação, seguido da formação inicial docente. A análise dos questionários respondidos por esses estudantes apresentam grandes similaridades à respeito do uso destas ferramentas visuais, porque de modo geral há um fraco questionamento à respeito da temática, resultando em concepções superficiais e ingênuas, bem como possíveis equívocos, à respeito da mesma.

Keywords: Visualization, Teachers Instruction, Models and Modeling.

Introduction

The approach to the development of chemical knowledge, and consequently its language, presents a close and natural link with the imagery field, regardless of the *vehicle of sign* used mostly. The verbal code itself cannot develop without images as evidenced by speech that is permeated with images, or, as Peirce would say, iconicity (Santaella & Nöth, 2008).

Verbal language, written and spoken, began as the most usual way to represent, communicate and solve problems in science. But, as knowledge has evolved, it became necessary for humans to associate other types of languages and new forms of representation (Ferreira, *et al.*, 2011). The quick development of information and communication technologies followed with several studies in the area of cognitive theory that promoted the construction of

several visual tools (3D concrete models, static and dynamic 2D and 3D simulations, animations, interactive software, etc.) (Ferreira & Arroio, 2009). These tools have been used increasingly, in different spaces, from formal and informal education, to daily journalism that reaches all audiences. However, in the field of education, research in science teaching is fundamental for understanding these resources and how they can be used and justified in the context of the main educational paradigms that have been discussed and consolidated in recent years.

Reviewing papers (Vavra *et al.*, 2011; Teruya *et al.*, 2013) has helped us to map the fundamental questions that can generate a better understanding of our subject, as well as direct our attention towards new investigations. How do the views influence the construction of scientific concepts? What is the nature of those images? What are the pedagogical strategies that allow better support of the teaching/learning process through using these resources? Is this theme being questioned by early phases of the courses of chemistry teaching?

Investigating the beliefs of pre-service chemistry teachers on the use of visualizations in science teaching can become a valuable tool for analyzing their training, allowing us to make specific and general evaluations of the training courses. As for Brazilian students, this study comes at a time when several Brazilian higher education institutions were rethinking their chemistry teacher education programs (Farias & Ferreira, 2012). For Portuguese students, in general, the country had invested funds focused on technology in public schools, which generated the visual tools, but insufficient concern for the pedagogical characteristics of their use, in

pre-service training in their initial training (Ferreira, 2010).

Models and Modeling

Science, among other things, seeks to build explanations for natural phenomena. Thus, models are at the core of any theory: they are the main tools used by scientists to produce knowledge and one of the main products of science (Justi & van Driel, 2005; Gilbert, 2005). Models emerge when scientists impose their ideas, which are considered the most relevant, to explain a complex phenomenon (Gilbert, 2005). It is important to explain basic characteristics of systems and make predictions. They are chosen to assist the macro level views (visual perception). Scientific models have even greater importance when their construction is done in order to explain phenomena in the submicroscopic level. They are an idealization of reality as it is imagined, based on abstractions of theory, and produced consistent to experimental observations.

However, model production is always a process of change. One of the main practices of scientific deductions hangs in the constant process of production and revision of models called modeling (Justi & van Driel, 2005). These characteristics about science explain its constitution in general, and, can demystify several concepts established by society coming to beginning students in science. There is a long human process in the construction of knowledge, which is dependent on the validation of a community and a constant presence of subjectivity. Thus, Ferreira & Justi (2008) argue that a model is not a copy of reality, even less the truth itself, but a way of representing it as originated from personal interpretations of the subject. They still believe that to bring up the discussion of this inability to learn the "truth", because it deals with models, is

knowledge that can motivate students. However, it is something that is not apparent, because scientific knowledge is usually presented as content, hiding the emotions, motivations, and pursuits of those researchers who have developed the knowledge. Knowledge, as seems unchanging. It is possible, however, if these practices are taught in the classroom, that the notion of a universe knowledge will be transformed in a stimulating way, aligning science teaching with a clearer conception of the knowledge construction process.

Models and representations

Santaella & Nöth (2008) presents an extensive discussion about the term "representation." Its meaning as a synonym of sign was the most appropriate for this work. The authors relate that Howard (1980) defines: "the words 'representation', 'language' and 'symbol' are virtually interchangeable in their uses wider," and they show that Peirce (1931) initially characterized semiotics as, "the general theory of representations." However, Sperber (1985) distinguishes between "mental representation" and "public representation."

Models and representations are already interrelated in their synthesis. It is from the representations that scientists infer and produce knowledge (Justi & van Driel, 2005). Gilbert (2005) indicates that the models can be represented by concrete, verbal, symbolic, visual and gestural modes. The use and understanding of each of these modes, in addition to the necessary and diversified ways of moving between them, are objects of great importance in investigating of the visual tools use in teaching chemistry.

Kosma & Russel (2005) investigate the role that representations can play in the chemical curriculum. From an ethnographic study,

they compared chemistry pupils and chemistry professionals in different chemical investigative processes in a laboratory. While the professionals associated the macroscopic phenomena with various forms of social chemistry representation, performing constant reformulations about the knowledge, pupils in their investigative practices were not motivated to build a social scientific discourse of what they were studying, that is, they didn't associate experiments to the molecular entities or dynamic processes. So, first all, the authors advocate the use of visual aids as possible to lead pupils to join the macroscopic field to the microscopic field of knowledge construction (models). However, contact with this representational world is not simple, as will be seen later, through some studies that investigated the main difficulties encountered by pre-service students and possible ways to overcome them.

Metavisualization

Those who view visualization as the accumulation of a series of information, reflect a naive view of the world, i.e., what is "out there" must have the same impact in all brains (Tufte, 2001 in Gilbert, 2005). Santaella & Nöth (2008), in a discussion about models of cognitive psychology, relates that Piaget sets the internal image as "representative scheme" of an external event and sees it as an "internalized imitation", i.e., a personal transformation of the event. Thus, he argues against a theory of "naive copy", which sees the mental image as a kind of vestige of an object, and advocates, on the other hand, a theory of assimilation image.

Therefore, there is a need to investigate some of the fundamental processes regarding the skills and competencies required for visualization. Several studies (Gilbert, 2005; Locatelli, Ferreira, & Arroio,

2010; Kosma & Russel, 2005; Barnea, 2000) focus on the necessary skills involved in the process to the representations. However, the ability to think about it, monitoring and regulating it also becomes essential in the learning process in chemistry because the self-regulation thinking had become possibly the visualization a process more efficient and flexible. The skills involved in conceptual formation from images and the discussions about the self-regulation of this process have been incorporated in definition of the “metavisualization” term (Figure 1).

In this perspective, “metavisualization” can be considered as a metacognition in respect to visualization processes. Thus, it will be briefly discussed these two last terms.

There are two ways that “visualization” can be used (Gilbert, 2005). First, visualization is a verb and research concentrates on the acts of interpreting an image and assigning meaning. The author defines this process as the formation of an internal representation from an external representation, such that the temporal/spatial nature and relations between the entities of which it is composed are retained. In the second use, visualization is a noun and studies focus on public materials available to the users such as diagrams, videos, animations, and images,

among others. Our focus is on cognitive processes, so we study visualization as a verb.

Locatelli *et al.* (2010) show that there is no uniformity about the term metacognition in the psychology literature. However, various authors suggest similar uses, and it can be understood as the capability to think about a determinate cognitive process. There are too many characters that can be encountered in “think about the process” such as active monitoring and supervision of the task to be developed (Livingston, 1997) or an active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects (Flavell, 1976). The main consequents to be able in metacognition is an individual would be more efficient in a problem resolution and be able to get innovative solutions, apart from can estimate their knowledge in several different areas, following its continuous learning, dynamically updating their knowledge and future planning new learning (Everson & Tobias, 1998).

However, since we can consider “metavisualization” as a “metacognition” in respect to “visualization,” some specific skills are cited in the literature that can be related to the term.

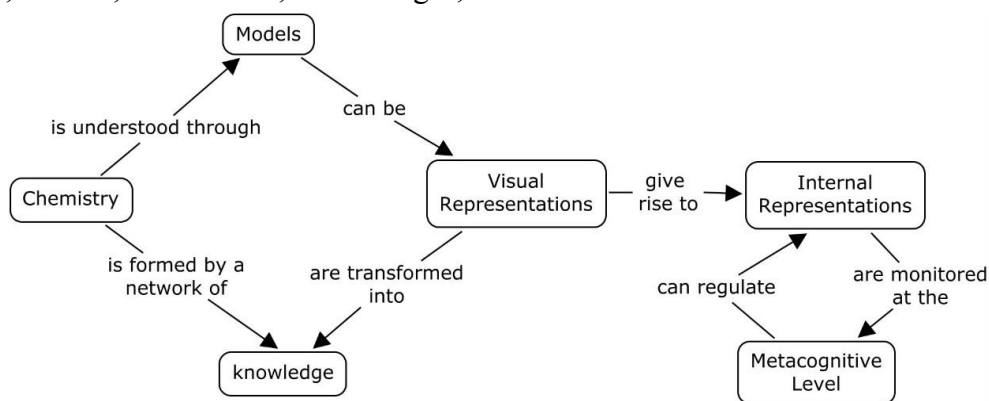


Figure 1. Metavisualization skill in the construction of student knowledge, Locatelli, Ferreira & Arroio, 2010.

Kosma & Russel (2005) cite representational competences as:

-The ability to use representations to describe observable chemical phenomena in terms of underlying molecular entities and processes.

-The ability to generate or select a representation and explain why it is appropriate for a particular purpose.

-The ability to use words to identify and analyze features of a particular representation (such as a peak on a coordinate graph) and patterns of features (such as the behavior of molecules in an animation).

-The ability to describe how different representations might say the same thing in different ways and explain how one representation might say something different or something that cannot be said with another.

-The ability to make connections across different representations, to map features of one type of representation onto those of another, and to explain the relationship between them.

-The ability to take the epistemological position that representations correspond to but are distinct from the phenomena that are observed.

-The ability to use representations and their features in social situations as evidence to support claims, draws inferences, and makes predictions about observable chemical phenomena.

Barnea (2000) cites spatial abilities as:

-Spatial visualization: the ability to understand three-dimensional objects from two dimensional representations of them (and vice versa);

-Spatial orientation: the ability to imagine what a three-dimensional representation will look like from a different perspective (rotation);

-Spatial relations: the ability to visualize the effects of the operations of reflection and inversion.

Gilbert (2005) claims that pupils to become metacognitively capable in respect to visualization, should:

-know the conventions of representation, both for the modes and major sub-modes of representation that they are likely to encounter;

-know the scope and limitations of each mode and sub-mode i.e. what aspects of a given model each can and cannot represent.

Pre-service chemistry teacher education

Over the years researches in education have identified a complex set of skills required of teachers, to support their practices, when facing several problems encountered in current environments of teaching/learning. Initially, researchers were concerned to investigate *attitudes* of teachers and generally believed in a linear model of cause and effect, i.e., it was possible to predict behavior based on a study of positive *attitudes* related (Mansour, 2009). This research was consistent with behaviorism and quantitative research methodology.

However, these investigations decreased with time, leading to studies that are less concerned with the controlling and predicting behaviors of teachers. The focus of new research is on understanding the relationship between varying forms of teachers' knowledge, experience and practices (Mansour, 2009). Thus, the term "teachers' beliefs" and qualitative methodologies now predominate in research related to teacher training. Defining the term "belief" is not a easy task, because as pointed out by Pajares (1992) it has different meanings, such as attitudes, values,

judgments, axioms, opinions, ideology, perceptions, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, personal theories, internal mental processes, action strategies, and conduct rules.

The research on teachers' beliefs, in our case of pre-service chemistry teacher education, is important because it influences, in a substantial way, teacher thoughts and actions (Ponte, 1992). Thus, beliefs regarded as personal methods or theories, which can play an important role in defining the set of teaching tasks. They are also characterized as "idiosyncratic unity of thought about objects, people, events and their characteristic relationships that affect his/her planning and interactive thoughts and decisions" (Mansour, 2009).

Finally, what are the sources of beliefs? Mansour (2009) suggests that *experiences* play a key role in the formation of teachers' beliefs and he divided them into formal and informal. A formal type is represented by formal education, within the school, university and teacher practical training as mediated by the university. Informal types are those derived from interpersonal interactions that result in a series of reformulations of pre-established beliefs.

The research on teachers' epistemological beliefs has accumulated in the literature and it is particularly relevant to our investigation about the visualization use in chemistry teaching. Studies argue that many educators are influenced by positivist and empirical-inductive beliefs (Maldaner, 1988), so they conceptualize science as absolute truth, which does not accept changes or questions. Therefore, they have as their main goal the transmission of content and the stimulation of "right answers" from pupils. It can be

concluded, then, that many students will form a similar epistemological conception of science. This can generate many obstacles in students' conceptual learning as well as in their perceptions of how human knowledge develops.

The viewpoint that science evolves from the careful and neutral observation of phenomena, providing for objective scientific knowledge production, is not consistent with current literature. Currently the observation of phenomena is presumably guided by theories that will bring support, and in turn, consists of symbolic generalizations validated at a given time and in an historical context (Lobo & Moradillo, 2003). Misconceptions about this process create serious problems for educators, making their practices less flexible and inappropriate.

The visualization act is influenced by the individual's epistemological conceptions about science. In the previous section, we discussed the modeling process, which helps us to build a consistent idea of scientific practice within the current thinking. Several specific features of the act of viewing, such as identifying the limits of representations, are established examples of discussions that might not have been done superficially or in isolation from a deep understanding of their nature.

Giordan (2007) points out the epistemological and historicist study of the chemical structural representations as helpful in understanding the main difficulties encountered by beginning chemistry students in their learning process. The author believes it necessary to change teachers' beliefs about the representations as expressive ways to scientific knowledge

production, as produced by an organized social group.

Methodology of research

We carried out a literature review focusing on the development of scientific knowledge, its relations with the use of representations, and, the initial training of teachers of chemistry. Then, relying on the qualitative interpretative framework, we used a questionnaire in order to investigate the beliefs of pre-service chemistry teacher on the use of visualizations in teaching in two countries: Brazil and Portugal. From this data, we conducted a content analysis of this.

We administered a questionnaire, consisting of 17 open questions, to the class of EDM431 - Methodology of Chemistry Teaching I (n = 23) which is a compulsory course in the Faculty of Education, University of São Paulo (FEUSP) for the chemistry teaching course in 2010. Students attending the course were mostly in the final stages of their coursework, and 19 of them already had experience teaching. Subsequently, we used a questionnaire with 15 open questions, to the class of Physics and Chemistry Didactics (n = 10), offered as a compulsory course at the Institute of Education, University of Lisbon for the science teaching course, in 2012. Students who attend the course are in the first half of the fifth year, and none possess teaching experience. The number of questions is slightly different because in the second application a few questions were merged or deleted. However, both questionnaires questioned experience with visual resources, their visualization beliefs, and the viewpoint about their own initial training with a focus on the thematic issues. Some questions were omitted from the analysis to allow a better result comparison.

Results of research

What follows is the interpretative analysis of questionnaires applied to Brazilian and Portuguese pre-service chemistry teachers. The use of the letter **B** refers to the responses of Brazilian students and **P** to Portuguese students.

Initially, it was noted that 19 of the 23 Brazilian students surveyed acted as teachers during the initial training period, while none of the Portuguese students did so. These data indicate that there are more sources of influence on the conceptions of Brazilian than Portuguese students, especially informal experiences (Mansour, 2009).

In relation to contact with the visual tools, both groups responded that it occurs often or very often. Portuguese students added that the frequency has intensified in higher education. Regarding the content of visuals tools, Brazilian students related that the majority is in the microchemistry field, as atomic models, chemical reactions and organic content in general. For the purposes and uses of visualization tools, students said: **B1**: “For structural chemistry content that is difficult to visualize mentally.” Meanwhile the Portuguese students responded that distributed for all content. However, **P1** specified.

P1: “Simulations of atoms, molecules, chemical reactions, solutions and dilutions.”

Another interesting response was that the use of visuals tools was an alternative to explaining complex processes in general. Thus, students use them primarily to access constructs of scientific theory. That is, models for the sub-microscopic field. The answer regarding "complex processes in general" can be interpreted as an opinion about the models role in simplifying reality for the macroscopic or submicroscopic field.

This relationship was presented by the minority.

Regarding the types of visual tools commonly used, Brazilian students cited static images and concrete models, followed by animations and videos. Portuguese students quoted mostly static images and videos, followed by concrete models and simulations. Therefore, the use of tools by these students is mostly for scientific representations through concrete and visual modes.

Some of the reasons why a teacher resorts to using visualizations in the classroom, in the view of the pre-service chemistry teacher, are to:

B1: "facilitate understanding"

B2: "make learning less abstract"

B3: "break the monotony."

The Portuguese responded:

P1: "make the class more dynamic"

P2: "break the routine"

P3: "be used as synthesis"

P4: "potentiate strategies and develop skills that other media do not develop as much"

P5: "go further in relation to theoretical concept."

In both cases, there were those students who tried to assign features to the visualizations use related with knowledge construction. However, there is a lack of justifications that support the ways their use "to facilitate the understanding" and "reduce the abstraction". It suggests a poor reflection about the scientific knowledge nature and its representative forms. The Portuguese also had no justification in order to explain the ways by which visual tools would reach its potential reported for its use. However, they demonstrated ideas related to differentiation and expansion of the skills related to the visualizations use. On the other hand, the

answers exclusively related to routine and classroom dynamic changes and omitted and/or underestimates the wide range of visual tools featured that support scientific knowledge construction.

It was asked, "What do you perceive by visualization?" The following exemplifies responses according to two conventions:

Convention 1 (verbal):

B1: "to make the student build a picture in your head of what you are explaining could be showing the image or analogies."

P1: "Visualization is a way to identify some data using the vision."

Convention 2 (noun):

B2: "the presentation of a concept or object in a sensory way (vision, hearing, etc.)."

P2: "All that is presented to us through images."

Brazilian students' responses predominantly reflected the second convention, while the Portuguese students' reflected both conventions. The absence of a verbal convention may result in a lack of questioning the act of visualization, omitting central discussions about the metavisualization features, e.g., representational competences and spatial skills.

So it was asked, "How is the receptivity of the pupils when visual tools are introduced in the classroom?" All the answers were positive. Two Portuguese students commented that the positive receptivity is dependent on the type of visual tool.

Subsequently it was questioned "Do you think pupils need some specific skills to learn through the use of images?"

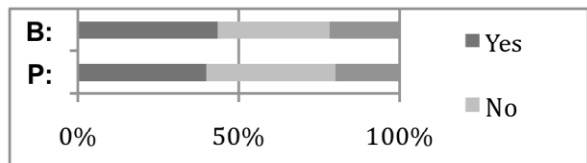


Figure 2 . Specific skills regarding to learn with images use.

According to Figure 1, Brazilian and the Portuguese students presented balanced opinions about the need to specific skills for learning supported through images. However, there were no specifications for the types of skills required, they were quite general as to planning, contextualization, organization and adaptation. The negative responses reflected the pupils' familiarity with various media types in their daily routine. In both cases, the justifications were not sufficiently specified to efficiently use planning and use of visual tools in the education field. In the first case, because comments about models, modeling and their representative forms were omitted (Justi & van Driel, 2005; Lobo & Moradillo, 2003; Giordan, 2007). In the second case, because they do not discuss the major differences between the nature of chemical entities and the several representations encountered by the pupils in their daily experiences.

It was asked "What for you is an image?" The answers encountered were diverse. Below are exemplifies reflecting distinctions made by Sperber (1985). Images as internal representations:

B1: "It's mental imagery"

P1: "direct or indirect representation of the 'real' formed in our mind"

Images as external representations:

B2: "One way to replace a large amount of words"

P2: "An image is a form of nonverbal communication"

The majority of respondents referenced images as forms of external representations.

Then it was asked "Find some special reason for the frequent use of models in teaching chemistry?"

B1: "Their use facilitates understanding"

B2: "due to the difficulty of abstraction of the students"

P1: "Yes. To explain situations, microscopic objects and other abstract concepts."

P2: "In order to bridge the gap with reality"

P3: "Models are useful in science, because they allow recreating and exemplifying concepts."

In a preliminary analysis, there appears little familiarity by Brazilian students of the term "model", because they interpreted it in a concrete way and they used the term rarely in the survey. Portuguese students showed a closer relationship to the idea of a scientific theoretical construct, but they cited the situations in which models can be employed.

To the next question, "Did you ever read something about the issue of visualization? What?" Only three Brazilian students have specifically read about the subject. None of the Portuguese students had. So it was asked "How do you define visual capability?"

B1: "to interpret what is being seen."

B2: "is the ability to reverse the images between two dimensions"

B3: "the ability to create image."

Eleven responses observed equivalents of B1. Some expanded their justification as B2 and B3.

P1: "to understand what is being seen."

P2: "Capacity to building imagery from what we are seeing"

P3: "Ability to display a particular subject recreating in your mind a determinate representation of reality."

Similar to Brazilian students, the predominant response exemplified by P1 and only a few elaborated as P2 and P3 above.

The predominant response "to correctly interpret what is being seen," reflects an idea that the activities supported by the use of visual tools put students in situations of passive learning. On the other hand, it has been argued in the theoretical section (Barnea, 2000; Gilbert, 2005; Kozma & Russell, 2007) that several skills and abilities, such as encouraging students to reflect on the limitations of scientific representations, adapting or evolving meanings, assuming epistemological positions, or transitioning among them, can be stimulated only when the pupils are able to participate in active learning ways.

Regarding their initial training, it was asked "Do you think that your education training allows you to sensibly use issues related to instruction through computers or visualization tools?"

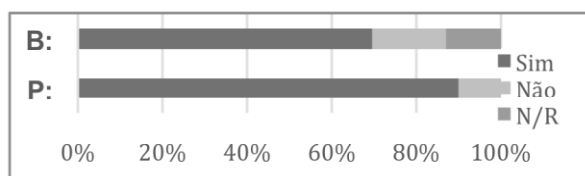


Figure 3. Initial training and the visualizations' use in classroom

According to Figure 3, most Brazilian students believe that their training provides a sufficient foundation to deal with issues related to the use of computers and visualizations tools in teaching/learning environments. Some answers:

B1: "Yes, my training provides me enough background to use a variety of tools usefully."

B2: "Yes, from my own experience images facilitate my learning, but when misused or misinterpreted can worsen or hinder learning."

Some students did not feel prepared and reported that:

B3: "No, because it was never discussed that picture is better for that matter, we chose

images according to what we consider ourselves better, but that does not mean it is the best to teach."

Others were in doubt:

B4: "I'm not sure, because my education was punctuated by visualization, however they were considered self-explanatory and I'm afraid of incurring my students' wrath with the same lack of discussion I experienced in school."

All the Portuguese students answered "Yes" and some of them justified that their training course was based on "new technologies".

Finally, the last question was "Throughout your educational training has this issue been discussed? Do you believe that in the specific case of chemistry instruction this issue is fundamental in the teaching process (to the teacher) and learning process (for the pupils)?"

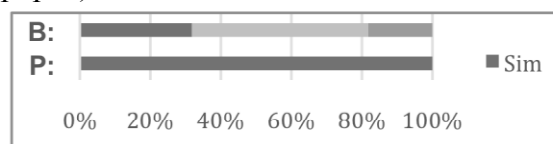


Figure 4. Initial training course and visualization discussion

B: To this question, the negatives responses were in the majority and a large portion of the positive responses showed that this approach was carried out only indirectly. On the second part of the question, in general, all students believed that the subject is fundamental to discussions of chemistry teaching/learning process. The response of B1 exemplifies this:

B1: "It was not widely discussed. Yes, because any new tool that aids in education should be discussed and tested."

P: All the students said that the issue was addressed. All agree that the issue is critical in Science Teaching. Some of the most important justifications were exemplified by

P1 and P2. Other students attributed only auxiliary importance and little problematic as P3, P4 and P5.

P1: "In the case of science the use of models, simulations, allow us a more effective approach in respect of certain contents."

P2: "A good visualization can allow students to understand the contents."

P3: "Tools that capture students' attention when usefully used according with the content and context."

P4: "In science education the use of the images may be a very important complement to the learning process."

P5: "The visualizations bring to school something that students enjoy and dominate."

Therefore, the Brazilian students see reduced presence of discussions of these issues in their initial training, compared to the Portuguese students. That explains partially the constancy of arguments based on their experience as students. Portuguese students showed high confidence in the efficiency of subject approaching in their initial training. Finally, both surveyed groups showed interest in the use of the visualization discussions, converging to the viewpoint that they considered it essential to the improvement of the teaching/learning process.

Conclusions

Although the contact and intention for visual aids use have been shown frequently, there are a low variety of visual tools mentioned. Static images, videos and concrete models were cited by a majority of students. Animations, simulations, interactive software, and other resources that involve complex use or construction have reduced presence. Furthermore, while its use in relation to chemistry contents is widespread, the students didn't associate that a specific

tool could have a particular impact on the formation of a specific concept to be developed.

The Brazilian and Portuguese pre-service chemistry teachers presented rather different opinions with regard to the reasons for the visual aids use in the classroom. The Brazilian students predominantly showed beliefs in improving the teaching/learning processes, while the Portuguese mentioned an expansion of the potentialities provided by these media resources, i.e., some differentiation idea. As a critical point, neither group claimed features or processes by which the visuals tools could address the points mentioned. There were Brazilian and Portuguese undergraduates who suggested that visual aids could break the classroom routine, monotony or make it more dynamic. As has been argued, that viewpoint could be a problem because it omits construction of scientific knowledge. In addition, there are studies (Vavra, *et al.*, 2011) indicating that only improving motivation by using visuals tools does not significantly alter the learning of scientific concepts compared to the use of more traditional teaching resources.

The responses about the "visualization" and "image" terms reflected the idea of external representations, i.e., those available to public access. In these cases, there is a scant reference to the processes of interpretation of meanings. This is reinforced by the divergence and insufficient arguments to our question about the specific skills needed to support learning through image use. As it was argued, mainly within the process modeling (Justi & van Driel, 2005) and representational competences (Kozma & Russel, 2007) that it is important to place pupils in active situations when faced with visual resources, encourage them to develop the construction and reconstruction of representative chemical entities. These

notions were only slightly included in the question about visual capabilities.

The beliefs about "models" also showed a distinction between the Brazilian and Portuguese groups. As noted, the Brazilian students predominantly associated the term with the concrete objects while the Portuguese sought the idea that these were theoretical constructs in order to explain the field.

Therefore, until the time of the training course in which this research was conducted, Portuguese students reported a larger contact with discussions on the subject than the Brazilian students. It was observed indeed that these students had occasionally more elaborate responses regarding why the visual aids could be important and their references about the term "model" were more elaborate. In addition, they expanded the meanings of "visualization" and what are "visual capabilities". First, this reinforces the idea that decisions taken within initial training course organization generates a corresponding impact on students' beliefs. However, there is a lack of evidence about the ways those visualizations could influence the construction of scientific concepts by these students. This makes it difficult for them to determine the limitations and potentialities of visual aids. Besides the possible misuses, unclear beliefs about visualization may not stimulate their search for new, different, or higher quality visual tools.

Given the frequent use of visual tools and their own confidence about using them, it is necessary that the University educators are attentive to the undergraduate students' beliefs. It is essential to encourage activities that bring to light effective practices and the

analysis of the use and planning of such resources by these students. Possible specific problems will need to be worked out. Positively, all future teachers show motivation to deepen their discussions about visualization issues.

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The System of Professional Eco-Pedagogical Teacher Training at Natural and Agricultural Universities in Poland

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Teachers of today require constant acquisition of new eco-pedagogical competencies, knowledge and skills to use in their professional activities. This issue is of great importance for academic staff at natural agricultural universities, since fast-paced technological progress in this field has been producing a significant effect on the environment. The article analyses the system of environmental education and advanced training of academic staff at natural and agricultural universities in Poland. The components of eco-pedagogical teacher training at such universities comprise: a psychological and pedagogical unit chosen by students in addition to their basic specialty which includes an environmental module; a PhD teacher training program which contains an environmental module; postgraduate education; advanced training courses in specialized institutions; and, participation in seminars, conferences, and internships that share themes.

Сучасний викладач потребує постійного набування нових еколого-педагогічних компетенцій, знань, умінь і навиків, які він використовує чи буде використовувати у своїй професійній діяльності. Особливо актуальним це питання є для науково-педагогічних працівників природничо-аграрних університетів, оскільки саме в цій галузі швидкий темп розвитку технологій супроводжується значним впливом на навколишнє природне середовище. Стаття присвячена аналізу системи екологічної підготовки, поглиблення та підвищення кваліфікації викладацьких кадрів у польських університетах природничо-аграрного типу. До складових системи еколого-педагогічної підготовки викладача природничо-аграрного університету належать: психолого-педагогічний блок, який вивчається за бажанням студента одночасно з отриманням основної спеціальності, зміст якого доповнено екологічним модулем; програма PhD-підготовки майбутніх науково-педагогічних працівників, зміст якої включає екологічний блок; післядипломна освіта, підвищення кваліфікації у спеціальних установах, участь у тематичних семінарах, конференціях, стажування.

Keywords: environmental and pedagogical training, academic staff, natural and agricultural universities

Introduction

Increasing competition among higher educational institutions and the European educational environment require that researchers and university teachers deepen their knowledge, apply creative approaches to solve educational problems and, above all, consistently update their teaching methods. Another feature of educational activities today is the rapid “aging” of information that requires continuous improvement and enhancement of one’s professional competences.

A modern teacher has a thorough basic education, adopts creative and innovative approaches to life, develops professional skills, and, acquires new competences.

On the whole, professional development assumes acquisition of new competencies, knowledge and skills, which specialists use or will use in their professional activities. It includes the process of training, retraining and advanced training in order to perform new functions, tasks and responsibilities when being promoted to new positions.

Thus, by combining these characteristics of a teacher, as to their qualifications and expertise, it is possible to determine the components of professional development.

Discussion

In Polish scientific and educational literature, the professional development of a teacher is interpreted as an orderly, systematic process of change within the domain of their personal life attitude, education and training concepts, knowledge, skills and practical activities, which optimize their professional performance and lead to personal job satisfaction (Szymszak, 1995; Hamer, 1994; Grondas, 2005).

Professional development can also be defined as a positive change in the level of

professional competencies of a teacher which is reflected in academic achievements of students. According to N. Hamer (1994), professional development can be characterized, on the one hand, as the development of professional knowledge and skills, ability to control emotions, resistance to stress, willingness to obey societal demands. On the other hand, it is a qualitative change in personality, which implies improvement of their role in modern educational institution.

R. Kwaśnica (2003) identifies the professional development of teachers with the evolution of their practical, moral and technical competences. These competences affect the comprehensive development of a teacher as well as the development of students and the institution as a whole.

According to Cz. Day (2004), professional development is a complex process in which a teacher develops their knowledge and skills, the emotional intelligence necessary to make effective decisions and professional plans regarding educational and research activities, and to collaborate with students and colleagues at every stage of the educational process.

Generalizing these approaches and concepts to the professional development of teachers, we can identify the following key indicators:

- complexity, regularity and planning;
- continuing education and cooperation;
- qualitative changes in the level of general and professional competence;
- activity which positively affects the quality of education;
- fulfilling educational tasks in a changing environment.

The main material

A teacher is an essential part of the educational system at all levels and in all educational institutions. The quality of education largely depends on the personality of a teacher and their level of professional training. Current reforms in education require enhancement and improvement of education as well as scientific and methodological training of scientific and teaching staff. A teacher is expected to adopt creative and innovative approaches to their work which provides fulfillment of various tasks in specific situations. From this perspective, the concept of post-diploma education is associated not only with the concept of continuity and regularity of this process, but with holistic and harmonious development, and an expanded scope of education and self-education as well.

Teaching professionalism can be represented in two dimensions:

- technological (praxeological), which finds its source in the educational needs of a society;
- personal (psychological), associated with the personality of the teacher, and reflected in their relationships with students (Buchcic, 2007).

The system of environmental training, extending and improving teachers' training in Polish universities of natural and life sciences includes:

1. Psycho-educational block, which is elected by students while obtaining the basic specialty.
2. PhD - program for training future researchers and teaching staff.
3. Post-diploma education.
4. Advanced training in specialized institutions.
5. Self-education, participation in seminars, conferences and internships.

The program of psycho-pedagogical training of future specialists for the agricultural sector includes the discipline

“Methodology of Environmental Education” into its psychological and educational cycle. The content of this course consists of three complementary modules:

- knowledge about the environment, i.e., the study of environmental issues with focus on understanding the relationship and interdependence in the system "human-nature";
- education in the environment where nature is used as a source of environmental knowledge, as space for observation and experiments;
- education for environment, which involves formation of positive attitude to life, moral values and beliefs about the necessity to realize principles of sustainable development in their daily lives and future professional activities.

The curriculum of the program “Methodology of environmental education” combines natural and humanitarian aspects. It aims at the professional environmental training of teachers, developing competencies with regard to the changes that occur in nature under the influence of human activities, developing moral and ethical attitudes towards nature, as well as, a commitment to pursue environmental activities.

The first module of the program deals with a discussion of global environmental problems in the form of seminars (Głowacki, 2007; Kozłowski, 2002). Students fulfil written assignments, where they dwell upon the international recommendations of education for sustainable development, issues concerning the environment as a social and cultural system, the state of nature in Poland in respect of EU requirements, the activities of environmental organizations in Poland and abroad.

Another module of the program involves an interdisciplinary approach to

environmental education and forms of its realization in an educational institution.

Students discuss the regulatory and variable components of environmental education in the curriculum and programs of training depending on their specialty and field of study. Much attention is paid to the discussion of human activity in the natural environment and its consequences. Environmental problems in daily life are discussed as well. The discussions are concentrated around the following themes: degradation and protection of water, soil, noise and vibration, the problem of waste, radiation, solutions to the problems of energy. Student groups prepare a portfolio, or posters on one of these issues. The course analyzes the educational standards, plans and training programs for relevant natural and agricultural fields of study in terms of including environmental knowledge in the content. Students examine the feasibility of certain environmental issues within the curriculum, and suggest their own ideas concerning content and teaching methods. In practical classes, students are introduced to scientific and methodological developments in organizations as a form of training (Borowska, 2001).

Another element of the program is practical training where students learn the methods of field practices and environmental monitoring. This training focuses on carrying out experiments using chemicals to determine composition of the water from local reservoirs and the soils from different urban areas. The results obtained during these experiments and outdoor observations, irrespective of their scale, encourage independent thinking. Students, as future teachers, learn from their own experience that this type of training and cognitive activity contributes to finding solutions to environmental problems in the process of training. During these workshops, students formulate and

test hypotheses, process the results of studies, and substantiate the assumptions. Future teachers become fully aware of the relationship of various branches of science to environmental issues and the importance of such studies for developing environmental awareness. In addition, students working in groups engage in planning field studies of some areas with specific natural conditions.

Of great importance for the environmental education of future teachers of natural and agricultural sciences is to master the method of projects. Being engaged in such practical classes, students are introduced to different didactic projects that have been developed and tested by experienced researchers and teaching staff, and analyze and evaluate them. Then, students independently develop the themes and course of activities to fulfil the interdisciplinary teaching projects in compliance with their field of study or specialty. Among the most common projects are: "Waste in the area where I live," "Natural environment near the Vistula sources," "My professional activities and the environment," "Pure environment - healthy population," "My town - yesterday, today and tomorrow. Evaluation and promotion of natural, cultural and tourist attractions," "Local water basins – the area for life, or dust-hole?," "State of the environment in my village."

In order to work on the project, each group is divided into subgroups. They receive a certain task as part of the overall theme of the project, formulate objectives and conduct the research.

The final module of the program deals with a healthy lifestyle. In the course of its implementation the following issues are discussed: healthy foods, the impact of food production on the environment, organic farming, active and inactive

recreation, environmental pollution and public health, the effects anthropic pressure caused by population growth and people's excessive desire to raise living standards without taking into account the natural environment.

Thus, the psychological and pedagogical training of future teachers at the educational institutions of natural and life sciences, in regard to formation of their ecological and pedagogical competencies, should be considered a basic element of their environmental training and advanced teacher training at Polish universities.

Another component in this system is the Ph.D. environmental teacher training program (postgraduate). According to the principles of the Bologna Declaration, Ph.D. training (postgraduate) is the third degree level of educational and professional training (after undergraduate and graduate). The main purpose of Ph.D. programs is to train scientific and teaching staff for higher education. Therefore, the Ph.D. curriculum contains a cycle of the humanities including the study of the basics of pedagogy and teaching methods for disciplines related to a particular educational institution. Universities of natural and life sciences pay special attention to the development of Ph.D. training programs which focus on studying the methods of learning ecological and natural sciences, the contents of which to some extent overlaps with the program of the course "Methods of environmental education" in a series of psycho-pedagogical training of future teachers of educational institution of natural and life sciences. Moreover, they focus on the development of skills to extend the content of the course with environmental issues, organizing scientific research on environmental issues, and engaging the aspects and principles of education for sustainable development.

The environmental and educational training in the Ph.D. program includes workshops as an important curriculum component of the discipline, which future postgraduate student is planning to teach at the university. In the process of development and organization of training postgraduate students have an opportunity to actively implement teaching methods with the elements of environmental education. The course program "Pedagogy and the basics of teaching methods" involves cross attendance of classes by colleagues, and writing reviews on the classes attended with the following discussion. This form of training promotes the development of professional teaching competencies, sharing experience on the application of active teaching methods and discussing their impact on the environmental awareness of students. Thus, Ph.D. programs at Polish universities play an important role in shaping the environmental and educational competences of future teachers and are undoubtedly distinguished in the system of environmental training and advanced training of teachers.

The next element of this system is post-diploma education, advanced training and self-education of teachers in the field of environmental education. As the Polish scientists and teachers claim, a key feature of modern academic and teaching staff is that they tend to improve their professional knowledge in terms of environmental issues. The teaching staff is the largest and most active professional group that consistently build up their competences in the field of environmental education, participate in a great number of seminars, special workshops, training courses on environmental problems (Ciesielska, 1996). Development and improvement of teachers' professional competences have always been a priority in pedagogical science and practice of educational activities in higher education. The new, humanistic-oriented paradigm of education

and social change require a new approach to teacher training - humanistic-oriented professionals.

Their professionalism is seen in the ability to integrate general education, special psycho-pedagogical knowledge and skills, competences, initiative, creative attitude towards training, education and development of student's personality. These features are especially important for teachers who are involved in implementing the principles of environmental education. Nowadays, the main purpose of improving teachers' training is to teach them to perform several important functions simultaneously: a leader, a manager, a diagnostician and a creator, and not just a mediator to communicate ready-made knowledge. Appropriate training of the teaching staff and their post-diploma systematic and comprehensive development is an indicator of the quality of education and its effectiveness.

Conclusion

We analyzed the psychological and educational literature of Polish scientists on the problem of improving teachers' professionalism, through regulations and organizational principles of higher education in Poland. Based on the experience of higher educational institutions in Poland, we can identify the following ways to improve the effectiveness of environmental education in a modern university:

- (1) provide teachers with opportunities to experience innovative teaching methods in higher education, information and communication technologies, developing scientific and educational projects, etc.;
- (2) develop cooperation of higher educational institutions with farms and businesses that adopt advanced environmental technologies of production and may organize on-the-job practical training;

- (3) participate in different level scientific-methodical and scientific conferences and seminars to exchange experience and identify prospects for mutual scientific and educational research;

- (4) share information on and didactic sources of various types (books, textbooks, practice books, scientific and teaching guidelines, websites, e-books, etc.);

- (5) introduce and develop advanced professional development through distance-learning.

These ways will help modify the professional development process in a modern higher educational institution in accordance with international educational priorities. In the process of developing training programs and curricula, it is necessary to provide an integrated environmentally-oriented education of students. Teachers are required to develop and extend their ecological outlook. In turn, this will affect their eco-educational activities. Implementation of effective models of environmental education at universities will contribute to the development of scientific and cognitive activities of students as future professionals (and future teachers as well), will form their ability to take eco-relevant decisions, and, encourage their participation in environmental activities.

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Science Learning in the Cloud

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Learning in the cloud is a dynamic environment of group learning including the sources and knowledge resources and tools as well as people involved in its creation, development and using. Today we experience the heyday of the media in a social dimension, which is reflected in the educational needs of C generations (Green, 1999, Tapscott & Williams, 2007, Levinson, 2010, Hartley, 2011, Visser, 2012). The theoretical assumptions of the model of online science education are presented in the article.

During this netnographic research (according to Kozinets, 2012), our assumptions about the different strategies and learning methods (information technology-aided) used to reach and connect with needed knowledge resources, was supported. The limits and perspectives of this model are also discussed. 105 student teachers participated in this research conducted in 2011-2013.

Nauka w chmurze jest dynamicznym środowiskiem uczenia się grupy włącznie ze źródłami i zasobami wiedzy i narzędzi, jak również osobami zaangażowanymi w jej tworzenie, rozwój i wykorzystanie. Obecnie doświadczamy rozkwitu mediów w wymiarze społecznym, co znajduje odzwierciedlenie w potrzebach edukacyjnych pokolenia C (Green, 1999, Tapscott i Williams, 2007, Levinson, 2010, Hartley, 2011, Visser, 2012). Założenia teoretyczne modelu edukacji online przedstawiono w artykule.

Podczas badań netnograficznych (za Kozinets, 2012) dokonano weryfikacji hipotezy zakładającej stosowanie przez studentów różnych strategii i metod uczenia się (wspomaganych technologią informacyjną), w celu dotarcia i łączenia się z niezbędnymi zasobami wiedzy. W artykule opisano również ograniczenia i dalsze perspektywy modelu uczenia się w chmurze. W badaniach, przeprowadzonych w latach 2011-2013, uczestniczyło 105 studentów-przyszłych nauczycieli.

Keywords: science education, learning in the cloud, online learning, model of learning

Theoretical background

The main principles of the new model of science learning in the cloud online grow out of the following theoretical assumptions:

1. Prosumerism and diversity of knowledge structures of the learners resulting from unrestricted access to information: the more information consumers are becoming

producers or proactive consumers, the more is needed the efficient set of educational media (understood primarily as the currently available web applications). Web 2.0 is a new Internet application where the primary purpose is to facilitate the exchange of information, cooperation and collaboration of users who are lead authors of published

content (Visser, 2012). According to four rules of Tapscott and Williams (2007) the main values of educational Web 2.0 are openness, partnership, sharing and global scale of operations. Wayne Visser (2012) describes the main differences between Web 1.0 and Web 2.0, according to Tim O'Reilly, pioneer of online media: private web sites and blogging; publishing and participation; cataloging (taxonomy) and tagging (folksonomy); and, protection and sharing.

Learners "in the cloud" choose a type of information adjusted to their individual skills and knowledge requirements. It can be assumed that information recommended by tags are accepted or rejected. Thus, a circle of "learning communities" is characterized by similar cognitive abilities, and a lot of these circles show a variety of possible emerging structures of knowledge of the phenomenon or the natural process.

2. The evolution of educational media: from the distribution of knowledge (traditional media) to communication and collective information processing systems and the production of knowledge (new new media, Levinson 2010).

John Hartley (2011), describes the use of YouTube in educational contexts. His experience in this field derives in large part from the project YIRN (Youth Internet Radio Network), the prototype of YouTube. The intention of the creator of this portal was learning through the exchanging of experience and sharing knowledge. Practice verified some initial objectives of the project, and clearly indicated the nature of social change. Young people do not consider new technologies as something external as 'it seems to be an inherent capacity to

develop text messaging and multi-tasking on multiple platforms'. This is confirmed by the *Manifesto of Network Children*, which states e.g. 'We grew up with the network [...] We are children of the network, we are different from you-analog [...] Network is for us a kind of shared external memory. All we need is abstract, information limited to its essence, useful in the processing and combining with other information. If we need details – we check it within a few seconds' (Netnography).

3. Open access to information and knowledge resources: cooperation with scientists and entrepreneurs (science centers, universities, industry) for updating databases and interdisciplinary, open research issues (access to scientific literature and scientific knowledge portals). Mass media is combined with other transmitters, creating an infrastructure metaphorically defined as the 'information highway' or 'information superhighway' (Green, 1999). An open network is important above all things. Success comes from being in the right place at the right time. Simplicity, ease of use, and accessibility are more important than a set of functions, control and purposeful direction (Hartley, 2011).

4. Design, production, decision-making, 'information literacy' without linking to 'scientific literacy' is seen as a lack of specific competencies that need to be considered in the context of lifelong learning. Learning Objectives: 'to know', 'to act', 'to live with others' and 'to be' included in the Report of J. Delors (1998), are regarded as the most comprehensive and accurate.

5. Metacognitive competence: If the cognitive processes are to take place in the best way we have to realize, control, and control them - in other words, you need to have metacognitive skills (Sternberg, 2001). Metacognitive competence, understood as consciousness, initiation and planning various activities, subjected to control and self-regulation, play an essential role in the transformation of information into knowledge (Lędzińska, 2002).

Research methodology

Aims of the research

The main aims of this research were to:

- Examine Internet use and users' activity on the Web 2.0 for individual searching of information related to environmental and health issues, as well as in answering simple questions about nature (e.g. 'Are there twins among birds?')

-Compare methods of information processing (available on the web) with the knowledge of users while solving environmental and health problems on a global scale and local level answering questions about nature.

Research hypothesis

It was assumed that despite the diversity of information obtained on the Internet, individual problem-solving models are related, and, social tagging made by the users of *new new media* facilitates their argumentation and decision-making.

For the students, it is important to adopt a strategy and learning methods (information technology-aided) to reach and connect with needed knowledge resources known as 'Web GPS'. The term 'Web GPS,' proposed by Jancarz-Lanczkowską and Potyrala in 2013, seems to be particularly relevant in the

context of the 'information superhighway' of Green (1999).

Research methods and tools

In the research (2012/2013), the scientists' role has not been limited to that of a moderator and leader of a group of students, but they also conducted 'ethnographic research in action' (Tacchi, Hearn, Ninan, 2004) recently called 'netnographic' or 'ethnographic research online' (Kozinets, 2012). 105 students participated in this stage of research.

Groups of 89 students solved two-step tasks (media-aided). The first stage was connected by individuals. The effects of work were recorded by the individuals as they (explored Internet resources, obtained information in the medium useful for the solution of the problem, and evaluated its usefulness with justifications). Results from the first stage was treated as a case study, tracking individual pathways of problem solving and analyzing the number of resources, the direction of movement through them and explored themes.

The second phase of the work was carried out in thematic groups giving students the opportunity to use the tag cloud (prepared during individual work) along with the traditional searchable answers to various questions. Folksonomy was used as a system of classification and categorization of knowledge by the study group, i.e. social classification (tagging) - information management and describing the contents' selection and evaluation. The result of the groups' work was described as 'Web GPS' in the context of 'information superhighway'.

A group of 32 students participated also in the focus interviews (groups of 4 - 8

persons, questionnaire, 25 questions grouped into three categories: Internet every day, IT in teaching, IT in learning). Statements of the participants were grouped thematically and analyzed in terms of reproducibility and uniqueness of the answers. At the same time, 16 student teachers were given brief tasks using online sources to answer simple questions about biological issues. Each student had to find answers to three questions. Altogether, 48 routes of investigation into answering the questions were analysed. The questions were made as a result of events that took place in the classes for student teachers.

Results

Internet-aided problem solving by students

The number of people that solved specific problems were different (which was caused by selection problems according to the individual interests of the respondents), ranging from 3 to 19 persons (Table I).

On average, the respondents declared three online sources of information in reaching a solution. One respondent took advantage of as many as 11 different sources. The results of case studies were used to determine if the number of sources used influences the quality of the solution. Respondents, who used three or more sources, gave more specific reasons for the adopted position in

problem solving and the character of operated data was more qualitative and quantitative. Analysis of the various solutions to the problems shows that the students had big problems with the arguments of the solution. These arguments were often mutually exclusive, they were wrong or did not indicate the uniqueness of the solution of the problem as "organic farms are producers of organic foods, but are related to the high costs, so they are not common."

Research on the ways used for socio-scientific problem solving, indicates that cognitive models of learners in the network are similar, but different knowledge structures are built. Certain regularities in the ways of using media sources and areas of interest explored by most respondents were noticed. In the process of problem solving requiring specific messages, most students have used the deductive model. They started out with the search for definitions, rules of construction, rules of operation, and only then progressed to seek details such as figures, arguments and concrete examples. A cognitive schema was represented in solving problems connected with diabetes, cancer and organic farms (Figure 1).

Table I. Topics of problems with the number of the students and the sources used to problem solving

Issues	Number of persons engaged in problem solving	Number of sources used in problem solving
Are organic farms really organic?	19	2 - 6
Municipal waste - Burn? Store? Minimize the number in households? Recycle?	13	2 - 3
Nuclear power plants - a threat or an opportunity to "clean" energy?	16	2 - 8
Chemical methods in agriculture - the need or unreasonable for its use?	14	2 - 11

Highways and town bypasses - a threat to wildlife or comfort for the people?	17	2 – 4
Diabetes as a social disease	7	2 – 5
Why prevention plays a huge role in the treatment of cancer?	3	2 – 5
Altogether (number of students)	89	

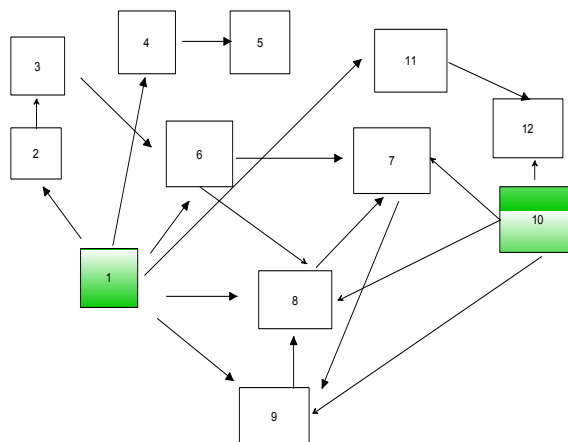


Figure 1. 'Web Learning GPS' for the problem "Are organic farms really organic?" The arrows illustrate the common path of the respondents leading to solution of the problem. The themes explored by the largest number of respondents are marked by darker fields. 1) What is this organic farm? 2) International Federation of Organic Agriculture Movements, 3) EU organic food logo, 4) Negative impact of fertilizers, 5) Combining ecological farm with agritourism, 6) Funding Policy of ecological farms, 7) Characteristics of plants and animals raised in ecological farms, 8) Advantages and disadvantages of organic farms, 9) Certificate of ecological farm, 10) Organic Food, 11) Examples of organic farms, 12) Quality of products.

This step (Fig.1) confirms the cognitive model of students' work associated with tagging. Students that worked on topics connected with diabetes, cancer and organic farms applied it in evaluation detailed tagging which can be called "definitional" (Table II).

Table II. Contents' categorization (tagging) made by users of new media referrers to information using optionally selected keywords for specific topics.

Problem /Information	Access	Credibility	Usefulness in problem solving
Organic farms	organic food, organic farm	quality of crops production, cost analysis	healthy food biodiversity certification
Municipal waste	waste, segregation	law, the amount of waste	methods of recycling utilization energy
Nuclear power plants	catastrophe, nuclear reactor, nuclear power	EU Directives, the safety, cost	coal plant vs nuclear power plant, construction and operation of nuclear power plants, the impact on human, radioactive waste
Chemical methods in agriculture	chemical methods in agriculture, chemicalization goals,	the amount of artificial fertilizers applied, organic food, use of chemicals,	health, organic farming, environment, microorganisms as an alternative to use of

	agro-chemicals, agricultural chemicals	costs	chemicals
Highways and urban bypasses	examples of investments, trucking	current data on the emissions of gases and dust	ecological highway, certification, legislation
Diabetes as a social disease	causes of diabetes	guidance on diet, treatment	types of diabetes, symptoms, lifestyle, number of patients
Prevention of antitumor	oncogenic transformation, causes of cancer	costs of preventive examinations, treatment, types of cancer	prevention phases, lifestyle disease factors, stages of cancer

In case of a more general and multi-faceted problems (such as construction of motorways and ring roads, the issue of nuclear power), students initiated the case study, using the same model of induction. Respondents in the first place were based on descriptions of specific events, the most widely known and popularized in the media (for example including nuclear disaster, protests against the construction of motorways and highways). Based on individual events they were looking for some general rules and regularity and to seek common arguments. From the descriptions of individual events they passed into the search rules for construction, operation rules and definitions (Figure 2).

The results presented in Figure 2 are consistent with *tag cloud* visualized in Table II created in order to solve problems. Interesting results were obtained in the groups working on the issue of nuclear power plants. On the one hand, the investigation shall determine that the starting point for the exploration of information was the construction and operation of a nuclear reactor, on the other hand, extremely important for students were examples of descriptions of disasters at nuclear power plants. Thus, in the diagram, we can clearly see two outbreaks of

propagation paths to solve the problems (Figure 3).

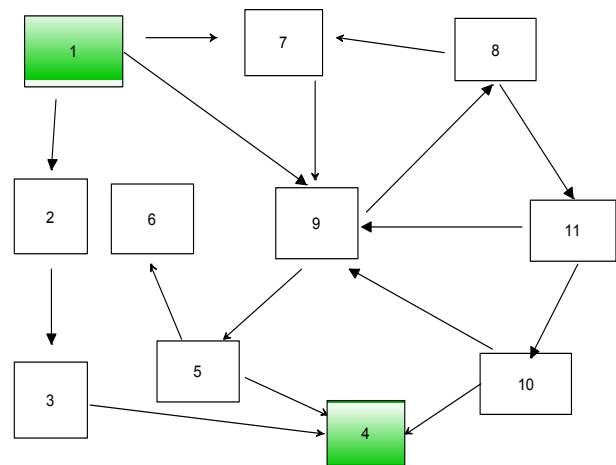


Figure 2. 'Web Learning GPS' for the problem 'Highways and town bypasses - a threat to wildlife or comfort for the people?' The arrows illustrate the common path of the respondents leading to solution of the problem. The themes explored by the largest number of respondents are marked by darker fields. 1) Analysis of a case study concerning the construction of highway or bypass, 2) Negative impacts, 3) The figures concerning the negative effects, 4) "Ecological highway", 5) Methods of limiting the negative effects of the construction of highways, 6) Animal Passage, 7) Conflicts with residents, 8) Influence of highways on the environment, 9) Benefits connected with the highways, 10) Conditions for highway and bypasses construction. Legislation, 11) Need for building highways and bypasses.

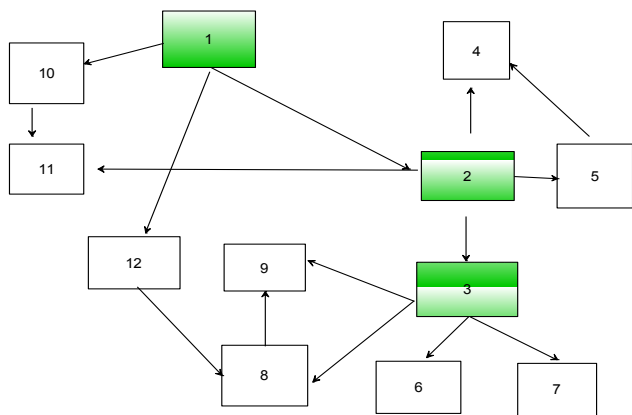


Figure 3. 'Web Learning GPS' for the problem 'Nuclear power plants - a threat or an opportunity to "clean" energy?' The arrows illustrate the common path of the respondents leading to solution of the problem. The themes explored by the largest number of respondents are marked by darker fields. 1) Nuclear power plant - construction and functioning, 2) Radioactive waste, 3) Failures - examples, 4) Environmental pollution, 5) Waste storage, 6) Disaster areas - current state, 7) Diseases Radiation, 8) Fears of society, 9) Environmental organizations, 10) Reserves of fossil fuels, 11) Costs of energy production, 12) EU energy policy.

Results of interviews in the focus groups

In connection with the questions, "What makes substantive information on the Internet? Which can be regarded as "good" or useful? How do you assess the reliability of information?," the respondents answered that they believe that credible information, supported by the literature, written in plain language, originated from a popular site, characterized by a large number of downloads, and has high ratings from other users." Similar arguments were given by the individual respondents in the first stage of problem solving. They said, "information supported by concrete figures, compiled by people with higher education, the article

short and written in an accessible language." At the same time, we notice a large distrust of respondents to Wikipedia. Although users have used it very often, they evaluated it negatively. Students responded that they first use a search engine and would rather use proven technologies and sources recommended by other users (by sending links, blogs, e-books, videos).

The results obtained in the research of 16 students looking for a network response to specific biological questions suggest different strategies to perform the tasks. It was noted that the majority of users moved to the same web-address, which did not happen in the group with the socio-scientific problems. It was therefore decided to consult google.pl search by typing questions. As shown in Table III, the vast majority of respondents have used only the first ten pages displayed by the search engine. The order of moving through the pages was different, but the selected information essentially the same. Respondents repeatedly stressed that they are not sure of the response, and the sources are not reliable. Attention should be paid to how questions are formulated such as, "Are there among birds the twins?" Respondents took advantage of a similar number of websites, but more often went out of the list of the search engine Google. Everybody seeking answers to basic biological questions indicated that the site led them to other sources of information, which also happened during socio-scientific problem solving.

Table III. Quantitative data showing the websites used during problem solving

Questions	Number of students seeking answers the questions	Number of the websites used to problem solving	The number of different websites visited by all participants	Number of pages from the first 10 search results google.pl
What is the difference between accommodation and adaptation of eye?	7	2 - 4	7	7
What is the difference between phototropism and fotonasty?	7	2 - 5	10	9
Do analogous organs can be considered as the evidence of evolution?	7	2 - 4	7	6
Are daffodil and narcissus the same species of plant?	9	2 - 4	12	6
Are there among birds the twins?	9	1 - 4	8	2
Is the print of language such individual as a fingerprint ?	9	1 - 4	14	2
Altogether number of analyzed answers	48			

Conclusion

Despite the two clear models of learning revealed in the research, the structures of learning of biological and environmental problems are difficult to standardize. This is due to the fact that unlimited Internet resources provide essentially limitless capabilities with cognitive roads. The maps of 'Web Learning GPS' show that the respondents moved along the same, limited, subject areas, but the direction of this search was not homogeneous.

Analysis of tagging in most groups of students shows that students, regardless of the problem being solved, consider reliable sources of information, to be specific and current figures. However, tags used in the assessment of suitability of the information for a final decision, point to the importance of information relating directly to human health, the impact on the environment, and, the certification and application of laws.

Studies have shown that the model of inductive learning occurs most frequently. This model, characteristic of Web-supported learning, is most effective in the creation of knowledge structures (while in traditional school deduction prevails). It can be concluded that if the question is formulated in a more problematic way, learners explore more diverse sources, going beyond sources indicated in the search engines. Students often use Wikipedia but proclaim the lack of confidence in the information provided on this page. In evaluating Internet sources breadth of information plays an important role.

The uses of media in education must be developed. A limitation of our model of learning in the cloud can be a phenomenon of stress due to the impossibility of vast information processing and information chaos (distress), leading to a weakness or loss of cognitive and metacognitive control.

There is also the opposite phenomenon (eustress), during experiencing strong emotions about positive sign (Lędzińska, 2012). Restrictions of this model are therefore often strongly linked with the typical limitations of modern man and the limits resulting from contact with traditional and connective education.

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The Role of Information Technology in Creating the Experimental Space in the Scope of Metabolic Changes

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Teaching biology and particularly metabolic changes should be supported by experimental and theoretical methods. Observations and experiments can be carried out by conventional methods (school books) and modern IT tools as well (virtual laboratories, graphic models, process visualization, multimedia, statistic data analysis). By introducing IT tools into teaching methods, the students' learning ability increases. Students are no longer passive listeners; they become active creators. In this situation students are highly involved in the learning process. The results of the conducted research point to a considerable increase in the skills among the students from the group where the laboratory computer-assisted method was applied.

Nauczanie biologii w szczególności przedstawianie zagadnień z zakresu przemian metabolicznych powinno być wspierane przez użycie metod doświadczalnych i teoretycznych. Obserwacje i doświadczenia mogą być prowadzone konwencjonalnymi metodami (podręczniki szkolne) i przy użyciu nowoczesnych narzędzi, TI takich jak (wirtualne laboratoria, grafiki modele, wizualizacja procesu, multimedia, analizy danych). Celem przeprowadzonych badań było określenie wpływu zastosowania narzędzi TI na tworzenie przestrzeni doświadczalnej w prezentacji zagadnień dotyczących przemian metabolicznych. Rezultaty przeprowadzonych badań wskazują na istotne zwiększenie się umiejętności przeprowadzania eksperymentów i doświadczeń biologicznych wśród uczniów w grupie gdzie zastosowano metodę laboratoryjną wspomaganą komputerem.

Keywords: IT tools, virtual laboratories, virtual environments, combination real and virtual experiments

Introduction

The teaching of biology, and in particular presenting the issues of metabolism, usually includes expository and laboratory methods such as observation and experience.

The main function of experiments in traditional science education was the function of illustrating processes and phenomena. In the current Polish national education program guidelines, the extended scope of skills that students should acquire is clearly defined:

“Student (...) can carry out and document the observations and biological experiments; he/she can formulate research problems, make hypotheses and verify them through observation and experiment; he/she can determine the conditions of experiment, distinguish between a control sample and research sample, and he/she can formulate conclusions on the basis of conducted observation and experiment.”

Teaching biology and full implementation of learning objectives established by the authors of the national program has become very difficult, which is partly the

result of the small number of hours of biology that is allocated to individual content, which makes it difficult to expand material to be mastered (Potyrała, 2007). In achieving high standards of teaching and learning requires the use of effective methods and strategies. It is therefore necessary to create appropriate conditions allowing for a combination of theory and practice.

According to Dewey (1988), the task of the teacher is to create conditions that stimulate thinking. Piaget (1952) calls for the creation of conditions which trigger thinking. Giordan (2012), in his "allosteric model," draws attention to the role of media in the creation of a learning environment. Tadeusiewicz (2002) assumes the use of a computer as a tool for illustrating phenomena and processes.

In creating a virtual environment in the natural sciences, we can use, among others: (1) animations which help visualize processes and phenomena at the level of molecules, whose observation at the micro and macro levels is difficult; (2) modeling and simulation; (3) virtual laboratories, (4) computer-aided measurements - laboratory measurements; (5) multimedia presentations; (6) visualisations; and, (7) the Internet (Chmurska & Kawecka, 2007; Maciejowska & Bilek, 2009).

The computer becomes essential in linking theoretical and empirical methods, which allows you to gather information, monitor processes, create models, and interpretations of phenomena (Bilek, *et al.*, 2009). Computer applications in biology lessons enable you to precisely monitor your experiments and, by automating the register of data, to reduce the time of their performance. (Felski & Służewski, 2012).

However, the use of a computer can increase the likelihood of success associated with the act of learning to

directly participate in the experiment (Maldarelli *et al.*).

In 2003, Hofstain and Lunetta already saw the need for research in the assessment of the impact of information technology on the activity of students while working with laboratory methods that would allow us to increase the effects of teaching.

Theoretical Assumptions of the Research

The main purpose of the study has been to determine the impact of information technology tools on the creation of an experimental space for a presentation of issues involving metabolism.

This study assessed the value of the use of computer-assisted measurements for the proper planning of experiments, analyzing the results and drawing appropriate conclusions.

The issues which were to be consolidated were selected from the detailed requirements for the biology high school curriculum in the extended program and focused on executing and documenting biological observations and experiments on the example of how metabolism changes during photosynthesis and cellular respiration.

The computer-assisted measurements focused, firstly, on the relationship between light intensity and the rate of photosynthesis, calculated by the rate of CO₂ consumption, and, secondly, on gas exchange in plant embryos of germinating seeds, which is necessary in the process of aerobic cellular respiration.

The research involved a group of 60 high-school students in Nowy Sacz. In order to compare the level of knowledge of respiration and photosynthesis in plants, a preliminary study with the use of quantitative methods was conducted. After the initial research, a natural pedagogical

experiment was conducted. In the experimental group, lessons were taught with the use of the laboratory method including computer-assisted measurements. In the control group, lessons were conducted without the use of information technology. Both groups were taught the same scope of program content.

To carry out experiments in the experimental group, the following equipment was used: oxygen sensor with a data recorder and light meter, carbon dioxide sensor with LEYBOLD data recorder, the software required for data recording (INSIGHT and CASSYLAB) attached to the apparatus, and the Microsoft EXCEL spreadsheet.

In order to compare and to examine the significance of differences in the level of competence reached in the skills of observing and documenting biological experiments, the same post test was conducted in both groups, and the results were subjected to statistical analysis. The posttest consisted of eight tasks which measure the mastery of the following skills: formulating research questions, hypotheses and verifying them through observation and experience, determining the conditions of experiment, distinguishing between the control and research sample, and formulating

conclusions from the conducted observations and experiences.

Test Results

Analyses of the pre-test and post-test results were conducted by means of the statistical package, PQStat ver. 1.4.2.324.

The relation between the results of the tasks and a test group was analysed by means of the dependency test X^2 and a detailed Fisher test.

Testing probability at the level of $p < 0.05$ was assumed as significant, while testing probability at the level of $p < 0.01$ was assumed as highly significant.

Prior to the commencement of the experiment, the level of information and skills was determined in both groups as far as the subjects of respiration and photosynthesis in plants were concerned. No significant dependency was determined ($X^2 p = 0.1826$, Fisher exact test $p = 0.2144$) in terms of the resulting distribution in both test groups. The majority of the answers are correct: in the first group it is 53% while in the second group - 70%, which justifies the statement that the students from both groups come from the same population and were properly selected for the experiment (Figure 1).

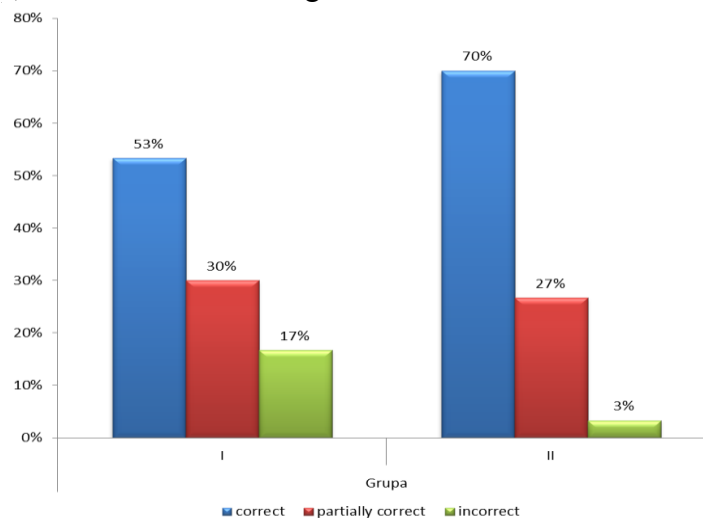


Figure 1. Distribution of results for a pre-test in both test groups

The results of the test checking the particular skills acquired during the laboratory classes for the control group and the experimental one have been presented in Table I.

Table I. Test results for particular tasks checking selected skills during the laboratory classes.

Task no	Type of skills being tested	test	Result
1.	formulating research questions	X^2 p=0,0730; test Fishera p=0,0787	no significant relationship
2.	Formulating hypotheses	X^2 p=0,3542; Fishera p=0,3746	no significant relationship
3.	determining the conditions of experiment	X^2 p=0,0866; Fishera p=0,0967	no significant relationship
4.	the control sample	X^2 p=0,0485; Fishera p=0,0581	A significant relationship
5	the research sample	X^2 p=0,0254; Fishera p=0,0256	A significant relationship
6.	Data analysis, graphs	X^2 p=0,0073, dokładny test Fishera p=0,0081	Highly significant correlation
7.	formulating conclusions	X^2 p=0,0172; Fishera p=0,0166	A significant relationship

Referring to the results, no significant dependency was determined in the development of such skills as formulating research-related problems, formulating hypotheses and the selection of materials and methods with the use of IT tools (Table I).

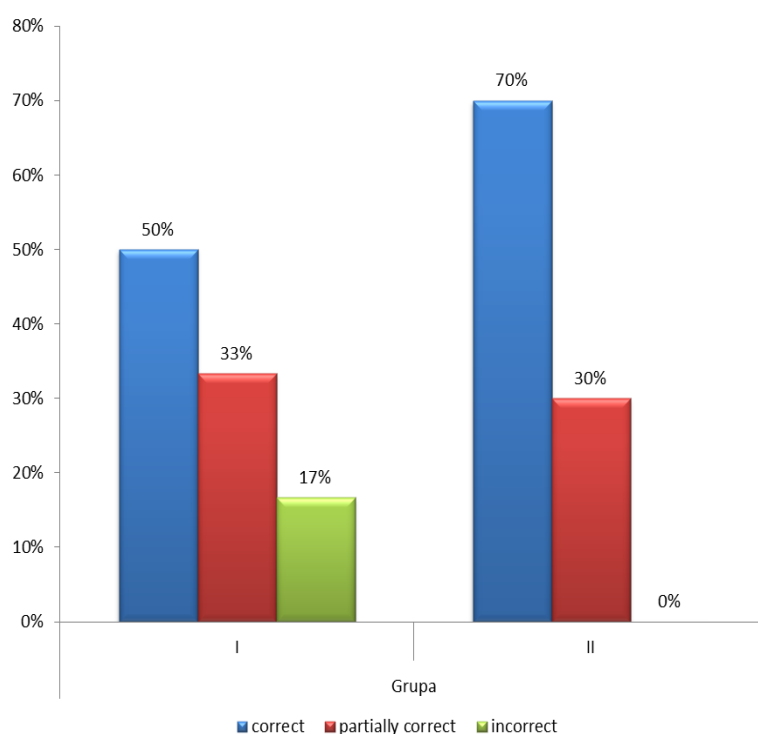


Figure 2. Distribution of results for a control sample in both test groups.

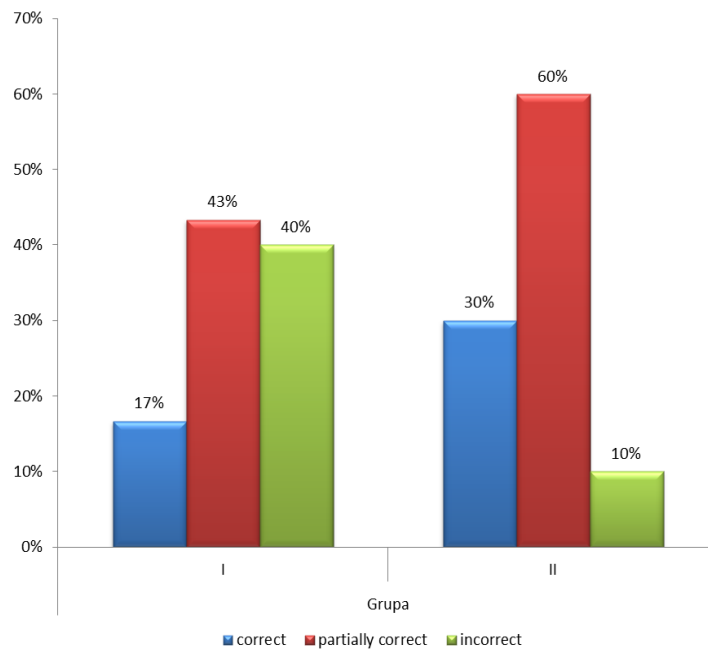


Figure 3. Distribution of results for the research sample in both test groups.

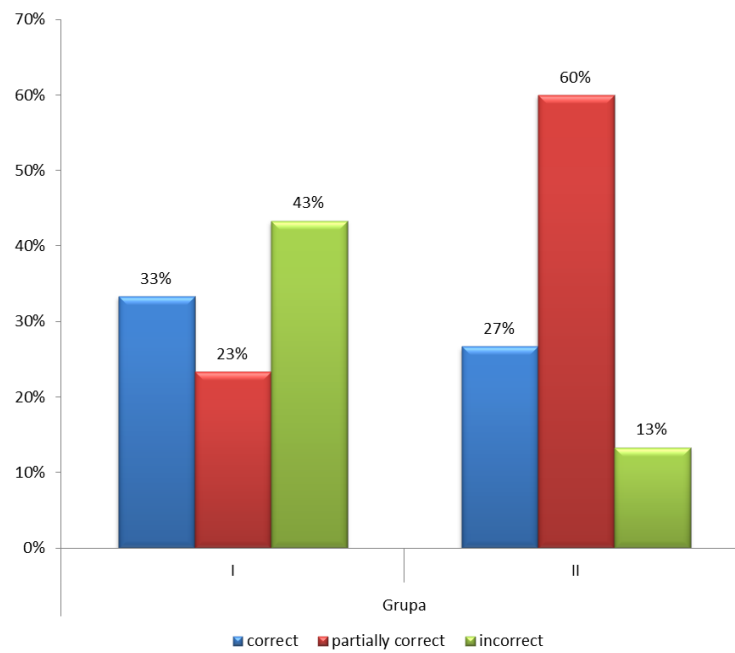


Figure 4. Distribution of results for a the date analysis, graphing in both test groups.

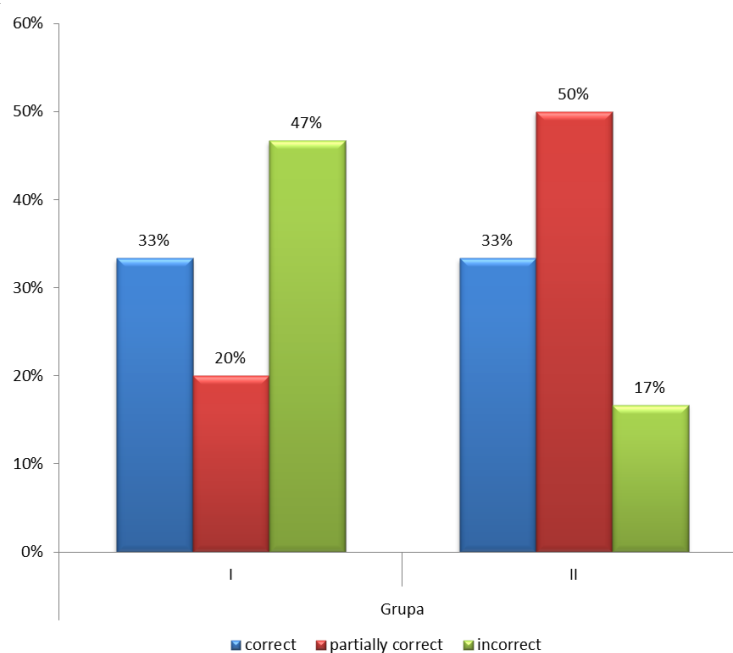


Figure 5. Distribution of results for formulating conclusions in both test groups.

Within the scope of distinguishing and describing a test and a control sample as well as drawing correct conclusions on the basis of the results obtained, a significant dependency was established (Fig. 2,3,5).

As we can see in Table 1, a highly significant (X^2 $p=0.0073$, detailed Fisher test $p=0.0081$) dependency was established in terms of the distribution of the results for task no. 6 in both test groups. In the first group, where experiments were conducted by means of traditional methods, the number of correct answers was equal to 33.33%, while in the second group - with the application of computer-aided measurements - the result is equal to 26.67%. In case of incorrect answers in the first group, there are 43.33% of them, while in the second group - only 13.33% (Fig. 4).

As one can notice on the basis of the test conducted, the use of computer-aided measurements during the class with the use of laboratory method has a significant influence on the acquisition of skills related to the conduct and documentation of observations and biological experiments among the students.

Discussion

The results of the experiment conducted confirm the opinions of other researchers, who assume the increase of cognitive efficiency during a class with the use of computer-aided measurements in relation to classes conducted with the use of the traditional laboratory methods (Potyrała, 2007; Turyło, *et al.*, 21; Vilkonienė, 2009; Maciejowska & Bilek, 2009; Bodolai, 2010).

Computerised environments help to build new structures of knowledge and affect the multidisciplinary understanding of the issues discussed (Gelbart & Yarden, 2005).

The use of detectors and sensors during the experiments that illustrate the occurrence of metabolic changes, such as photosynthesis and respiration, made it possible to achieve an increase in the students' progress when it comes to their skills of conducting and documenting observations and experiments.

The students conducting experiments with the use of IT tools achieved better results; the experimental group manifested a highly significant increase in the skills of proper

data analysis, diagram drawing, determining variables as well as correct conclusion drawing. The students were designing experiments and changing parameters on their own, which increased the efficiency of their work. Computer tools made it possible to quickly achieve data which could be analysed and displayed on a computer screen, e.g. diagrams of CO₂ or O₂ concentration in relation to light intensity were displayed on a screen during the experiments (on-line or off-line measurements). Measurement systems such as “integrated systems”, “learning space” or “micro world” are becoming part of the environment in which students ask questions and search for answers while conducting experiments (Poziomek, 2007), make fewer mistakes while drawing conclusions and the generated knowledge is more solid (Feliński & Służewski, 2012).

Conclusion

The combination of the natural and the virtual environments in natural sciences is supposed to increase the experimental activity of the students (Bilek, *et al.*, 2009); it encourages them to find out more about the nature of phenomena and facilitates their understanding.

The creation of experiment area with the use of IT is particularly helpful to analyze and interpret the results of observations and experiments.

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The New Educational Environment Mediated by New Technologies and Social Media: A Three Level Analysis (In-Class Environment, Micro-Environment, Macro-Environment)

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The integration and the use of new technologies and social media within education constitute a significant issue to consider in a global and a local level, more and more. New technologies and social media lead to the transition from the traditional learning model to a new model mediated by social media and new technologies, which bring many changes in the educational environment. This transition is expected to be completed with the consolidation of the three dimensional technological environment. This article aims to analyze the characteristics of the new mediated educational environment in three levels: the in-class environment, the micro-environment (organizational level), and the macro-environment (societal level). First, the traditional in-class environment is compared with the mediated environment. In this comparison, “mental models” theory is used to analyze communication and learning processes. Second, in order to figure out key characteristics of the mediated educational environment at an organizational level, SWOT analysis is used. At a societal level, theories of the role of the media within societies are mentioned. Finally, issues of concerns around the use of social media in education are mentioned, with a view of finding how to integrate them effectively into the educational agenda, both globally and locally. This issue requires further research.

Keywords: social media, educational environment, mediated learning

L'intégration et l'utilisation des nouvelles technologies et des médias sociaux dans l'éducation constituent un enjeu important à considérer au local, ainsi qu'au global. Les nouvelles technologies et les médias sociaux conduisent à la transition du modèle d'apprentissage traditionnel vers un nouveau modèle médiatisé par les médias sociaux et des nouvelles technologies, qui apportent de nombreux changements dans l'environnement éducatif. Cette transition devrait être complétée avec la consolidation de l'environnement technologique en trois dimensions. Cet article vise à analyser les caractéristiques du nouvel environnement éducatif médiatisé en trois niveaux: l'environnement en classe, le micro - environnement (niveau organisationnel) et le macro - environnement (niveau sociétal). Tout d'abord, l'environnement traditionnel en classe est comparé avec l'environnement médiatisé. Dans cette comparaison, la théorie des «modèles mentaux» est implémentée pour analyser les processus de communication et d'apprentissage. Deuxièmement, pour déterminer les caractéristiques essentielles de l'environnement éducatif médiatisé dans un niveau organisationnel, une analyse SWOT est implémentée, ainsi que et à un niveau sociétal des théories sur le rôle des médias dans les sociétés sont mentionnés. Finalement, des questions de concerne autour de l'utilisation des médias sociaux dans l'éducation sont mentionnés, en vue de trouver comment les intégrer effectivement, dans l'agenda éducatif, au globale et au locale ; un sujet qui nécessite des recherches supplémentaires dans l'avenir.

Mots clés: médias sociaux, nouvel environnement éducatif, apprentissage médiatisée

Introduction

In the new educational era, where new technologies and social media dominate, Marc Levinson supports that “Our education system is in the midst of a paradigm shift, where new methods, environments, and assessment models need to be acquired if schools are to keep pace with our increasingly networked culture” (2010, in Bosman and Zagenczyk, 2011). This transition, from the traditional learning model to a new model mediated by new technologies and social media, transforms and affects teachers’ and students’ relationships (Mason and Rennie, 2008; Atay, 2009; O’Brien, 2009), their roles (Easton, 2003; Rosen, *et al.*, 2010), and the way they communicate and interact (Rosen, *et al.*, 2010; Munoz & Towner, 2009; Sturgeon & Walker, 2009; Minocha, 2009). Gradually, these changes lead to the transformation of learning itself (O’Brien, 2009). Learning is highly dependent upon the communication process within an organization. According to Bronn and Bronn, “effective communication” leads to “increased learning” (2000).

According to Bronn and Bronn (2000), organizations’ operations’ are affected by important factors of the external and internal world. “These factors are not independent and their interactions result in a business and communications environment that is characterized by detail complexity and dynamic complexity, conflict, abrupt change and a host of other confounding factors” (Bronn and Bronn, 2000), in which “organizational learning is a process and not an end state and the central discipline is “mental models” (Page, 2000).

Based on Bronn and Bronn’s analysis about interactivity between different environments of an organization, an educational institution can be perceived as composed of three different environments: macro-environment (economic, technological, educational, societal factors), micro-environment (communications, management, rules of educational institutions) and the in-class environment (relationships, communications, roles, interactions between students and teachers). Their interactions and transformations result in a shift to communications and learning processes, which according to Bronn and Bronn constitute the “heart” of any organization (2000), as illustrated below (Figure 1).

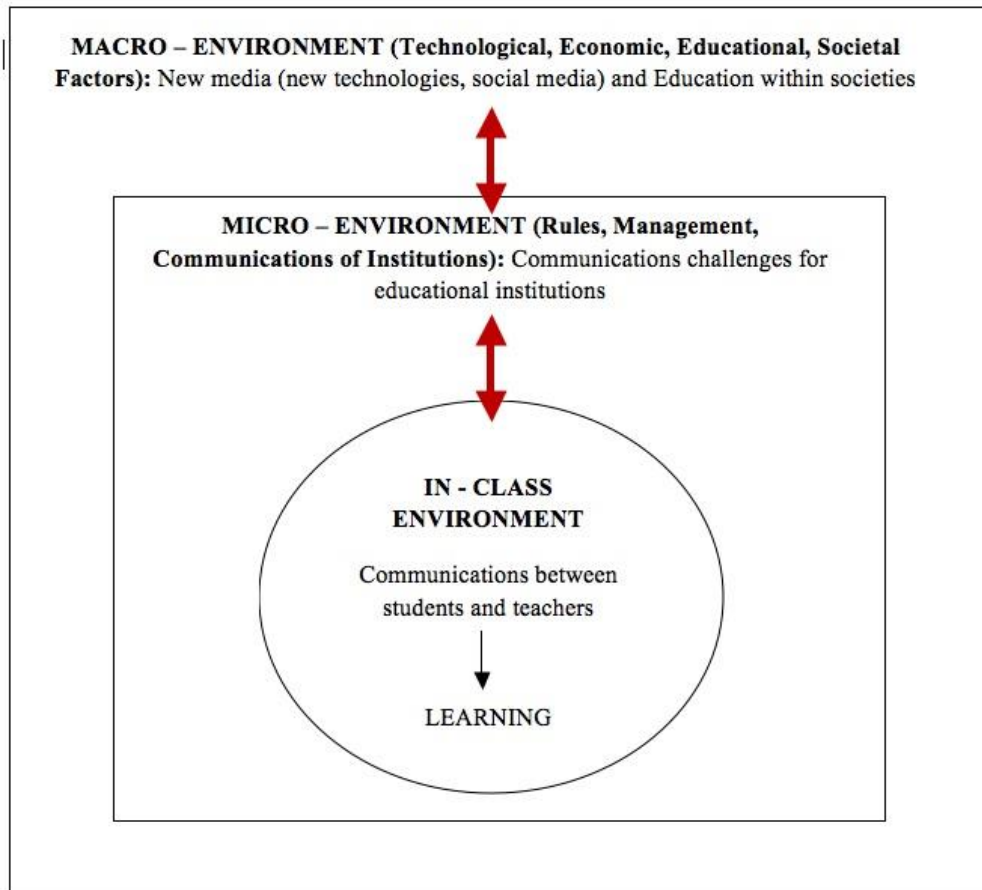


Figure 1.

Consequently, in this article we compare the two educational environments. We started from a communication point of view, by analyzing the in-class environment, using “mental models” theory to compare the effectiveness of communication between teachers and students within these two educational environments. At the micro-level, in order to figure out the communications challenges of educational institutions, SWOT analysis was used. Finally, in a macro-level, the relationship between education and new media within society is analyzed, using theories about the role of the media in massive societies.

The in-class environment

According to Atay (2009), the emergence of social media, as a new form of

communication, transforms and affects communication, and teachers and students relationships (Mason and Rennie, 2008), which "have progressed into [a] cyberspace-based friendship [...] compared to traditional relationships, which were often monitored by the rich academic traditions and practices" (Atay, 2009). Moreover, Sturgeon and Walker reveal that teachers and students relationships in social media are characterized by "informality", an element "which can make for a more open line of communication, resulting [...] in more student engagement in the classroom." (2009) Thus, they believe that social media should be integrated into the educational agenda: “Anything that helps students feel more comfortable in the classroom environment, where they can feel a

connection with their instructors, opens the door for better understanding, better communication and better learning.” (A teachers’ statement that participated in Sturgeon and Walker’s research; Sturgeon and Walker, 2009).

This change is attributed to many factors such as easy access to information (Mason and Rennie, 2008; Sturgeon and Walker 2009), the possibility to record communications, the development of creative thinking, the existence of interactivity in "online" relationships (Mason and Rennie, 2008, Minocha, 2009) and the transition from the one-way direction of knowledge (from teacher to student) to the common creation of content and knowledge, all factors that make the new educational environment more engaging for students (Rosen, Carrier and Cheever, 2010).

O'Brien (2009) states that one of the biggest challenges that the educational environment of Web 2.0 has to face is the transition to new forms of teaching and learning the traditional role of the teacher changes from one who sets the rules and supervises students’ actions, and the student changes from a passive recipient of knowledge, to an active content creator, who in this process, can take various roles at the same time: become a public speaker, a social or political commentator, or an author. These active roles give more realism to students’

activities and they become more interesting for them. The degree of creativity increases significantly. (Rosen, Carrier, and Cheever, 2010).

On the other hand, in the “on-line” by distance learning (Online Distance Learning: ODL), as stated in Easton, the role of the teacher remains active as in the traditional educational environment. However, in the new educational environment, their role is enriched with more responsibilities and requirements: social activity, complex managerial responsibilities, and the use of more technical and technological skills (2009). Eventually, teachers, in the virtual world, become the regulators of student’s activities; they move beyond being a simple distributor of knowledge, as they used to be in the traditional environment. (Shelton, Lane, & Waldhart, 1999 in Easton, 2003) In particular, according to Professor Zane Berge, the teacher's role in the new environment changes in four areas: "pedagogical, social, managerial and technical” (in Rosen, Carrier, & Cheever, 1999).

These changes, which are outlined by many academics and teachers (Rosen, Carrier and Cheever 2010, O'Brien 2009, Sturgeon and Walker 2009, Munoz and Tower 2009, Minocha 2009, Easton 2003), constitute the key characteristics of the two educational environments and can be summarized as follows (Tables 1, 2):

Table 1. Features and differences of the two educational environments

Traditional educational environment	Mediated through new technologies and social media educational environment
Flat	Multifaceted
Two-dimensional	Two-dimensional (Facebook, Myspace) with ability to use tools of three dimensional environments and open to be transferred in three-dimensional environments (Second Life) (Rosen, Carrier, & Cheever, 2010)
Time and space limited	Personalization of time and space
Limited to basic senses	Multisensory
<i>Old fashioned</i> , boring to new generation students' requirements	Modern and attractive, according to new generation students requirements.
Passive learning dominates	Engaging, interactive
Use of limited communication channels	Use of additional communication channels
Massive supply of teaching	Ability of personalized learning (through repetition)

Table 2. Teachers' and students' role and relationship in the two educational environments

	Traditional	Mediated
Teachers' role	<ul style="list-style-type: none"> • Active • Limited managerial activities • Classroom monitor • Limited requirements for technical skills • Instructor • Regulator: in accordance of the course content and University rules 	<ul style="list-style-type: none"> • Active • Complex managerial activity: integration of the new environment to the traditional agenda • Virtual guide and supervising on-task behaviour • Technical advisor • Facilitator • Connective: Bridging educators' and students' demands
Students' role	<ul style="list-style-type: none"> • Passive receiver of knowledge • One-dimensional • Limited creativity 	<ul style="list-style-type: none"> • Active creator of content • Multi dimensional: political, social commentator, public speaker, author, etc. • Increased creativity
Teacher-student relationships	<ul style="list-style-type: none"> • Typical • Limited in classroom and University areas • Limited by University rules often • Non-productive • No connection between relationship and learning 	<ul style="list-style-type: none"> • Web-based friendship, informal • Developed outside university as well • Relationship development and sustainment by themselves. • Productive • Relationship is a decisive factor to better learning

Communication and learning

The comparison of features in two educational environments (Tables 1,2,3) is necessary to illustrate the changes in the processes of communication between teachers and students and in students' learning. According to Bronn and Bronn, the communication environment developed in any organization is characterized by detail complexity and dynamic complexity, conflict abrupt change and a host of other confounding factors [...] such as environmental effects, influences on other cultures, and the transformation of the nature of work from production-to knowledge-based services. (2000). Furthermore, they believe that the increased understanding between members of an organization, leads to “effective communication and eventually to increased learning” (Bronn and Bronn, 2000). In the communication processes of an

organization, employers and the management are mentioned (Bronn and Bronn, 2000). In this article, as members of the educational environment, students and educators are mentioned. McLeod and Chaffee (1973 in Bronn and Bronn, 2000) develop a co-orientation model, which provides a framework to identify the relationships between groups in the communication process. The main axes are mental models (Senge 1980, 1992 in Bronn and Bronn, 2000) and stakeholder's theory. (Bronn and Bronn, 2000)

In the communication process, groups and individuals (from ...original data selection to deciding upon a course of action) follow specific stages which are shown by Argyris (1990) via the ladder of inference [...] in which mental models exist at the middle and upper steps of the ladder of inference. (in Bronn and Bronn, 2000). (Figure 2)

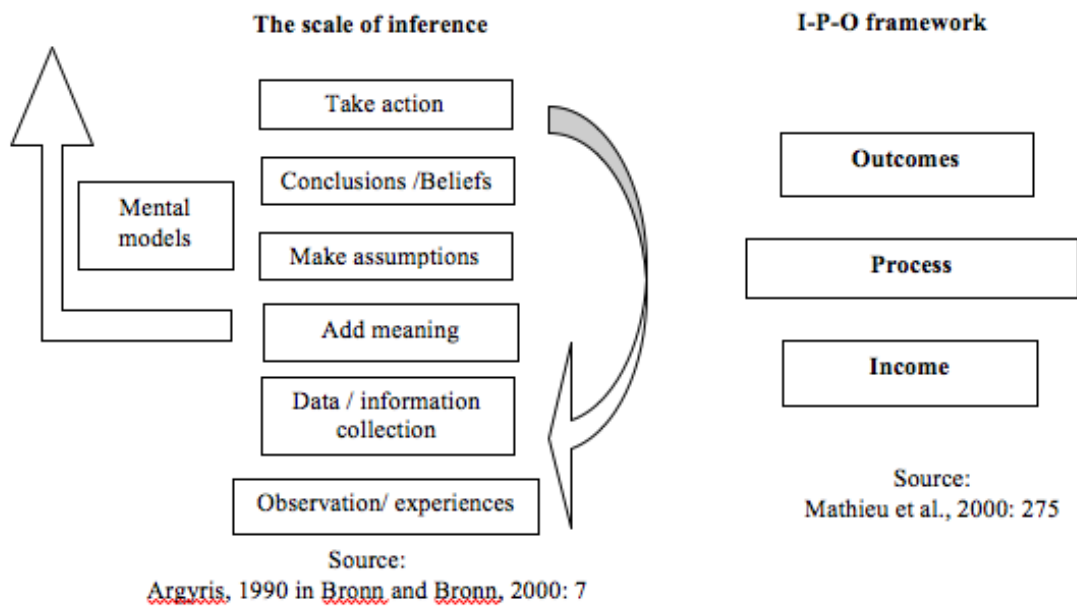


Figure 2.

According to the scale of inference, effective communication is dependent on the extent of the convergence of mental models between members of a group and the mutual understanding of the world around them, (Bronn and Bronn, 2000), while Mathieu *et al.* believe that in the IPO framework (Figure 2) ...the following are important for linking shared mental models with team performance: communication processes, strategy and coordinated use of resources, and interpersonal relations or cooperation (2000).

Using the above illustrations, there is a difference in the two educational environments, both in the first stage of information collection, as well as in the use of students' mental models in the upper stages or information interpretation stages. In the mediated educational environment, in the collecting information stage, due to the fact that many communication channels are available, the educator has the ability to convey information in various, different ways. Thus, there are more chances that more students will receive and interpret information sent, compared to the traditional classroom where communication channels are specific and limited (Table 1). Particularly, when information is transmitted in the three dimensional environment, understanding is greater and learning is increased, as "the key to learning is enhanced realism, and this is where technology comes into play" (Rosen, Carrier, Cheever, 2009).

Moreover, in a physical classroom, the educator, as the sender of information, can only assume the extent to which students receive and understand transmitted information. Cannon & Bowers, *et al.* mention that, "the more knowledge team members have about one another (and the

more accurate that information is), the more efficient and automatic this process can be." (1995, in Mathieu *et al.*, 2000)

Therefore, the mediated by social media educational environment, which is multifaceted, enables the existence of many sources of information and the student's activity is apparent (through posts, discussions, personal views, etc.) (Table 1). The teacher has the opportunity to know in depth the students' perceptions and thus to approach their mental models, without intervening, but through the adoption of the appropriate teaching methods, thus targeting effective communication and increased learning. Then "to the extent that the organization's perception is closely correlated with the stakeholder's, the organization has a solid basis for developing a communications strategy. The less accurate the perception, the more ineffective the communications will be." Organization is the communicator (the sender of information) and in this article this role is attributed to the educator (Bronn and Bronn, 2000). In the same direction, Cannon & Bowers *et al.* indicate that the convergence of members' mental models in a group "... allows team members to draw on their own well-structured knowledge as a basis for selecting actions that are consistent and coordinated with those of their teammates." (1993 in Mathieu *et al.*, 2000) (teachers, students).

More precisely, many researchers (McIntyre & Salas, 1995, and Morgan, Glickman, Woodard, Blaives and Salas, 1986) mention that "...in order to be successful, team members not only need to perform task-related functions well but also must work well together as a team. Accordingly, they distinguished between [...] two different types of mental models, task and team and

then related them to indices of team processes and performance” (in Mathieu *et al.*, 2000) In the mediated by social media learning environment, the above "real convergence" seems to be easier to exist, compared to the traditional, isolated without interactivity environment, since its members’ actions transparency (teachers, students, classmates together, parents, etc.) enable educators to collect information on both their students’ opinion toward tasks (content, style class, etc) as well as on students’ relations with different groups they interact and by which they are influenced in the process of the ladder of inference (Figure 1).

Pavlik (1989) also reveals that two-way communication can increase effectiveness of communication in organizations and it is a more “moral” form of communication, compared to one-way communication (in Grunig and Grunig, 1992: 309). In the same direction, Grunig (1984) states that one-way communication is a 'monologue', aiming at dissemination of information and persuasion of the public, while two-way

communication, is a "dialogue", where information is exchanged, aiming at “understanding” (in Grunig and Grunig, 1992: 289)

Consequently, associating the flow of communication in the two forms of educational environments, with models of Public Relations and in accordance to the features of the two-educational environments (Tables 1, 2), effective communication and increased learning between educators and students, is more likely to be achieved in the mediated by social media educational environment. In the traditional, physical classroom, the educator disseminates information in accordance to the pre-set course content, which is not open to many changes, and students receive and absorb it, giving little attention to understanding. Whereas in the new environment, the content is a common creation and the main educational goal is understanding as opposed to students persuasion and information absorption. The above could be captured as follows (Figures 3a, 3b):

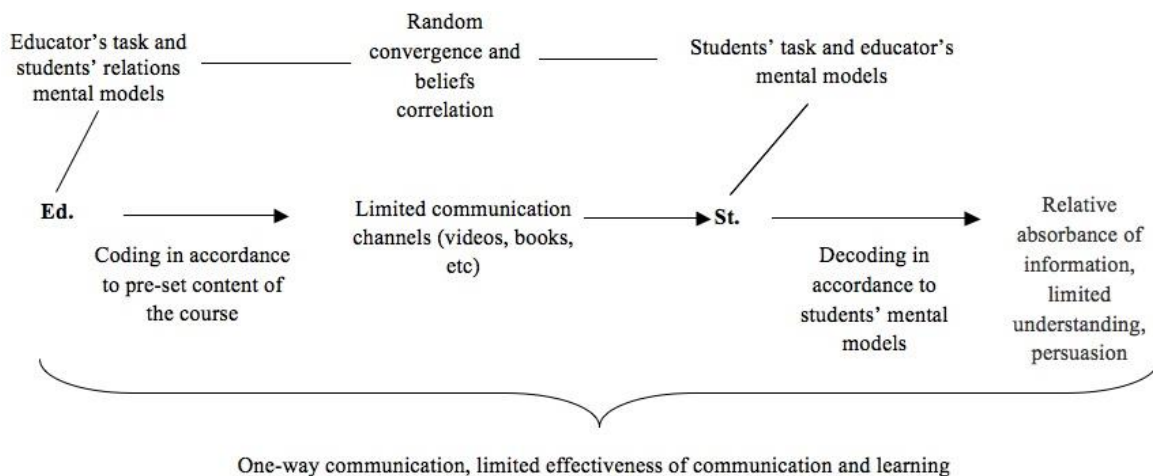


Figure 3a.

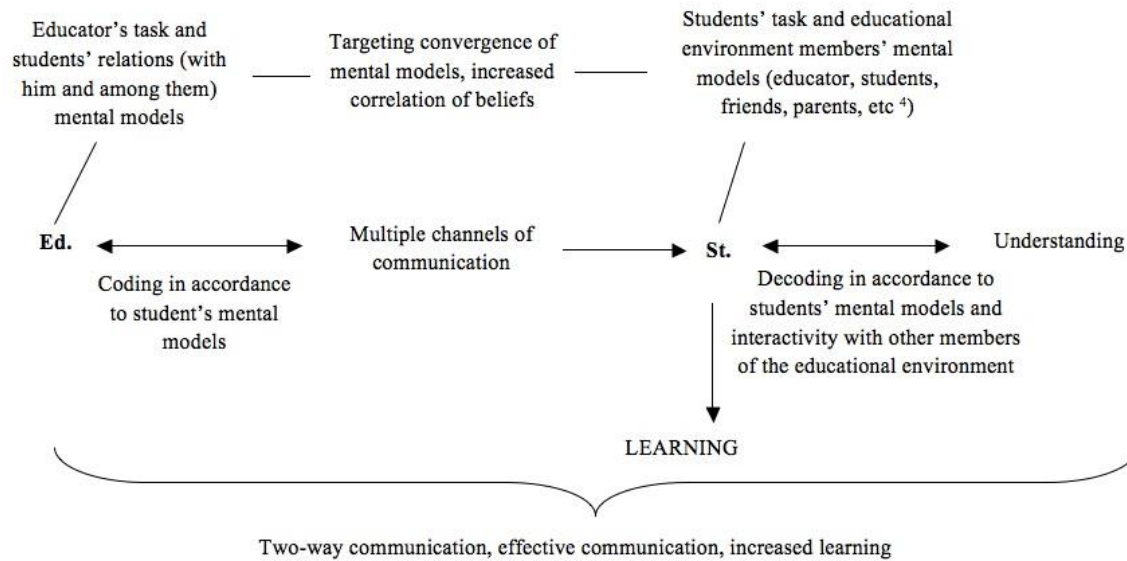


Figure 3b.

The Micro-environment

At an organizational level (micro-environment), in order to explore key issues, which are associated with the integration and use of social media into the educational agenda, a SWOT analysis was used. According to Bosman and Zagencyk, “The SWOT analysis is used to better understand the strategic benefit of integrating social media into the educational institution’s goals and missions. It assesses the institution’s (or classroom’s) strengths, weaknesses, opportunities and threats, associated with social media. The strengths describe the institution’s assets, resources, as well potential benefits of using the social media.

The weaknesses describe the challenges the institution will face in adopting a specific social media. The opportunities describe the institution’s possibilities for implementing social media. Finally, the threats describe the potential danger or risk associated with the use of social media.” (Bosman and Zagencyk, 2011)

In this article, SWOT analysis is used to figure out strengths, weaknesses, opportunities and threats from a communication point of view (Table 3 – SWOT analysis), based on characteristics of the new mediated educational environment, as they are mentioned above (Tables 1, 2).

Table 3. SWOT analysis of an educational organization, in the new mediated educational environment (Adapted by Bosman and Zagenczyk, 2011)

<p style="text-align: center;">Strengths</p> <p>Additional communication channels More attractive and engaging environment for students Supports both synchronous and asynchronous communication Enables networking (other universities, parents, etc.) Easy access to information</p>	<p style="text-align: center;">Weaknesses</p> <p>Assessing validity of information Requires computer and internet access Existence of various social networking tools: Difficult to memorize different usernames and passwords; Social networks tools are not officially integrated to universities' educational agendas, officially.</p>
<p style="text-align: center;">Opportunities</p> <p>Ability to use tools of three dimensional environments Open to be transferred in three-dimensional environments (e.g. Second Life): More realism Opportunity to launch social networking tools specially designed for educational purposes Social media recruits more and more members: They can become a main information networking tool within educational institutions. Can support in-class teaching when this is limited by time, space and methods used.</p>	<p style="text-align: center;">Threats</p> <p>Privacy and ethical concerns could result in legal implications for the educational environment Concerns that the mediated educational environment would replace the in-class environment Student-Teacher relationships boundaries are not clearly defined Lack of preparation and coordination between universities to accept innovation that new technologies and social media bring. Needs of a culturally diverse educational institution via a social networking tool.</p>

The Macro-environment

For a societal level (macro-environment analysis) it is of great importance to explore the role of the media itself in the learning process. These two concepts are social institutions (Pleios, 2005) while Postman "agrees that education is the most massive means of communication among the other means of communication, and in this way it equates education with other mass media "(2002, in Pleios, 2005: 29, 30). From this point of view, there are theories of" independent relationship "between the

educational processes, including learning, supporting mainly that the television and other visual media do not affect education and its components, while theorists of "strong influence" on education, argue that the media has acquired a central role in the structure and function of society and therefore have the ability to influence education. (Pleios, 2005), (Figures 4a, 4b)

Figure 4a

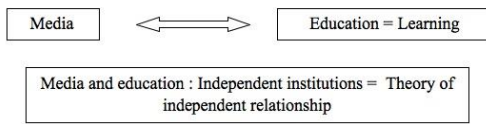
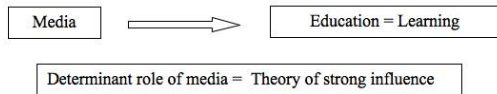


Figure 4b



In addition, according to Pleios, "in the process of interpretation of the world –via coding and decoding messages –, the formation of the ideology of actors has a central role" (2005: 307). "By the end of the period of industrial modernity, an important feature of ideology is its communicative dimension, in which the technological image is the communicative medium of ideology [...], the virtual ideology and consumerism are the fundamental points of coding and decoding, for the interaction between actors." (Page, 2005)

In the new era of digital media, Weigel *et al.* show that the main impacts on learning relationships involve changes in the students' attention, the preferences of the information-seeking practices of students, the relationship between student and teachers, as well as relationships among students (2010).

Consequently, the transition in the new mediated educational environment indicates differences in the educational practices as well as in the role of the new media within societies. As such, the integration of new media within Universities in a macro-level refers to:

- The examination of the role of the new media within society.

- The examination of the educational system within society.
- The examination of relationship and interaction between these two institutions within society.

This analysis seems important for the integration of the new media within educational environments, taking into account that the different environments of an organization are not independent and there is a significant degree of interaction among them (Figure 1).

Discussion

At the same time, many concerns are raised about the extended use of social media in the new educational environment (Atay, 2009, Munoz and Tower 2009, Sturgeon and Walker, 2009). Most of them are related to issues such as self-disclosure of stakeholders (teachers, students) in the new medium, security of participants, corruption of privacy, the validity of the knowledge that is created in the base of informal information exchanged (O'Brien, 2009). O'Brien considers that in the new educational environment: "At mediated by technology systems there is no easy way of verifying and validating usefulness of informal learning: Who produces and validates the unofficial information content? How, where and when is it created, archived and accessed? How is it updated and improved?" The replacement of physical in-class teaching by the mediated educational environment by social media and new technologies (Rosen, Carrier and Cheever, 2010).

Issues to consider for the integration of social media in the educational environment
Relating safety to the use of these technologies, Patil and Kobsa (2005), seem more reassuring, as they believe that ... the

use of privacy controls in technology is dependent on the knowledge of security features, and the technology itself (in Mendez, *et al.*, 2009). Additionally, even the fact that the multifunctional structure of social media and new technologies offer opportunities for educational evolution, it is time consuming and requires increased technical knowledge for both groups (teachers and students) (Rosen, Carrier, Cheever, 2010). Especially for teachers because their role in the new educational environment also requires a technical advisory dimension, as appropriate. (Table 2)

Concerning the existence of a wide variety of social networks tools, whose integration and use into educational agenda of educational institutions seems difficult, Dalsgaard argues that “though many existing social software tools can support learning activities, they were not specifically designed for educational purposes, and therefore a directed effort to develop educational social software tools to support learning activities is necessary.” (2006, in O’Brien, 2009)

One such effort, based on marketing principles, is the segmentation of content exchanged in social media. According to mass marketing literature and practice on market segmentation, if the solution to meet the diverse preferences of customers is the segmentation of the mass market, which is "characterized by mass production, distribution and promotion of a product for all customers (Kotler, 2006), the same could be applied for social media mass content (like Facebook) where the information is distributed in a mass audience and users gather information they need. For instance, if Facebook is the “mass market” design “niche markets” (social media with specific content), by taking into account the

preferences of the “buyers”- in this case the members of the educational community- could be an effective way to create a “healthy” and technologically safe mediated learning environment.

At an organizational level, given the fact that the integration of social media in education can create communication and educational opportunities to educational institutions and at the same time constitute a challenge that most educational organizations face more and more, this should be incorporated into the overall strategy process of every institution. As Bronn and Bronn state to this direction, “although communications is claimed to be an important element in the organization’s overall strategy process [...], very little is presented for the form of how to integrate communications with the strategy development and implementation work” (2000). Actually, Pascal mentions that new technologies cannot be easily accepted to European universities as “in Europe and particularly in European universities there is lack of overall and strategy both in a global and local level, lack of coordination, and a lack of preparation” (2001).

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Using Manipulative Models to Develop Tree-Thinking

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Students often struggle with tree-thinking even though it is a core aspect of evolutionary education. Phylogenetic trees are considered multidimensional hypotheses of evolutionary relationships by scientists. However, students often only view textbook diagrams as static, two-dimensional images. Physical manipulatives have been used to facilitate learning science content in areas such as genetics, but these instructional tools have not yet been tested in tree thinking. In order to circumvent students' tree-thinking struggles, we investigated the use of manipulative, three-dimensional tree models in an introductory biology course designed for non-science majors. We compared three treatment groups across three semesters: 1) control; 2) multichromatic model; and 3) monochromatic model. We used a mixed methods approach gathering data from pre/post assessments and course observations to measure student tree-thinking learning gains and interactions when exposed to each instructional treatment. We found that students had the highest tree-thinking learning gains when given explicit instruction tied with a multichromatic model. The use of multiple colors aided students understanding of the major components of trees; they were able to easily distinguish among the multiple taxa represented. This investigation provides empirical evidence to support the use of manipulatives in tree-thinking instruction.

Keywords: tree-thinking, manipulative models, college biology course

Introduction

Illustrations are commonly used to aide in teaching evolution. One of the one most commonly used and recognized illustrations in teaching evolution is a phylogenetic tree, or evolutionary tree. Symbolically, phylogenetic trees use a branch system to represent occurrences of speciation; they capitalize on the visualization that physical trees represent, a series of lineages that branch from one another. These depictions prove to be an integral part of evolution

teaching, but only when utilized correctly. The term “tree-thinking” has been coined to describe a person’s ability to conceptualize evolutionary relationships (Meisel, 2010). Unfortunately, because of pre-existing misconceptions, students often struggle with interpreting the information that phylogenetic trees depict (Halverson *et al.*, 2011; Catley & Novick, 2008; Gregory, 2008). For example, when asked to represent or describe how organisms are evolutionarily related, some students draw

on their previous knowledge about organismal behavior and ecological information (Halverson, 2011). One way to help students overcome these misconceptions is by teaching students how to understand tree-thinking representations.

Representations can enhance learning across various content disciplines (i.e., biology, chemistry, and mathematics) by improving problem solving skill through creativity, and facilitating the development of connections between new and prior knowledge (Cook, 2006; Peterson, 1994). Representations provide different methods of presenting information than traditional lectures and are critical to effectively communicate abstract science concepts (Gilbert, 2005; Mathewson, 1999; Novick & Catley, 2013; Patrick *et al.*, 2005). Phylogenetic trees are representations that depict evolutionary relationships. To understand a phylogenetic tree the learner needs to understand all of its parts, similar to being able to read a map. Without the knowledge of what each line and symbol on a map means, the map-reader will not understand the information the map conveys (Tversky, 2005). Therefore, if a student does not understand the fundamental basis of phylogenetic trees, the illustration is useless.

Using manipulatives allows students to gain a deeper understanding of complex subject matter, such as evolution and phylogenetic trees, but only when used in conjunction with explicit classroom instruction (Krontiris-Litowitz, 2003). However, in order for students to become experts with representations, they must use representations correctly and as a reasoning tool when investigating problems (Halverson & Friedrichsen, 2013). Representations are often used to represent and communicate difficult subjects (Halverson *et al.*, 2011; Gilbert, 2005) and

are a central component of instruction, comprehension, and creating scientific ideas (Tversky, 2005). When a student is able to understand and interpret representations accurately, they have reached a level of representational competence (an individual's ability to understand and interpret representations) (Halverson *et al.*, 2011). Therefore, finding ways to help students increase their representational competence is integral to helping students succeed academically. The study investigated the use of a manipulative tool to facilitate students' representational competence development in tree thinking.

Literature Review

Visualizations can take two-dimensional or three-dimensional forms, and can be either hand drawn or computer created. The key to a successful visual representation is that it explains the complex subject matter in such a way that the user can accurately interpret the meaning. Many visual representations are found in print media (e.g., images in text books). Often times when students are studying for an exam or looking for information they will go to images in text books to help interpret the text information found on the same page. However, previous research has found that representations found in print media offers the fewest cognitive gains for learners, whereas visual models and simulations offer the greatest (Gilbert, 2005). Visual models are able to illustrate a concept and can make abstract science ideas more accessible to learners. These visual tools are often used to simplify complex problems and present them in a manner that aids in problem solving. For example, maps are highly utilized visual tools that illustrate information needed for navigation. Many road maps only contain key streets, not every dirt road that a driver may pass from point A to point B. In this instance the map is a simplified version of

reality, the main streets still exist, but not every point in reality is represented and the driver is still able to determine which direction to go. The map has simplified the area but the overall content remains the same and users are still able to navigate (Tversky, 2005). Although it is accepted that visualizations are important to science education, there are challenges to incorporating them into learning environments (Rapp, 2005). One challenge is the practice of simply including visualizations into instruction to augment for teaching difficult topics. However, poor visualizations are as ineffective as poor text or poor lectures and may inhibit learning.

Additionally, student learning is often inhibited due to previously held beliefs that are particularly resistant to change (Posner *et al.*, 1982). As such, a student's prior knowledge can influence how they approach visualizations (Rapp, 2005). One of the challenges to creating quality visualizations, that address specific education ideas, concerns students' prior knowledge. Many times problems arise because students' prior knowledge is incorrect or incomplete (Gomez *et al.*, 2010). However, visualizations can be informative if the individual using them can understand what information the visualization is providing.

A central focus of biology education is learning basic evolutionary principles; students should be able to understand evolutionary relationships between taxa. Phylogenetic trees are the most conventional visualization tools for displaying evolutionary relationships, however, they require a level of tree-thinking ability for readers to understand the information represented by the trees (Meisel, 2010). A person's knowledge of life sciences is based largely on understanding evolution (Catley *et al.*, 2010), yet misconceptions persist,

particularly with tree-thinking. These misconceptions lead learners to be confused by concepts represented in the phylogeny (e.g. common ancestry; Baum *et al.*, 2005; Sandvik, 2008).

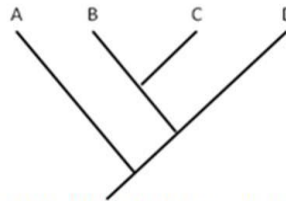
Phylogenetic trees are intended to represent multidimensional hypotheses about the nature of relationships among taxa, with branches being able to "swivel" around nodes and not alter the relationships represented by the topology (Halverson, 2010). However, textbook representations of phylogenetic trees are restricted to two dimensions. The nature of these images limits the amount of information represented (Halverson *et al.*, 2013). Additionally, evolutionary trees are used to show evolutionary relationships among genes in multi-gene families (Omland *et al.*, 2008) which are not easily represented in a single print image. Scientists interpret phylogenetic trees by identifying groups of taxa that share common ancestry. Taxa branch off from one another at nodes (intersections representing hypothetical common ancestors). Taxa sharing the most recent hypothetical common ancestor are more closely related to each other than any other taxa represented on the tree. However, students' rationales when evaluating phylogenetic trees are often non-scientifically based (Halverson *et al.*, 2011; Novick & Catley, 2013). Some students base taxa relationships on the distance between the branches tips of evolutionary trees, with closer tips being inaccurately interpreted as meaning closer relationships (Halverson *et al.*, 2011; Novick & Catley, 2013; Baum *et al.*, 2005). For example, when tips of the branches are close to each other, students assume that this indicates a closer relationship among the taxa represented even when this is not an accurate interpretation. However, taxa relatedness is inferred by interpreting the patterns of nodes

(the point organisms diverge on phylogenetic trees.

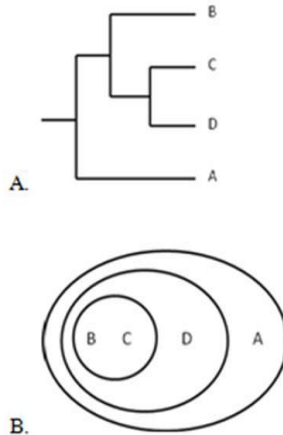
Additional common tree-thinking misconceptions include: incorrect mapping of time, node counting to determine relationships, and confusing straight lines as equating no evolutionary change after the point of divergence (Meisel, 2010; Gregory, 2008; Meir *et al.*, 2007). Additionally, English speaking students tend to read trees from left to right assuming that more primitive organisms are on the left (Novick *et al.*, 2012). This is problematic as students are interpreting phylogenetic trees as ladders of progress rather than as a system of biological relatedness (Omland *et al.*, 2008).

These misconceptions about evolutionary trees can be detrimental to understanding the patterns and processes in evolutionary history (Gregory, 2008). Gaining a better understanding of the core features and information presented in a phylogenetic tree representation is the key to developing representational competence with phylogenetic trees, leading to an increased tree-thinking ability (Halverson *et al.*, 2011). Helping students develop representational competence and tree-thinking skill development will increase their understanding of evolutionary history, a critical component of biology education.

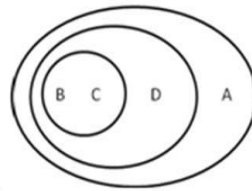
Interpret the relationships depicted in the following image:



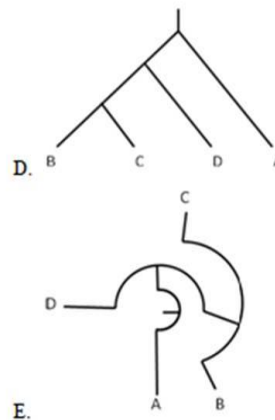
Indicate which of these images below illustrates the equivalent relationships to the image above (you may circle more than one answer).



A. ((D(BC))A)



B.



D. B C D A

E.

F. None of these trees are equivalent to the original tree above.

Figure 1. In this pre/post-test question, students were asked to compare alternative phylogenetic tree representations. Tree 'B', 'C', 'D' and 'E' show equivalent relationships while Tree 'A' shows an alternative set of relationships.

Phylogenetic tree representations are included in biology textbooks at both the secondary and post-secondary level (e.g., Figure 1). However, students struggle with correctly interpreting and understanding these trees, especially given the varying styles used (e.g., Halverson *et al.*, 2011; Catley & Novick, 2008; Gregory, 2008; Catley *et al.*, 2010). The varying styles and lack of consistent instruction results in students having poor tree-thinking ability and are unable to answer tree-thinking questions correctly when using traditional textbook images of phylogenetic trees (Sandvik, 2008). Flawed understanding and inaccurate rationales used by students has prompted a need to revise how Evolutionary Biology textbooks illustrate the relationship among lineages of species (e.g., Halverson *et al.*, 2011; Catley & Novick, 2008; Omland *et al.*, 2008). The science textbook representation of a phylogenetic tree is restricted to two dimensions, which can hinder full understanding of the relationships these trees represent and limit real time interaction (Ruths, *et al.*, 2000).

In phylogenetic tree representations, it is understood among scientists that the branches can swivel around a node without altering the monophyletic groupings (all of the descendants of one ancestral taxon; Baum, 2008). However, traditional textbook images require the reader to imagine how the branches can swivel around the node. Therefore, using a three-dimensional, manipulative model (Halverson, 2010) would allow learners to physically rotate tree branches rather than relying solely on their imaginative ability.

Manipulative models are used across numerous disciplines to illustrate various fundamental concepts. Manipulative models are often found in science classrooms and

are becoming more frequent in mathematics classrooms. For example, in one math class, subjects were subjected to three treatments: an abstract manipulative, concrete manipulative, and no manipulative (Belenky & Nokes, 2009). The results indicated improvements in student learning from pretest to posttest with the use of manipulatives. Organic Chemistry courses use model kits to depict the physical structure of molecules. The kits allow students to create different bonds and manipulate how atoms and molecules rotate. Similarly, manipulative models of phylogenetic trees can supply students with an alternative way of understanding phylogenetic tree representations and enhance students' tree-reading skills (Halverson *et al.*, 2013; Meir *et al.*, 2007). Classroom use of manipulatives helps demonstrate the importance of structural models in scientific discovery and communication (Jungck, *et al.*, 2010). Phylogenetic tree representations are one way systematists convey their findings about evolutionary relatedness among organisms. As new information is discovered and incorporated into existing knowledge the phylogenetic trees communicate the changes to the rest of the systematics community. If students are unable to understand these trees due to poor tree-thinking ability, they may not be able comprehend the changes in evolutionary relatedness.

Manipulative models enhance how students think about specific content (i.e. phylogenetic trees). When students actively think about the new information they learn from using manipulative models, they organize that knowledge in a what way that makes it accessible to them to interpret future representations (Brandsford *et al.*, 2000). Manipulative models provide a way for students to increase their representational

competence by learning how to interpret information from the model and apply it to future representations. There is little research investigating students' phylogenetic representational competence (Halverson *et al.*, 2011) or how manipulative models interact with students tree-thinking ability. This project aims to improve undergraduate biology instruction by using a novel, low-tech, three-dimensional, tactile, manipulative model of a phylogenetic tree (Figure 2) to help students overcome known challenges associated with tree-thinking. This manipulative model will allow students to physically interact with evolutionary relationships represented in phylogenetic trees. Students will be able to manipulate the tree by flipping branches, comparing topologies, identifying informative features of a phylogenetic tree, and identifying evolutionary relationship patterns.



Figure 2. Two versions of a manipulative tree model: one monochromatic and one multichromatic.

Research Questions

- What are the differences in tree thinking learning gains when using a traditional tree thinking approach versus using a multichromatic or monochromatic manipulative?
- How do students interact with manipulative tree models with learning tree thinking?

Undergraduate learning outcomes were tested using three types of representations during tree-thinking instruction: a two-dimensional textbook image, a three-

dimensional multichromatic manipulative and a three-dimensional monochromatic manipulative. Additionally, this study explored the superficial aspect of color layered into the multichromatic model. The monochromatic model mirrors the multichromatic model in shape and orientation of the branches, the only difference was the use of one color, black, rather than the five colors used in the multichromatic model. However, without the use of appropriate cues such as, color, design, and organization, students are less likely to know what is being conveyed by the visualization (Rapp, 2005). We hypothesized that the multichromatic model would elicit greater learning outcomes than the monochromatic model.

Methodology

Data was collected in a lower division, non-majors Biology course and included 163 student participants across three course sections. Any identifying student information was replaced with an alphanumeric code to ensure the anonymity of the participants. Over half of the participants were freshman level students and 51% were female. The course was divided into four topics: Unit One - Nature of Science; Unit Two - Environment; Unit Three - Genetics; Unit Four - Evolution. The first three units were taught with a foundation in evolution in an effort to help students be less resistant to instruction on evolution. The Evolution unit (Unit Four) is comprehensive, bringing information from previous units together, and uses a tree-thinking approach to teach evolution content. During this unit one instructional intervention was completed. The intervention was a semi-structured activity that lasted 1.25 hrs. The students were provided with a tree-thinking worksheet (Halverson, 2010). The tree-thinking worksheet was mirrored in the power point

lecture so students could see the instructor work through the worksheet after they completed different stages. The instructor let the students work through the worksheet, providing ample time for students to work and ask questions.

There were three treatment groups, each from a different section of the same course: Control, Multichromatic and Monochromatic (Table 1). In the Control treatment group, the instructor taught students how to read phylogenetic tree using only traditional textbook images. In the Multichromatic treatment group, the instructor taught students how to read phylogenetic trees using a supplemental multicolored, manipulative tree model. In the Monochromatic treatment group, the instructor taught students how to read phylogenetic trees using a supplemental single colored, manipulative tree model. All three treatment groups received the same instructional intervention; however the Multichromatic and Monochromatic groups were also given one of the manipulative models to use during the worksheet activity. All groups were taught by the same instructor and grade distributions were consistent across all course sections.

Table 1. *Distribution of treatment groups.*

Number of Participants	Section	Treatment
21	1	Control
129	2	Multichromatic
13	3	Monochromatic

Data was collected from tree-thinking, multiple choice pre/post-assessments (Halverson, *et al.*, 2011) and course observations during the instructional intervention. For the quantitative portion of our study, we calculated students' scores on the pre/posttest based on tree-thinking accuracy. We reported differences in mean

scores based on treatment groups and conducted a Mixed-Methods Repeated Measures ANOVA to determine if there were significant differences in student responses within and between the three treatment groups. We assigned statistical significance when $p < 0.05$.

For the qualitative section of data analysis, we conducted classroom observations while students used either of the two manipulative models (multichromatic and monochromatic) dependent upon which section students were enrolled. We used observations to provide additional evidence regarding how students interacted with each model type. We used the same observers for each treatment group. The observers took targeted field notes, specifically identifying the following: the types of questions posed by students; student engagement, noting if students were on or off task; statements made about the activity, including comments about the images or models used; and noting students actions, noting what students were doing as they worked through the activity.

Student learning outcomes were measured by scoring the scientific accuracy of student responses on the two-tiered tree-thinking pre/posttest. Each question in the pre/posttest was comprised of two parts, the first part was a multiple choice question; the second part asked students to explain why they chose their answer to the multiple choice question. We assigned a score (0 or 1) based on the multiple choice answer selected and students' explanation of the answer selected (for example, see Figure 1). After scoring student responses on both the pretest and posttest, data was stored and analyzed in SPSS. We ran a paired t-test and identified a significant difference in student responses between the pretest (M=0.35, SD=0.15) and post test (M=0.65, SD= 0.21) scores; $t(162) = -14.845$, $p < 0.01$. Next, we

compared the results from the monochromatic model to those collected from the monochromatic model and textbook images of phylogenetic trees. We ran an ANOVA to analyze the pre/posttest results between and within the three representation types. We highlighted the differences in student learning outcomes between the instructional models to identify the most effective tree-thinking instructional intervention.

Findings

We hypothesized greater learning outcomes with the use of manipulative models than

traditional textbook instruction. Additionally we hypothesized that the multichromatic model would develop a greater learning gain than the monochromatic model.

Students' Learning Outcomes with Manipulative Models

Student scores improved from the pretest to the posttest in all treatment groups (Figure 3). The gains from pretest to posttest within each treatment group were all statistically significant (test factor $F(1, 160) = 50.27$, $p < 0.001$).

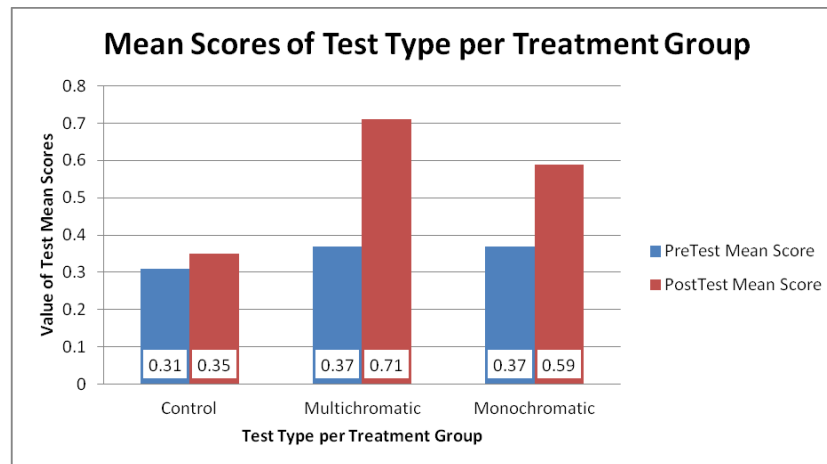


Figure 3. Changes in mean pre/post scores by treatment group

The multichromatic treatment group had higher learning gains between the pre/posttest than both the monochromatic and control groups (test * treatment interaction $F(2,160)=15.608$, $p < 0.001$; Table 2).

Table 2. *Tests of Within-Subjects Effects*

	Type III Sum of Squares	df	Mean Square	F	Sig.
Test	1.346	1	1.376	50.272	0.000
Test * Treatment	0.854	2	0.427	15.608	0.000
Error (test)	4.378	160	0.027		

The monochromatic treatment group had higher learning gains between the pre/post-test than the control (treatment $F(2, 160) = 28.17$, $p < 0.001$; Table 3) but not the multichromatic group.

Table 3. *Tests of Between-Subjects Effects*

	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	27.52	1	27.52	959.463	0.000
Treatment	1.616	2	0.808	28.17	0.000
Error	4.589	160	0.029		

Interactions in the Classroom

Through the instructional intervention using the manipulatives, students altered the shape and style of the tree to mirror that of the instructor's. Students responded positively to the use of manipulative models when learning tree-thinking. One student stated that using the manipulative model helped her, "think of the sister branches as a propeller on a helicopter." Another student stated that using the tree manipulative helped him see that tree-thinking was similar to decorating a Christmas tree, "If you could take your decorated Christmas tree, hold the bottom and turn the top until the tree looked like a corkscrew, then turn it upside down without all the decorations falling off, it would certainly look different but everything within the tree would still have the same configuration."

The monochromatic model presented some challenges for students. The most common challenge students reported was tracking which branch represented which taxa. One student resorted to tracking the location of each taxon on the tree on a separate piece of paper. This issue was compounded further when students began rotating branches around nodes. While all students that used the manipulative models recognized that monophyletic groups were not changed during this process, students using the monochromatic model struggled with remembering what taxa each branch represented. However, with the

multichromatic model, each taxon was represented by a unique color and students could easily distinguish and track the different taxa. We found the same trend when students tried to identify the lineage of a single taxon.

In the multichromatic model, the *trunk* is comprised of intertwined colors and when a specific lineage diverges, the color differentiation is apparent visibly. Students using the multichromatic model accurately understood and identified a lineage as extending from root to tip, while students that used the monochromatic model more often stunted the lineage and only thought it extended from the tip to the first node (or intersection). The lack of color distinction made interpreting when lineages share evolutionary history more difficult with the monochromatic model.

Discussion

Communicating phylogenetic hypotheses using trees, even within the scientific community, can be a difficult task due to the complex relationships being distilled through the visual representations. Helping non-science majors understand the meaning in these trees is substantially more difficult because some students have strong, but incorrect beliefs about evolution (Halverson & Friedrichsen, 2013). Compounding the problem of communication difficulties due to flawed prior ideas (e.g., by relating ecological principals to evolutionary

concepts), two-dimensional textbook diagrams cannot represent the dynamic nature of evolutionary relationships between taxa. Furthermore, accurately using tree representations in the classroom can be a difficult task for instructors, particularly if they are also unfamiliar with these models (Rapp, 2005). If the tree representations are not used accurately, students may leave the classroom more confused than when they arrived. Therefore, rather than decrease misconceptions regarding phylogenetic trees, the inappropriate use of these representations may increase students' misconceptions. However, when used effectively, representations can increase student learning of scientific concepts (Halverson *et al.*, 2011; Gilbert, 2005; Mathewson, 1999; Novick & Catley, 2013; Patrick *et al.*, 2005).

This study provides a different way for students to consider tree-thinking. The use of physical, tactile models allowed students to develop concrete ideas about tree-thinking concepts that are often represented in abstract ways. Our findings are similar to those found in neurophysiology (Krontiris-Litowitz, 2003) and Mendelian genetics (Grumbine, 2006); using a manipulative model with explicit content instruction (e.g. tree-thinking instruction) is an effective tool for improving learning. Of the two models we tested, we found that while both increased learning gains, the multichromatic model was the most effective model for increasing students' posttest scores, but there was a greater increase using the monochromatic model than no model at all. However, there was an increase in scores from pretest to posttest for students in the control group. This suggests that explicit tree-thinking instruction helped students understand the traditional textbook images of phylogenetic trees more so than they would without explicit instruction. After

exposure to both models, we found that students used trees as reasoning tools to explore evolutionary relationships based on clades (descendants of shared common ancestry) rather than rely upon tip proximity (e.g., Baum *et al.*, 2005). Both models were effective in demonstrating the ability of branches to swivel around the nodes eliminating the need for mental rotation that is required by traditional textbook illustrations of phylogenetic trees. Students were better able to understand that evolutionary relationships between taxa did not change when the branches were rotated. Students also discovered that no matter which direction the tips point, the evolutionary relationships are still the same.

Past research has found that superficial features, such as color, often hinder students learning outcomes when using visual representations (Patrick *et al.*, 2005; Kozma & Russell, 2005). However, in the case of phylogenetic trees, color plays an important role in learning tree-thinking. When used with a clear purpose, some superficial features (e.g. color) can increase student learning outcomes rather than hinder them. In our model, the use of multiple colors facilitates communication of distinct lineages, shared histories, and points of divergence. During course observations, students tracked lineages more easily because of the differentiation of colors in the multichromatic model. Students were able to follow the taxa divergences because some colors branched off while others remained intertwined. In comparison, the students found it harder to use the monochromatic model. The biggest challenge for students was keeping track of which branch represented which taxa when they rotated the branches. The monochromatic model did not allow for students to be able to track taxa by looking at the tree alone. It required students to create a mental map of where

each taxon was located before and after each rotation to remember how they were related. The confusion that comes from the monochromatic model as students try to keep track of the different branches as they rotate is similar to the confusion students have when studying traditional textbook images.

This investigation supports the use of manipulative models as interdisciplinary tools that provide a tangible, effective alternative for teaching abstract concepts. One contributing factor that increases the effectiveness of manipulative models is color. This is supported by previous studies that found that some superficial features are necessary for students to understand what is being represented (Rapp, 2005). Our study found that for any manipulative to be effective, it must be combined with explicit instruction and only superficial characteristics that enhance the model rather than take away from it. By exploring the mechanics of different models, researchers are one step closer to developing a refined model that enhances evolutionary biology instruction.

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Biology Students' Attitudes to Intersexuality and Transsexuality Issues

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Changes in social attitudes within society and constantly changing social transformations make education in gender identity and human sexuality a necessity. The aim of this research was examining phenomena of intersexuality and transsexuality and biological, psychological and social consequences of it in opinion of Pedagogical University Krakow Biology students. It has been shown that under the influence of teaching materials on gender identity, often negative attitudes of students of various forms of human identity have changed. According to responders sexual education should fight xenophobia. What is more, issues of inter- and transsexuality should be included in the syllabus of biology at the various stages of education.

Keywords: sex education, biology curricula, social transformations, sexual identity, transsexuality, intersexuality

Przemiany w zakresie obyczajowości i nieustannie zmieniające się zasady procesu socjalizacji powodują, że edukowanie w zakresie płciowości i seksualności człowieka staje się koniecznością.

Celem badań było: rozpatrywanie zjawisk transseksualizmu i interseksualności oraz następstw biologicznych, psychicznych i społecznych z tym związanych w opiniach studentów biologii UP w Krakowie, ich postaw wobec wpływu pozaszkolnych modeli popularyzowania wiedzy o tożsamości płciowej.

Wykazano, że pod wpływem materiałów dydaktycznych na temat tożsamości płciowej, często negatywne postawy studentów wobec różnych przejawów tożsamości człowieka, zmieniły się. Zdaniem respondentów edukacja seksualna powinna walczyć z ksenofobią, a zagadnienia inter- i transseksualności powinny znaleźć się w zakresie treści programowych biologii na różnych etapach edukacji.

Introduction

Social and cultural transformations are a permanent feature of human life. An individual's behavior and reactions regarding inter alia, sexual and cultural factors are related not only to procreation, but also with the formation of the identity of each person and the perception of it by individual members of society.

This research was carried out in the framework of an investigation of the problems of human biology considered in the light of social transformation and changes in the school curriculum. It consisted inter alia to obtain information on the relationship between sexual behavior in terms of biological standards and perceptions of the "norm" for students of biology. In this context, a relatively new term for education was gender identity, the analysis of which was focused primarily on human sexuality in biological and

social terms. It was considered important to investigate (1) students' opinions on the range of biological intersexuality and transgender issues that should be included in school curricula and (2) what is the attitude of the respondents to the curricular changes based on the operation of these issues in society.

Research method

Objectives of research: (1) to determine student attitudes towards issues of human sexual identity (2) investigate students' attitudes towards the impact of extracurricular models by improving understanding of sexual identity (mainly the media) in shaping public perception of sexuality, (3) the development of teaching materials about socio-cultural transformations in order to broaden students' knowledge about sexuality. Hypotheses, methods and research tools used in the study are presented in Table 1.

Table 1. Hypotheses, methods and research tools

Hypotheses details	
1	Media and social transformations have a significant impact on shaping public attitudes to the problems of human biology in terms of sexuality, through the promotion of certain models of behavior.
2	Biology students identify sexual education in Polish schools as important, especially in the context of issues relating to problems of human biology of sexuality.
3	According to the students' opinions, there is no coverage of intersexuality and transgender in the curriculum of biology and "Education for Family Life," have a negative impact on attitudes to the problems of human biology.
Research methods	
	diagnostic survey
	pedagogical experiment
	focus interview
Research tools	
	questionnaire
	Thurstone attitudes scale
	interview questionnaire

Biology students of the Pedagogical University of Cracow took part in all the studies carried out (40 students in the pedagogical experiment and the survey, 12 students in a focus interview). Selection of the research group was dictated by the fact that the student group joins the views of young people and adults who relatively recently were high school students, who in the near future also will be the teachers.

The experiment was carried out under the guidance of Łobocki (2010) in order to

determine whether the biology students change their attitudes towards sexual education at school under the influence of the applied experimental factors (determined by educational materials which the author's concept of research was made available to the students during the lecture in the field of biology). Thurston's attitudes scale was used in the experiment (pre and post-test), which was prepared as indicated by Marszałek (2004). In order to analyze the results of the pre- and post-test, statistical analysis was performed

according to the instructions of Stanisiz (2001).

The purpose of a questionnaire (containing six open-ended questions) was to find out biology students', former students' and prospective teachers' opinion about the factors influencing the sexual education.

Verification of hypotheses has also been made based on focus interviews conducted with two groups of students (the first group consisted of four students and in the second group there were eight students) on sexual education. The choice of research method was based on the information of Lisek-Michalska and Daniłowicz (2007).

Results

Analysis of the survey results on transgender and homosexuality showed that 25% of students felt that every person has the right to be happy, and that one should not prevent such people to live according to their beliefs. However, there are also many negative reviews - about 10% of students believed that homosexuals, in any case, should not have the right to adopt children, and transgender and homosexuality are too strongly promoted in the media which is unnecessary. Also, nearly 10% of the students expressed that such people should be treated with the therapy for psychiatric disorders, because such feelings and sexual behavior may be related only to a disease and problems with his or her own psyche.

Survey of students on educational and social determinants of perception of sexuality showed that groups involved in the focus interview had similar opinions, so analysis of the results was carried out for both groups by combining them. The interview took place shortly after a group of students learned about transgender (classes led by a panel discussion). Participants noted the need for including the term intersexuality in the curricula. In their view, students need to be aware of

people with sexual organs of both men and women and have every right to decide what sex they want to be. However, differentiation of being intersexual, transversal and transsexual is the knowledge useful in life and to speak about intersexuality in biology when discussing fetal development or genetic disorders linked with sex. In their opinion, it is very important that students have learned it at school - this would reduce the aggression against homosexual or transsexual individuals and would learn to use their cultural vocabulary. "That is why there should be a compulsory subject discussing deviations, contraception, intersexuality and mental maturity" and "a curriculum should be modified to discuss terms as intersexual individuals and transsexual individuals in biology."

Pre-tests and post-tests conducted as part of the pedagogical experiment included three thematic modules: knowledge about sexuality, sexual education in schools and in the media (in this study, we posted only changes in students' attitudes with respect to statements regarding transgender and intersexuality).

Results of the investigation students' knowledge of teaching materials about transgender and intersexuality which were available after conducting the pre-test, showed that there had an impact on beliefs about the problems of human biology and formed a basis for the post-test.

All respondents demonstrated knowledge of the phenomenon of intersexuality, 93% - the definition of gender identity, and nearly all were able to explain the concept of "femiman" and "androgyny". 75% of the students knew the position of the Church against sex change operations by transsexual individuals and was able to point out the differences between the terms M/F and F/M in the case of transgender people.

There were no significant differences in the responses of the respondents in the pre- test and post-test in some of the statements concerned occurring in each of the thematic modules, such as: AIDS, sexually transmitted diseases, contraception, sex determination, and disorders caused by problems of sex chromosomes. Approximately 70% of the respondents, both pre-and post-test claimed that sex determination is linked to the presence or absence of Y-chromosome. Also, they indicated that Klinefelter's syndrome is characterized by infertility, gynecomastia and testicular digenesis. About 80% of the students claimed that

Turner's syndrome patients should be treated to raise the level of estrogen, which determines the complete feminization of the body and prevents the pathological consequences of their deficits.

A significant change in the views of students has taken place with regard to homosexuality and transgender intersexuality.

Post-test results showed that 35% of students changed attitude towards homosexual people who were earlier seen as a threat (Figure 1).

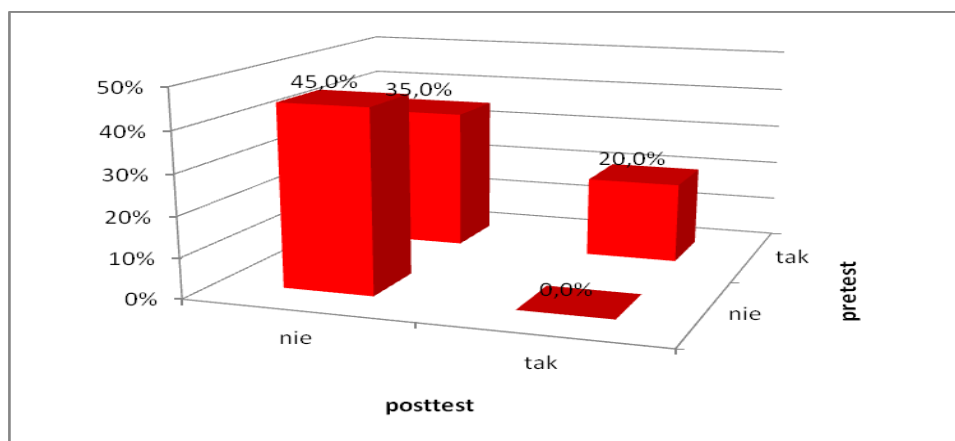


Figure 1. Change in the attitudes of respondents in relation to the conclusion that homosexuality is a threat to the modern world.

55% of the respondents in the pre-test did not agree with the statement that the pathogenesis of homosexuality may be due to abnormalities in androgen levels *in utero*; in the post-test they changed their minds (Figure 2).

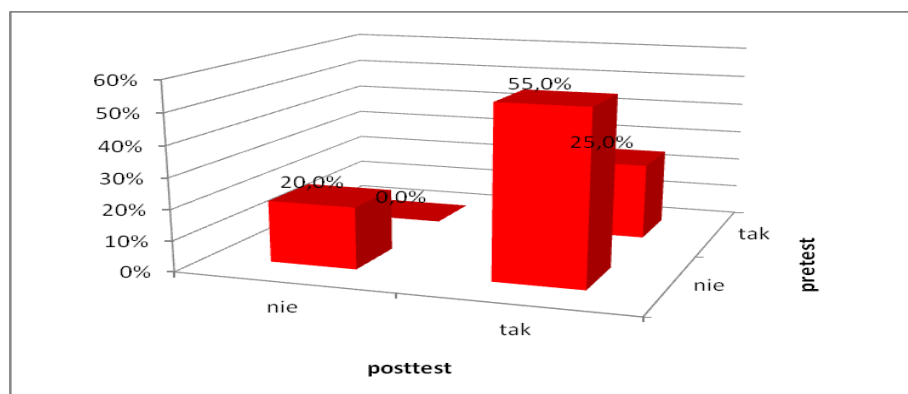


Figure 2. Change in the attitudes of the respondents with regard to the conclusion that the pathogenesis of homosexuality may be due to abnormalities in androgen levels in fetal life.

72.5% of students in the post-test felt that trans-sexuality and transvestism are phenomena that deserve respect for dissimilarity, even if in the pre-test these same students had a different view (Figure 3).

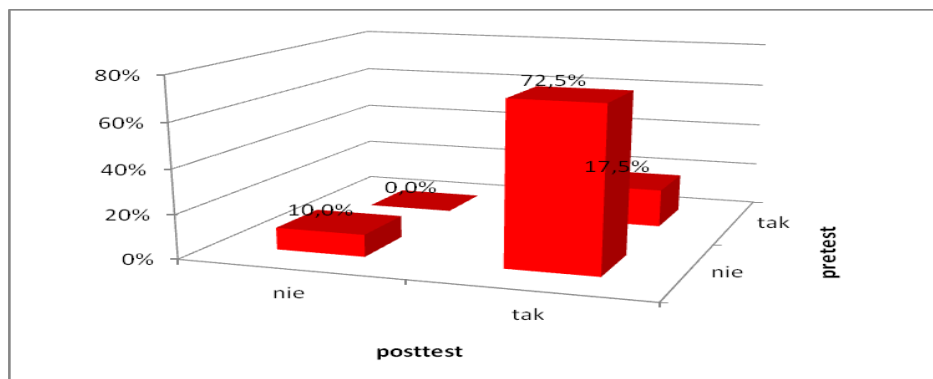


Figure 3. Changing the attitudes of the respondents with regard to the conclusion that transvestism and transsexualism are phenomena that deserve respect.

55% of students changed attitude toward the newborn intersex and found that the determination of sex's register should not be held within the first two months of life (Figure 4).

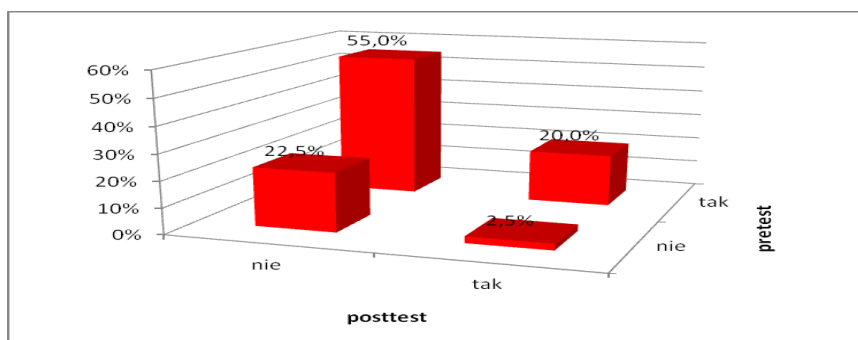


Figure 4. Change in the attitudes of respondents in determining gender intersex infant.

20% of students changed their attitude towards the legitimacy of discussing issues of intersexuality in biology and in the post-test concluded that it is necessary to help shape appropriate attitudes of students towards this phenomenon (Figure 5).

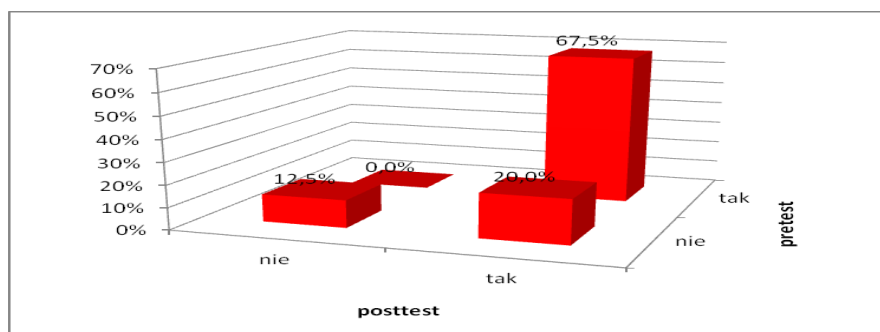


Figure 5. Change in the attitudes of respondents to discuss the merits of the issues of intersexuality on biology lessons.

The post-test showed that 35% of respondents changed their attitude towards discussing transgender issues in the classroom "Education for family life." (Figure 6).

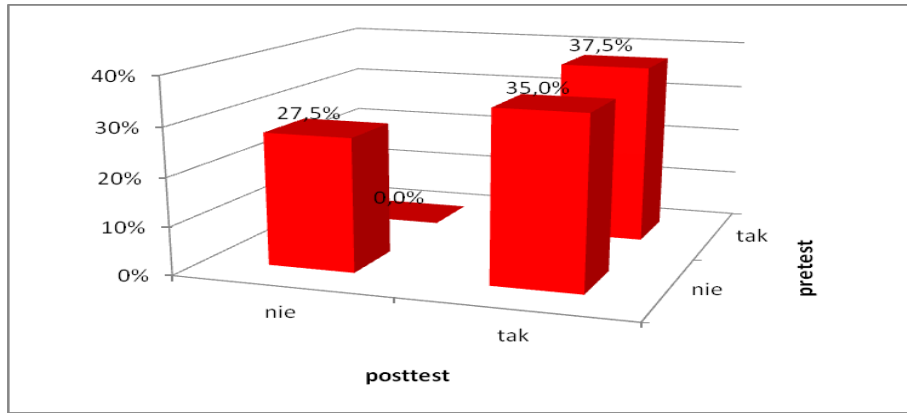


Figure 6. Change in the attitudes of respondents to discuss issues of trans-sexuality in the lessons of "Education for Family Life".

15% of students changed their attitudes towards raising awareness on the issue of knowledge of being intersexual. They acknowledged the need to spread information about intersexuality as a biological phenomenon that poses no threat or harm to others and it is not the result of mental disorder, even if in the post-test, it was perceived that way (Figure 7).

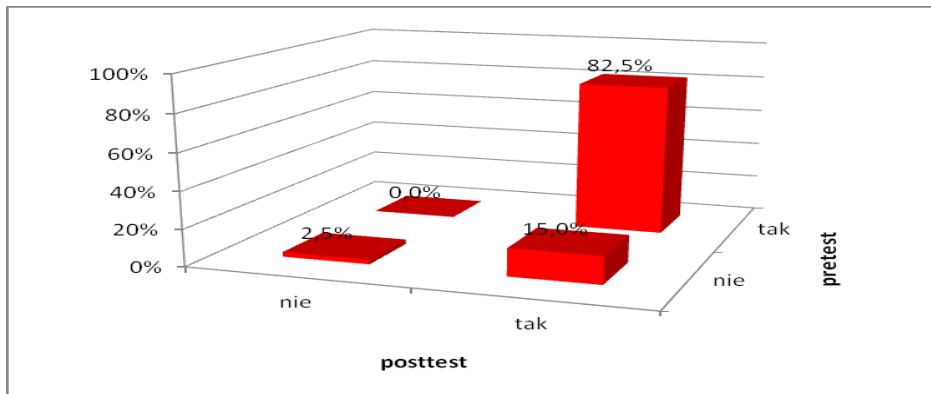


Figure 7. Change in the attitudes of respondents to raise the awareness on knowledge of the issue of being intersexual.

The post-test showed that 27.5% of students changed the attitudes towards social campaigns that overcome feelings of inferiority intersex individuals to the rest of the population and felt that they should be organized (Figure 8).

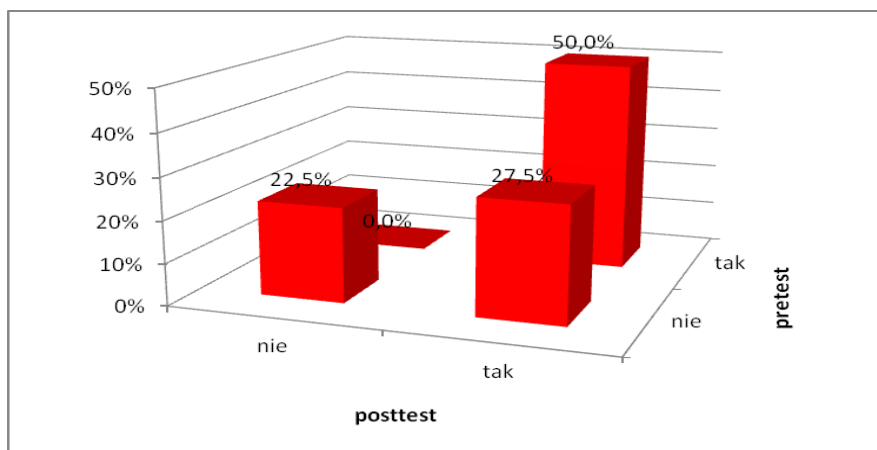


Figure 8. Change in the attitudes of respondents to the organization of public campaigns for intersexual individuals.

Initially, a lot of negative feedback was received amongst students towards transgender and intersexuality. For example, some students thought that transgender people should be isolated from society, as they are mentally disturbed. However, the use of an experiment in the form of teaching materials and lessons on transgender, caused student's to have a transformation of their approach to these issues. The results of a pedagogical experiment showed that the students of biology expanded their knowledge about transgender and intersexuality by familiarizing themselves with educational materials connected with issues of sex and gender. This resulted in a change of attitude towards the problems of sex determination and transgender that were frequently regarded as a threat to the society. Deepening the knowledge of students about transgender during their studies caused a change in the attitudes of some of them - students with a negative attitude towards the organization of public campaigns to promote tolerance to the problems of human biology of sex and gender, changed their mind due to scientific progress in this area and social transformations.

The respondents also changed their attitude towards the legitimacy of discussing the issues of transgender and intersexuality in schools – they decided that such information would change the negative attitudes of students towards "otherness". The respondents said that one of the lessons of biology should be dedicated not only to the biological background of both Turner syndrome and Klinefelter's syndrome, but also to the consciousness of those who are affected with it. It was also proposed to discuss these issues not only in biology lessons, but also during educational lessons that encouraged students to expand their knowledge about intersexual people.

One of the participants of the interview, said: "There should be a separate lessons devoted to intersex people, to compensate for generally negative attitudes towards them. It is a disadvantage associated with the development of the fetus, and most people treat these people as deviants, renegades, misfits. Therefore, this subject should be discussed with students." Especially because of the negative attitudes towards gay people. One of the students gave an example in support of this opinion:

"At my high school there was a lesson on the topic 'Homophobia.' One of my colleagues has written on the board: 'We do not want to fags in our city,' and that was it. The teacher did not commented on that and went out of the class when the bell rang. The inscription remained on the board during the whole break, and all of the students were laughing at it. All in all, the implementation of the subject failed, because it seems to me that it was still too early for it. I think it was also the teacher's fault, because he ignored the behavior of students, left it and went out."

According to the participants of the interview:

"The issue of transgender, intersexuality and homosexuality should be discussed in high school, as students call 'these phenomena' aberrations and they have no idea about the background of it. They do not know that some of them are diseases because the school remains silent about those issues. I'm sure none of us did hear about it in the classroom."

The students of biology at the Pedagogical University in Cracow, while studying the subject "Sexology", discuss the issues of homosexuality and transsexuality. Thus,

the authors of the study, evidently have decided that educating future teachers in this area may be essential in biology classes. Moreover, the transformation of academic knowledge about sexuality at the school level is necessary due to increased public awareness in this area, increasingly popularized knowledge about transgender and actions of the governments to issue laws, directives, and regulations at national level as for the European Union.

Conclusions

1. Sex education should fight xenophobia, teach tolerance, and shape appropriate attitudes of students towards the problems of the human biology of sex. It should also, in this regard, take into account the latest research and social transformations.
2. According to the students of biology, textbooks ignore the issues of sexuality. Thus, texts do not encourage the development of student attitudes in this field.
3. Educational materials on human sexuality reinforced the level of knowledge of students. Some students who treated intersexuality and transgenderism as a risk have changed their mind and decided that there is a need to introduce these issues into school curricula.
4. Information on the biological basis of human sexual identity should be updated. The curricula and textbooks should be characterized by an adequate level of educational transformation of knowledge about the definition of human sex, gender identity and tolerance for diversity and biodiversity.

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Karolina Czerwiec's scientific interests focus on human biology, health education, human gender and problems of sexual identity. Her research is connected with teachers and students at all levels of education, as well as

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Editor's note: Three popular American articles by biology educators are:

Fausto-Sterling, Anne. (1993). The Five Sexes: Why Male and Female Are Not Enough. *The Sciences*. 33(2): 20–24.

Fausto-Sterling, Anne. (2000). The Five Sexes Revisited. *The Sciences*. 40(4): 18–23.

Blackless, Melanie, Anthony Charuvastra, Amanda Derryck, Anne Fausto-Sterling, Karl Lauzanne, & Ellen Lee. (2000). How sexually dimorphic are we? Review and synthesis. *American Journal of Human Biology*. 12(2): 151-166.

Some Thoughts on BioMathematics Education

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We discuss a proper point of view for teaching mathematics and computation to biology majors. This involves the inculcation of digital literacy and problem solving capability in our young students. We propose that the calculus for biologist's course MATHSC 106-Bio should be a prerequisite for BIOL111. BIOL110 would teach **R** to its students and MATHSC 106-Bio would teach **MatLab** to its students. MATHSC 106-Bio would cover the basics of calculus and modeling up to and including portions of calculus of several variables. Regression is covered carefully in MATHSC 106-Bio also as well as a general discussion of the evolutionary biology law known as Hamilton's Rule. All of this background is then made a prerequisite for the six courses BIOSC 443 (Ecology) , BIOSC 302 Animal Diversity), BIOSC 335 (Evolutionary Biology), BIOSC401 (Physiology), BIOSC 461 (Cell Biology) and GEN 440 (Bioinformatics). This is done via the inclusion of quantitative modules that use mathematics and computational modeling to illustrate important concepts in each class. The instructors can assume the students have familiarity with the use of **R** for statistical modeling and **MatLab** for mathematical modeling. Such an assumption frees the instructor to cover material at a more sophisticated level enabling a better transition to modern biological usage.

Keywords: mathematics requirements for biology, computer and digital literacy, computation for biology

Developing Literacy

When I was a younger man, I worked at Union Carbide as an operator who helped run the equipment that made the plastic that is used in baggies and the coating of telephone wires (among other things). My responsibilities were split into an *outside* and an *inside* job. Every other day, I would have the *outside* job that entailed me walking around the plant looking for mechanical problems. If I found some, I would shut equipment down and prepare it for the maintenance staff by shutting valves and so forth. On the other days, I would be *inside* the

control room operating the controllers that determined the kind of plastic we were making on my shift. I liked both jobs as they were interesting and used different skill sets, but I particularly liked the outside one as it let me rub elbows with some of the master class maintenance people. I remember in particular a pump repairman named Dave. This was about 1973 and even then an expert such as Dave was being ridiculed for his emphasis on problem solving and correct technique. We used huge pumps driven by as much as 5000 hp motors. All of them had a typical flange and seal

design. When the material they pumped began leaking from the seal, the pump had to be shut down, the flange removed from the head by unbolting it and a new seal put in. This needed to be done delicately and Dave used a dial indicator attached to the head and the flange to make sure the heavy flange would be attached absolutely level once the new seal was put in place. Then, the flange bolts would be tightened like we tighten the bolts on a tire when we replace a flat: tighten bolts in pairs that are 180 degrees apart. This ensured the flange seated properly against the seal. Dave's precise maintenance procedures led to rebuilt pumps lasting for many months of continuous service. The other guys in the pump repair crew thought Dave was too fussy and didn't want to learn all these careful and useful ideas. They didn't value his skills and they didn't want to learn his skill sets. They did not take as much care in their maintenance procedures and the pumps they repaired typically lasted only a month or so. So, the general ability of the pump repair crews at the Union Carbide plant I worked at went down each year. Of course, it is also surprising that the engineering staff in charge of plant operations accepted such lax behavior. The message is clear. If we want to encourage the development and retention of such mastery, the work environment must encourage it. Dave was a master craftsman whose way of looking at the world was not valued by both his peers and by the plant managers; hence, it was not passed on to the next generation despite his many attempts to do so. I used to listen to him explain about pumps and all sorts of other things in which he would try to make me see how to look into a machine and feel its wrongness. He was very good at taking a big problem and breaking it down into smaller sub problems. These smaller sub problems were, of course, easier to solve. He showed me in a very real way how to make progress on a complicated thing, you needed to subdivide the larger issues into pieces small enough to work with.

I used to watch other craftsmen also at my plant. Some worked on metal lathes, some worked on assembly and disassembly of large machinery and all of the good ones were masters of their craft in the sense discussed above.

These early lessons for me occurred while I was working full time and going to college part time and so I was in the great position of being exposed to both the abstraction I saw in college and the pragmatism I saw in the trades. In both fields, the ability to move between theory and practice is exemplified by the situational fluency of the expert craftsman, but I am afraid we are moving away from it more and more. The *Nuts and Bolts Foundation* is concerned that our young people are losing this ability to connect practical aspects of diagnosing problems and building solutions to the theoretical knowledge they learn in high school and college. They think (B. Bergeron, 2010)

"more has to be done in the American educational system. For example, shop classes - once popular - are now rare. As a result, most students who finish high school are functionally illiterate when it comes to basic mechanical skills such as the ability to read a ruler. [Also, many employers have a complaint about] new engineering graduates. Apparently, they often can't build anything because they don't know how things are made. Theoretical knowledge alone just doesn't cut it on the shop floor."

They also believe (B. Bergeron, 2010)

"resources [must be] devoted to the pleasures of 'tinkering' - getting away from ... video games and TV sets and into the backyard building things. In that way, we will create the next generation of artisans, inventors, engineers, repairman, and skilled workers - in short, a self-sufficient, self-sustaining society."

This idea of tinkering and creative play can also be applied to what Resnick (Resnick, *et al.*, 2009) refers to as digital literacy.

"It has become commonplace to refer to young people as "digital natives" due to their apparent fluency with digital technologies. Indeed, many young people are very comfortable sending text messages, playing online games, and browsing the web. But does that really make them fluent with new technologies? Though they interact with digital media all the time, few are able to create their own games, animations, or simulations. It's as if they can "read" but not "write". As we see it, digital fluency requires not just the ability to chat, browse, and interact but also the ability to design, create, and invent with new media. To do [this], you need to learn some type of programming. The ability to program provides important benefits. For example, it greatly expands the range of what you can create (and how you can express yourself) with the computer. It also expands the range of what you can learn. In particular, programming supports "computational thinking," helping you learn important problem-solving and design strategies (such as modularization and iterative design) that carry over to non programming domains. And since programming involves the creation of external representations of your problem-solving processes, programming provides you with opportunities to reflect on your own thinking, even to think about thinking itself."

So it would be nice to return to undergraduate courses designed to develop a sense of general literacy in the students. This would include the ability to use computation and simulation to develop insight, to build appropriate blends of mathematically enabled science for the purpose of exploration and utilize creative play in generalized learning. These attitudes would, of course, enhance the student's ability to problem solve and integrate theoretical and practical knowledge. A general philosophy might be one I often use in my own classes. We should be

developing tool builders rather than tool users. No matter how careful the training, all classwork is eventually obsolete in the light of rapidly advancing technology and science. Hence, what is of paramount importance, is to teach students how to think for themselves; to learn how to rapidly scan lots of information in books and manuals to gather the gist and to know when to assemble a new tool from scratch to efficiently solve their current problem. In many of my engineering jobs, I was routinely simply handed a mountain of information in the form of poorly written manuals and hand written documentation and told to make something happen in a few days. Well, you just can't read all of the stuff in a few days, so you have to be good at sifting through the pile for the useful nugget. This also means you have to be good at taking the task you are given and breaking it down into smaller problems more amenable to attack and then use tools to develop more insight. This definitely involves what Resnick said above. You have to create new representations of the process you are using to solve the problems given to you and reflect on how you are thinking about your tasks. So how do we inculcate this kind of attitude in a class? I myself always try to get the students engaged intellectually by asking questions verbally, by applying the things we discuss to real problems and reiterating that it is important to carry a lot of material locally in your head. "Look", I'll say, "if you are working for a company and are at the water cooler or lunch when you get into conversations with your boss, the boss will appreciate your ability to think on your feet. If you always say you have to go look it up, your boss will slowly but surely learn to rely on others who can have an informed opinion using their skills on the fly." So the bottom line is that a student does need to master their coursework in such a way that they can draw on it in real life situations without access to a book or notes. They become leaders then and that is what we need. We also need students to be able to pull out of complicated situations and data, the bones of the underlying

ideas buried inside the mess. My own training has been very much in the physical sciences, but I'll mention a few examples to show how I was trained to abstract out of messiness underlying principles.

- ^ When I was in grade school in the sixties, we had to outline every chapter we read in our textbooks as our first assignment. We were being taught how to quickly find the main points of our reading. Oh, we complained, but since we all had to do it, it soon became second nature.
- ^ In grade school, we also had to write all of our homework in ink and we were not allowed to erase anything. So, if we made a mistake, we had to rewrite the whole page! This sounds horrible today, but it had a huge benefit for us. We very quickly learned to write well in our minds prior to committing to paper. It made a lot less work for us to organize first and write second. Also, not being allowed erasures made us learn real fast how to do it right the first time. I am sure these simple demands helped shape my ability to pick out main ideas, shape my arguments efficiently and so on. And it was just what is now considered an onerous exercise.
- ^ In calculus, we learn to integrate functions that are very simple at first. Then, we learn to use a technique called substitution which allows us to see how buried in a very complicated integral is a much simpler pattern we can find by using the substitution idea. The details of the mathematics are irrelevant. The point is by doing many of these sorts of problems, I was training myself to recognize underlying patterns buried in ostensibly complicated expressions. After awhile, any of us being taught this way, had a light bulb go on in our head. Forever after, we would always see the simpler pattern buried in the

complicated one. We could then take this newfound skill and use it when we looked at interactions of people, insects, gases etc. and start to see laws that governed interaction. Hence, a simple rote training exercise using a mathematical tool was actually a much bigger exercise in helping us to see how abstraction – the process of pulling patterns out of complexity – was useful.

As a final comment on how we are trained, consider that I learned to write themes on paper by hand in ink. I was not constrained to use short and simple sentences and constructions; the pristine white of the page was my playground. We have now transitioned to doing most of our creative writing on laptop screens. The geometry of the page we write on is very different now. It is easy to start thinking in terms of 24 line, 80 column text as it fits nicely on our display. But make no mistake, this limits us. We are now moving towards new writing and reading displays which are even smaller – Ipod screens and the like. This is having a profound effect on how we both create and process written information that we are seeing in our students. Also, note the rapid move to e-reader technology where the normal book size has been reformatted to 5×7 or smaller. This will inevitably push printed content delivery towards shorted sentences, simpler paragraphs and so forth. Also, note large complicated diagrams such as are common in technical text and mathematical equations are harder to deliver on the e-reader platform. This will also create a strong move towards the removal of such technical content. Now, of course, interdisciplinary work does require such technical material: messy and very dense blocks of information for the students to absorb. Our technologies are moving us away from this. There are similar things that crop up when you look at how a person learns to program. I learned to program in the late sixties and seventies before there were terminals, text editors and the like. I had to type my programs

onto cards and any mistake meant I had to type the whole card again. Needless to say, my early grade school training was helpful. Yes, it was annoying and I was happy to move on to better tools for writing my programs but I suspect my early training actually helped a lot. Of course, all of this stuff is lost now and I think that has a lot to do with why programming and other abstract endeavors are so hard for our students now. With that said, new techniques to help students with implementing problem solving strategies in programming are available. For example, there is a really good programming environment called Scratch (Lifelong Kindergarten Research Group, 2010) which enables young people pre college and even pre high school to learn how to assemble building blocks of code to solve problems.

Image how such kids trained in this fashion in their early years will develop! I believe we need to rethink our approaches to the freshman and sophomore courses at the university to stress the ideas mentioned above: learn literacy in problem solving, tool building not just tool using and the ability to skim lots of information quickly to get the basics assimilated. The problem with all of this is that the teacher's role is huge! All students are essentially unique and helping a student with their journey towards becoming their best requires a lot of effort tailored for each student. In Hecht (2004), a comment is made about how a particularly ineffective psychologist looks at their patient load:

"He was ... one of that breed of psychologists who looked for a tidy, encompassing theory that wrapped the human psyche into a neat diagnostic bundle. The trailing ends, the parts that didn't fit, were to be ignored or cut to size. It was the outlook of a man accustomed to dealing with human problems in quantity: to treating an unending flow of short-term patients, managing their acute stages and referring them on, but never having to dig in

for the long haul and the messy, irregular, and highly individual process of healing."

Of course, if you simply replace psychologist by teacher, it is clear this comment is equally relevant to my teaching and research profession. Many teachers want to automate their assignments with standardized testing, large class sizes so economies of scale can be brought to bear on resource allocation issues and evaluation procedures that minimize subjectivity. The problem is that in all of my years in teaching, there are always students who don't fit into any grading scheme I devise. My life is easier if they do, but it seems like my job is to help them find their path to greatness, if possible. The students have many problems of their own to work out and that will always be so; however, in the classes we teach we need to offer them tools to help with that process rather than hinder it.

Interdisciplinary Science

A good example of how many problems there are in trying to build better freshman and sophomore courses that address integration of material is to look at my attempts to increase the integration of biology, mathematics and computation in the training of new biological scientists. This has made me focus on the much deeper questions of how to train students to think in an interdisciplinary manner not only in the biological sciences but also as part of a new general educational curriculum. I think it is clear that to do this, we will have to foster a new mindset within both the students and the faculty related to interdisciplinary interaction. In addition, we will have to introduce new metrics for faculty evaluation and reward systems to ensure that the hard work and creative effort to build such a curriculum is acknowledged. This means also that new discussions of the tenure process are inevitable. The following discussion will add some meat to the bones of this tale. Let's focus on the interdisciplinary triad of ideas from Biology, Mathematics and Computational tools which for expositional convenience, I will denote by

the symbol **BMC**. The implementation of **BMC** will require the building of bridges between mathematical, computer and biological sciences departments. For convenience, let's call this integrative point of view Building Biological Bridges or **BBB**. The typical biological sciences major thus must have a deeper appreciation of the use of **BMC** as bridges are built between the many disparate areas of biology and the other sciences. The sharp disciplinary walls that have been built in academia hurt our students' chances at developing an active and questing mind that is able to both be suspicious of the status - quo and also have the tools to challenge it effectively. Indeed, I have longed believed that all research requires a rebellious mind. If a student reveres the expert opinion of others too much, they will always be afraid to forge a new path for themselves. So respect and disrespect are both part of the toolkit of our budding scientists. Blending many disciplines into one program, even when there are good reasons to do so, is very hard.

Astrobiology as Metaphor for Biomath

Consider the attempt to create a new Astrobiology program at the University of Washington. Even a cursory examination of the new textbook *Planets and Life: The Emerging Science of Astrobiology* (Sullivan and Baross, 2007) illustrates the wealth of knowledge such a field must integrate. This integration is held back by students who are not trained in both **BMC** and **BBB**. Let's paraphrase some of the important points made by the graduate students enrolled in this new program about interdisciplinary training and research. Consider what the graduate students in this new program have said (Sullivan and Baross, 2007):

"...some of the ignorance exposed by astrobiological questions reveals not the boundaries of scientific knowledge, but instead the boundaries of individual disciplines. Furthermore, collaboration by itself does not address this ignorance, but instead compounds it by encouraging

scientists to rely on each other's authority. Thus, anachronistic disciplinary borders are reinforced rather than overrun. In contrast astrobiology can motivate challenges to disciplinary isolation and the appeals to authority that such isolation fosters."

Indeed, studying problems that require points of view from many places is of great importance to our society and from (Sullivan and Baross, 2007), we hear that

"many different disciplines should now be applied to a class of questions perceived as broadly unified and that such an amalgamation justifies a new discipline (or even meta discipline) such as astrobiology."

Now simply replace the key word astrobiology by biomathematics or **BBB** and reread the sentence again. Aren't we trying to do just this when we design these new interactions? Since we believe we can bring additional illumination to problems we wish to solve in biological sciences by adding new ideas from mathematics and computer science to the mix, we are asking explicitly for such amalgamation and interdisciplinary training. We thus want to create a cadre of biomathematically literate majors who believe as the nascent astrobiology graduate students do (Sullivan and Baross, 2007) that

"Dissatisfaction with disciplinary approaches to fundamentally interdisciplinary questions also led many of us to major in more than one field. This is not to deny the importance of reductionist approaches or the advances stimulated by them. Rather, as undergraduates we wanted to integrate the results of reductionist science. Such synthesis is often poorly accommodated by disciplines that have evolved, especially in academia, to become insular, autonomous departments. Despite the importance of synthesis for many basic scientific questions, it is rarely attempted in research..."

To paraphrase Sullivan and Baross (2007), we believe that

"[**BBB** enriched by **BMC**] can change this by challenging the ignorance fostered by disciplinary structure while pursuing the creative ignorance underlying genuine inquiry. Because of its integrative questions, interdisciplinary nature, ..., [**BBB** enriched by **BMC**] emerges as an ideal vehicle for scientific education at the graduate, undergraduate and even high school levels. [It] permits treatment of traditionally disciplinary subjects as well as areas where those subjects converge (and, sometimes, fall apart!) At the same time, [it] is well suited to reveal the creative ignorance at scientific frontiers that drives discovery."

To address these needs and concerns, we are going to propose a plan of attack that would include a mathematical component in each of the four years of the typical undergraduate degree in biology. In the past, we attempted to do this with colleagues in the Department of Biological Sciences with a Quantitative Emphasis Area within the biological sciences department. We have labored to design this emphasis area as a linchpin for the interdisciplinary training of biomathematical majors. We believe, as do the astrobiology students, (Sullivan and Baross, 2007) that

"The ignorance motivating scientific inquiry will never wholly be separated from the ignorance hindering it. The disciplinary organization of scientific education encourages scientists to be experts on specialized subjects and silent on everything else. By creating scientists dependent of each other's specializations, this approach is self-reinforcing. A discipline of [**BBB** enriched by **BMC**] should attempt something more ambitious: it should instead encourage scientists to master for themselves what formerly they deferred to their peers."

Indeed, there is more that can be said (Sullivan and Baross, 2007)

"What [**BBB** enriched by **BMC**] can mean as a science and discipline is yet to be decided, for it must face the two-fold challenge of cross-disciplinary ignorance that disciplinary education itself enforces. First, ignorance cannot be skirted by deferral to experts, or by other implicit invocations of the disciplinary mold that [**BBB** enriched by **BMC**] should instead critique. Second, ignorance must actually be recognized. This is not trivial: how do you know what you do not know? Is it possible to understand a general principle without also understanding the assumptions and caveats underlying it? Knowledge superficially "understood" is self-affirming. For example, the meaning of the molecular tree of life may appear unproblematic to an astronomer who has learned that the branch lengths represent evolutionary distance, but will the astronomer even know to consider the hidden assumptions about rate constancy by which the tree is derived? Similarly, images from the surface of Mars showing evidence of running water are prevalent in the media, yet how often will a biologist be exposed to alternative explanations for these geologic forms, or to the significant evidence to the contrary? [There is a need] for a way to discriminate between science and ... uncritically accepted results of science."

A first attempt at developing a first year curriculum for the graduate program in astrobiology led to an integrative course in which specialists from various disciplines germane to the study of astrobiology gave lectures in their own areas of expertise and then left as another expert took over. This was disheartening to the students in the program. They said that (Sullivan and Baross, 2007)

"As a group, we realized that we could not speak the language of the many disciplines in astrobiology and that we lacked the basic information to consider their claims critically. Instead, this attempt at an integrative approach provided only a superficial introduction to the major contributions of each discipline to

astrobiology. How can critical science be built on a superficial foundation? Major gaps in our backgrounds still needed to be addressed. In addition, we realized it was necessary to direct ourselves toward a more specific goal. What types of scientific information did we most need? What levels of mastery should we aspire to? At the same time, catalyzed by our regular interactions in the class, we students realized that we learned the most (and enjoyed ourselves the most) in each other's interdisciplinary company. While each of us had major gaps in our basic knowledge, as a group we could begin to fill many of them."

Now we can place this comment into the biomath world by simply paraphrasing as follows:

"Students can not speak the language of the many disciplines **BBB** enriched by **BMC** requires and they lack the basic information to consider their claims critically. An attempt at an integrative approach that provided only a superficial introduction to the major contributions of each discipline cannot lead to the ability to do critical science. Still, major gaps in their backgrounds need to be addressed. What types of scientific information are most needed? What levels of mastery should they aspire to?"

In many ways, our focus on a quantitative emphasis is trying to address these concerns. However, it requires a lot of infrastructure and culture changes to make an impact. For example, simply writing lectures is a challenge. From the comments above, it is clear we must introduce and tie disparate threads of material together with care. I tend to favor theoretical approaches that attempt to put an overarching theory of everything together into a discipline because it offers insight into the basic building blocks hidden inside complexity. So I pay a lot of attention to books that approach various aspects of biology theoretically in order to enrich a biomathematically interdisciplinary approach. Reading these books gives me insight

into the design of biologically inspired algorithms and models that, in later presentation, I use frequently when I design undergraduate lecture and research experiences. A selection of these books includes theoretical systems biology (Alon, 2006); theoretical genomics (Davidson, 2001), (Davidson, 2006) and (Lynch, 2007); theoretical Neuroscience (Kaas and Bullock, 2007), (Kaas and Bullock, 2007), (Kaas and Krubitzer, 2007) and (Kaas and Preuss, 2007); models of the thalamus (Sherman and Guillery, 2006); and theories of organ development (Schmidt-Rhaesa, 2007) and (Davies, 2005). All have helped me to see the big picture and have helped motivate our design of interdisciplinary training techniques. However, it is not clear other mathematicians would be willing to invest this much time into the development of the lecture material. Of course, in order for a new approach to take off, more than one person such as myself must become engaged fully. We will have more to say on that issue later. For now, let's end this section with a nice quote from the astrobiology community (Sullivan and Baross, 2007)

"Too often, the scientific community and academia facilely redress ignorance by appealing to the testimony of experts. This does not resolve ignorance. It fosters it."

This closing comment sums it up nicely. We want to give the students and ourselves an atmosphere that fosters solutions and the challenge is to find a way to do this. The interdisciplinary training needed to foster thus requires all of us to be aware of these underlying philosophical changes that must be made.

The Quantitative Emphasis Area

Between 2006 and the Spring of 2013, my colleagues and I developed a plan to enable an integration between biology, mathematics and computational tools for placement within a typical existing department of biological sciences. It is well known, that in a traditional biology college department 80% to 90% of the

tenured faculty have little interest in the use of BMC in their own course development and teaching. Hence, there are great challenges in implementing this plan that revolve around both faculty retraining and student training issues. In this traditional college department, we see incoming majors who have an uneven training in mathematics and computer science and who may even be biased against mathematics and computer science as part of the discipline of biology. Until the Fall of 2013, there was an existing mathematics requirement of two semesters of engineering based calculus and a one semester course in statistics. There was no computational requirement. The typical engineering calculus sequence did not serve the interests of biological sciences well and so in 2006, we designed a new second semester calculus course just for biologists. We assumed the students did take the traditional first semester engineering calculus and the new course built on that foundation.

Now in the remarks that follow, we will be very detailed in our descriptions of what we did in order to develop these courses. Hence, there is a fair bit of mathematical detail, but if that is not one's cup of tea, just try to get the overall flow. Note how complicated it is to merge as seamlessly as possible, mathematical and computational ideas into a traditional biology department's curriculum. We start at the freshman level and try to encourage existing faculty and students into a newfound appreciation of the **BMC** triad. This then permits integration of these ideas from the freshman to sophomore year and prepares students for quantitative biology in the junior and senior years. As mentioned earlier, our basic plan was to keep the existing First Semester Calculus Course for engineers as a mathematical baseline since different universities use different course numbers, call this course **Math-OneEngineering** for convenience. However, we replaced the existing Second Semester Calculus Course, called here **Math-Two-Engineering**, with a new

course specifically designed for Biology majors called **Math-Two-Biology**. We also added model-based points of view to the first year fundamental biology sequence that we call **Biology-One** and **Biology-Two**. In these introductory biology courses, the students write three papers per semester. Four of these six papers have a required statistical analysis to determine the significance of the difference between two treatments. At the moment, this is confined to the χ -square median test but other statistical tests using Excel spreadsheets are planned. In addition, there are two labs on bioinformatics. One is a general overview that shows the students a lot of different tools, and the second one specifically asks them to use bioinformatics tools to look at the evolution of humans through mitochondrial DNA sequences. Next, using Stella (ISEE Systems, 2009), students build models of an equilibrium chemical reaction and human weight regulation. In each of these examples, more complex Stella models are then used to explore more sophisticated questions. There are also several embedded modules that go beyond the traditional lectures to expose the students to beginning research concepts. These include

- ⤴ the use of the Hardy-Weinberg equation to predict equilibrium genotypic frequencies;
- ⤴ a population genetics simulation used to study the effects of selection and genetic drift on allelic frequencies;
- ⤴ an elementary treatment of exponential and logistic population growth models;
- ⤴ simulation of complex populations with different age classes;
- ⤴ a large unit on cladistics in both lecture and lab.

So in general, despite the fact that in most topics the use of mathematics is minimized, the course is quantitative in philosophy.

The **Math-Two-Biology** course uses discovery-based learning and introduces biomathematical

research based topics that are appropriate to the level of these beginning students. It was run as a special section of Math-Two-Engineering (at Clemson University MTHSC 108) labeled MTHSC 108-B and enrollments climbed steadily. Until the Fall of 2013, we taught approximately 100 students per year in this course. Between 2006 and 2013, we therefore taught about 700 - 800 students. This experimental course was formally approved (Fall 2009) as the new course MTHSC 111. We have developed this course using the following point of view. We feel to serve the needs of the BMC point of view, mathematics is subordinate to the biology: the course therefore builds mathematical knowledge needed to study interesting nonlinear biological models quite carefully. We emphasize that more interesting biology requires more difficult mathematics and concomitant intellectual resources. We choose a few nonlinear models and discuss them very thoroughly; e.g., logistics, Predator - Prey and disease models. Since graphical interfaces lose value with more variables, at the end of the course, we explore how to obtain insight from a six variable linear Cancer model. We always stress how we must abstract out of biological complexity the variables necessary to build models and how we can be wrong. We also focus on how to solve problems that have many steps (so that in the modeling portions, typical assignments can have 3 - 4 pages turned in per problem). We believe strongly that this is a first step towards training them to see the larger picture for long-term projects. We therefore are preparing them for extended research experiences. We are successful at developing very sophisticated mathematical ideas in these students. We achieve this by organizing our topics in the following way. From the standard Math-Two-Engineering (here MTHSC 108), we choose as topics simple substitution, the Fundamental Theorem of Calculus (FTC), the Logarithm and Exponential Function developed using the FTC, integration by parts and partial fraction decomposition methods and the ideas of approximating functions by tangent lines and

the error that is made. Since we use these mathematical tools right away in logistic models, the students always see a correlation between the mathematics we choose to cover and its usefulness in our model building. We need concepts from linear algebra (here MTHSC 311, a sophomore or junior level course) as well. So we cover vectors and matrices, linear systems of equations, determinants and what they mean and eigenvalues and eigenvectors for 2×2 matrices. This prepares them to study more differential equations. From a traditional sophomore level differential course (here MTHSC 208), we can then cover simple Rate Equations and their applications, the idea of an integrating factor, building a Newton's Cooling model from data, the logistics model complex numbers and simple complex functions and second order linear homogeneous equations. Our discussion of the second order linear differential equations covers all three cases: distinct roots, repeated roots and complex roots. In addition to these ideas, we have also been showing them the use of computational tools a little at a time. We have chosen MatLab, but other interpreted tools are of course possible to use instead. Hence, we discuss approximations with tangent lines, Euler's method and MatLab implementations concurrently with these topics. We also introduce the ideas of Runge - Kutta methods as a more sophisticated numerical approximation tool. We finish our discussions of linear models with linear systems of differential equations, although we restrict our attention to the distinct real root case. At this point, we also move toward qualitative graphical means of understanding the solutions we are finding. This is all done by hand to let them grow insight. We then segue into nonlinear differential equations. Little of this material is covered in a traditional differential equation course. We thoroughly discuss the Predator - Prey model without and with self-interaction, a simple SIR disease model and a cancer model at the end of the course. We stress heavily that models can have explanatory

power but need not unless there is a careful interaction between the science, the mathematics and the computational tools. We note graphical analysis and numerical methods are not always useful and determining the validity of the model is the most important thing. We help them to realize that interesting problems are inherently difficult; realistic biology requires nonlinearity, which implies more sophisticated mathematical and numerical tools must be brought to bear. In our implementation of this course, we therefore interweave the calculus, differential equations, MatLab and numerical methods, linear algebra and modeling material in non-traditional ways. Roughly speaking mathematics is introduced as needed for the modeling, although not at all in a just in time paradigm. We believe firmly that these difficult tools need to be carefully brought out over time, not quickly. The first part of the course introduces specific mathematical material as they are not quite ready for models. Hence, they find this more challenging and great care must be taken to keep them motivated. However, daily homework with lots of algebra and manipulation helps as well as daily mention of where we will be going with this material. We follow the general principle that doing 1 or 2 problems encourages mimicry,

while doing 6 of each type builds mastery. Graders help with the daily busywork. The ideas discussed above have been used to develop a textbook that has evolved from handwritten notes in Spring 2006 to a full textbook (Peterson, 2012).

We also have a discovery learning project in MTHSC 111 based currently on Newton's Cooling model. Each student chooses a liquid and brings it to a boil. Its temperature is then measured as carefully as possible and this data is used to build a mathematical model. This module is a first example of how many disparate tools from science, mathematics and computer science are brought to bear to solve a real problem. They are also asked whether or not their model explains the data they measured so that they see that the efficacy of a model must be grounded in its real world explanatory capability. The follow-up course, MTHSC 390 (taught as MTHSC 450 in a special section), has been fully developed and has its own textbook (Peterson, 2012). It has been taught to select students for the last six years. For concreteness, we show a typical MTHSC 111 syllabus in Table 1 and a version of the MTHSC 390 syllabus in Table 2.

Units	Topic
1	Riemann Sums, Fund. Theorem
1	Fundamental Theorem, continued
2	Defining ln and e
2	Basic Rate Differential Equations
2	Gene Transcription Rates
1	Partial Fraction Decomposition
2	Integration By Parts
2	The Logistic Type Model
1	Discussion Of Cooling Model Project
2	Euler's Method

1	MatLab for First Order ODE
1	Complex Numbers
4	Order 2 Linear ODE
6	Linear Systems
2	Solution Linear System
3	Phase plane analysis
9	Predator – Prey
3	Predator – Prey Self Interaction
3	Epidemiological Model
4	Cancer Model

Table 1: MTHSC 111 Syllabus

Units	Topic
2	Multivariate Functions
2	Partial Derivatives
2	Complex Eigenvectors
4	Jacobians; Linearizations
3	Ion Movement Through Membranes
3	The GHK and Cable Model
2	The transient cable model
2	Ideal impulse solutions
5	Boundary Value Problems
4	MatLab Solutions
2	Finite Length Cables
4	Hodgkin–Huxley Models
2	Excitable neuron simulation
2	Cognitive models

Table 2: MTHSC 390 Syllabus

A Quantitative Emphasis Approach

We began the process of enhancing interdisciplinary training by adding mathematical and computational modules in a variety of ways to the freshman and sophomore years. As we have

discussed above, we achieve this by adding then to the courses MTHSC 111, BIOL 110 and BIOL 111. We think of this as a precursor to a new reasoned approach to making these ideas a core part of the entire biological sciences curriculum. As a starting point, consider the details of a typical Quantitative Emphasis Area approach, as seen in Table 3 and Table 4.

Year	Course	Description
I(F)	BIOL 110 (5)	Biology I
	BIOSC 101 (1)	Frontiers in Bio I
	CH 101 (4)	Chemistry I
	COMM 150 (3)	Communication
	MTHSC 106 (4)	Calc I (Eng)
	Total 17	
I (S)	BIOL 111 (5)	Biology II
	BIOSC 102 (1)	Frontiers in Bio II
	CH 102 (4)	Chemistry II
	ENGL 103 (3)	Composition
	MTHSC 111 (4)	Calc For Biology
	Total 17	
II (F)	CH 223, 227 (4)	Organic Chemistry
	MTHSC 390 (3)	More Calc For Biology
	BIOSC 302, 303 (4)	Animal Diversity
	BIOCH 301, 302 (4)	Biochemistry
	Total 15	
II (S)	BIOSC 443, 444 (5)	Ecology and Lab
	EX ST 301 (3)	Statistics I
	BIOSC 304, 308 (4)	Plant Diversity
	GEN 300, 301 (4)	Genetics
	Total 16	

Table 3: A Typical Quantitative Emphasis B.S. Freshman and Sophomore Year. F and S denote the Fall and Spring semester, respectively. The number in parenthesis behind the course is the number of credit hours.

The table shows the basic format; as always, there are caveats and substitutions, but there are not essential for our arguments. There are several important points to make here. Note that essential ideas of Physics, say force and energy, which are so necessary to many of the threads that run through

quantitative biology ideas are not discussed formally until the junior year. Also, note the calculus in biology course, MTHSC 111, coupled with the usual first semester engineering calculus course, gives students a full year of mathematical training during their freshman year. Then in the sophomore year, there is a more advanced mathematical modeling course based on a partial differential equation point of view and the first semester of statistics. However, formal mathematical training, per se, stops at that point. Also, there is no formal computer science course work that teaches some choice of programming language. Hence, to develop the triad of mathematical, biological and computational science absolutely requires large amounts of teacher based instructional materials and pedagogical development to bridge the gap. The junior year is quite crowded with necessary start up biology course work. Currently, the real freedom in the schedule is in the senior year with 12 credit hours of advanced biology course to be chosen.

Year	Course	Description
III (F)	BIOSC 335 (3)	Evol. Bio.
	ENGL 315 (3)	Science Writing
	EX ST 311 (3)	Statistics II
	PHYS 122, 124 (4)	Physics I and Lab.
	BIOSC 401, 402 (4)	Physiology
	Total 17	
III (S)	BIOSC 428 (4)	Quant. Bio.
	BIOSC 461, 462 (5)	Cell Bio. and Lab
	PHYS 221, 223 (4)	Physics II and Lab.
	Social Science (3)	
	Total 16	
IV (F)	BIOSC 493 (2)	Senior Seminar
	GEN 440 (3)	Bioinformatics
	Arts and Humanities (3)	Literature
	BIOSC 3xx-4xx (7)	More > 300 Bio.
	Total 15	
IV (S)	BIOSC 491 (1)	Under. Research
	Arts and Humanities (3)	Not Lit.
	BIO 3xx-4xx (5)	More > 300 Bio.
	Social Science (3)	
	Total 12	

Table 4: A Typical Quantitative Emphasis B.S. Junior and Senior Year. F and S denote the Fall and Spring semester, respectively. The number in parenthesis behind the course is the number of credit hours.

In the junior year, BIOSC 428, Quantitative Biology, continues to expose students to critical BMC concepts. It applies quantitative methods to a wide range of biological problems. The main focus is on building modeling skills using population, physiological, genetic, and evolutionary problems. It also includes a review of statistical principles, and introduces basic bioinformatics techniques. A typical syllabus is shown in Table 5. BIOSC 428 is a 3 credit lecture and 1 credit lab course. To fully energize and engage current biology and mathematical majors in beginning research experiences and to potentially recruit new students it is important to develop a wide range of undergraduate research experience modules. These can be deployed in a classroom lecture or a laboratory setting. The development of such textual material is a highly nontrivial task and requires a substantial investment of faculty time. To make these new initiatives self-sustaining, it is important for these ideas to become firmly entrenched within both the Department of Mathematical Sciences and the Department of Biological Sciences.

Units	Topic
1	Mathematical models
2	Excel, Stella, and MatLab
5	exponential, logistic growth
2	Population growth – Leslie matrices
2	Optimal life history strategy
1	Optimal diet (linear programming)
2	Compartmental models (epidemics)
4	Predator–prey Models
2	Competitive interactions
3	Biochemical mathematics
3	Cell biology, development models
6	Physiological, biomechanical mathematics
2	Mathematics of genetics
3	Evolutionary mathematics
3	Statistical principles
2	Bioinformatics tools

Table 5: The MTHSC 428 Syllabus

This is both a retraining issue and an interest issue. The courses MTHSC 111, MTHSC 390, BIOL 110 and BIOL 111 and BIOSC 428 are not taught in a standard manner and require much from the instructor. To teach MTHSC 111 effectively requires that the instructor both respects and loves both mathematics and biology. Since this is not true in general of any department's teaching staff, this is a significant faculty and instructor training issue. Indeed, training and mentoring must be a fundamental design component as it impacts departmental resource usage. Now, since projects teach a lot of interdisciplinary science (each of the above spills out into many areas) and require mathematical and computational tools to gain insight and illumination, we have worked hard to find a working philosophy towards their development.

- ⤴ All parts of the modules must be integrated, so we do not want to mathematics, science or computer approaches for their own intrinsic value. Experts in these separate fields must work hard to avoid this. This is the time to be generalists and always look for connective approaches.
- ⤴ Models must be carefully chosen to illustrate the basic idea that we know far too much detail about virtually any biologically based system we can think of. Hence, we must learn to throw away information in the search of the appropriate abstraction. The resulting ideas can then be phrased in terms of mathematics and simulated or solved with computer-based tools. However, the results are not useful, and must be discarded and the model changed, if the predictions and illuminating insights we gain from the model are incorrect. We must always remember that throwing away information allows for the

possibility of mistakes. This is a hard lesson to learn, but important.

- ⤴ Models from population biology, genetics, cognitive dysfunction, regulatory gene circuits and many others are good examples to work with. All require massive amounts of abstraction and data pruning to get anywhere, but the illumination payoffs are potentially quite large. In all of these examples, we must address fundamental principles for model construction, parameterization, and validation. However, our enthusiasm for these projects must be tempered by the understanding that these are students who are beginners at modeling tasks.

Consider the process by which a given mathematical and biological model is converted into an embedded module for deployment into BIOL 110, BIOL 111, MTHSC 111 and MTHSC 390. This basic flowchart is also applicable to such development in BIOSC 428 although that is specifically a junior level course.

Protein Synthesis: To develop this module, we must ask several important questions: what science, mathematical and computational background do the students have? In the case of a protein production model, at the freshman level we must discuss basic facts about how a gene is converted into an amino acid chain via the standard mRNA → tRNA → protein sequence. Since the students come into the courses with varying backgrounds, this is not a trivial exercise. Next, we must decide how much mathematical background can be assumed and how much must be explained. In the context of BIOL 110, prior to MTHSC 111 exposure, such mathematical training may be minimal and so the textual material that accompanies this set of lectures

must include preliminary mathematical concepts. In MTHSC 111, we can assume the students have seen first order linear models and the tools for their solution prior to the protein model discussion. Either way, there is a significant amount of planning that must be done.

Kinetic Proofreading: In this module, we must decide how much the student knows about a simple model of the ribosome factory. Then, two different models are presented. The first uses equilibrium analysis to find that the error rate is $1/100$, a hundred times too large. The tools needed here are algebra and a knowledge of what equilibrium means but knowing how to solve first order linear differential equations is not necessary. However, there are sophisticated biological concepts and we must carefully discuss why we approximate the messiness of the real biology as we do with the model. To introduce the concept of kinetic proofreading we must alter the ribosome production model to add intermediate molecular states to the tRNA + Amino Acid complexes previously used. This new complication allows us to determine the error rate is actually $1/10,000$, which aligns nicely with experimental evidence.

We can do a similar analysis for any sort of module we plan on using. We must determine

- ⤴ What is the appropriate biology level? Do we need to write explanatory material to supplement our lecture?
- ⤴ What is the appropriate mathematical level? Again, do we need to develop textual materials to supplement our lecture?
- ⤴ What is the appropriate computational tool level? Do we

write our own simulations in MatLab, Stella or something else? Do we need to write explanations of the use of MatLab, Stella and so forth for use within the lecture or the lab?

In our experience so far, it takes a minimum of 4 - 6 weeks of hard work to develop this material even in preliminary draft form. It then needs to be deployed within a classroom situation to make sure it works in that context. A typical module is then covered within a 2 - 3 lectures or perhaps in a laboratory setting. In MTHSC 111, the protein synthesis module is covered in 2 and $1/2$ lectures.

Changes in the Mathematics Requirements and What It Means

As we have discussed, since 2006 or so, we have been teaching a replacement for second semester calculus specifically designed for the biology majors. There has been a lot to learn about the biology department and teaching such an interdisciplinary course that we have tried to do over the last 7 years or so. In the Spring of 2013, the biology department voted to change the mathematics requirement from two semesters of calculus to just one. They retained the original one course in statistics but still do not require a computational course. Once this happened, the work to develop a quantitative emphasis area had to be restructured. Between Spring 2013 and the start of the Fall 2013 semester, a new version of first semester engineering calculus was designed for biologists and deployed as a special section of MTHSC 106 just as had been done when we began a special version of calculus two for engineers for biologists. Hence, in Fall 2013, the enrollment of MTHSC 111 drop sharply (50 to 10) and we started with 60 students in MTHSC 106-Bio spread over two sections. The biology department made this choice to

give biology majors more flexibility in their choices. We suspect from conversations with the biology faculty that this was to ensure that students had enough free hours to sign up for lab research experiences. As you can see the biology department is in a difficult position: there is a vast amount of traditional material they want everyone to know and not enough hours to fit it into. And in addition, they want research experience. In mathematics, over the last thirty years, we pruned the traditional mathematics course list by removing topology, differential geometry, advanced ode and so forth. The department offset this by adding statistics, OR and computation so that our majors are quite rounded. And of course, their strict mathematics training is not as vast as in the past but the trade off has been worth it to most of us. We don't think the biology department has done this and so there is very little room for the extra courses in mathematics and computation and so forth that many biological experts are asking for. The new change then means that biology majors need one math course and one statistics course. Of the 400 new majors each fall, some will get AP credit for both and may never have another mathematics and computation course in their Clemson career. With the biology schedule so demanding, the only realistic chance at introducing this material is in their one required calculus course. Now, we certainly can simply have all biology majors just take traditional MTHSC 106 engineering based calculus, but they will not be exposed to other ideas such as simple ODE models which they should see. It is very difficult for a biology major to take as electives MTHSC 108, MTHSC 206, MTHSC 311 and MTHSC 208 as they simply don't have the room to do so. So I think it is very important to give them more in their version of MTHSC 106. To understand the difficulties

one has in teaching this material, there are a few things that should be mentioned.

- ⤴ The biology majors have a schedule that is filled completely. Starting their sophomore year, they have one to two lab courses per semester which are 5 - 6 credit hours and meet in three hour time chunks. The required course lists give them very little free time for mathematical or computational electives. And even if a student wants to do so, the time conflicts with the lab courses are severe.
- ⤴ If a biology student wants to go on the graduate school at Clemson, they need to get involved with some biology faculty member's research as early as their junior year. This involvement takes about additional credit hours and so makes it even more difficult for the student to take mathematical and computational course.
- ⤴ When a student wants to go into graduate work in the biology department at Clemson, to be admitted they are assessed as to where they will fit into the research of the department. If they have had prior research experience in a lab similar to a lab here, they will be placed with that research adviser from the moment they arrive at Clemson for their graduate work. In the mathematics department, students have about two semesters to take courses before they choose an adviser that fits their interests. That is not the way it works in biology. The adviser is chosen for the student by a small committee. I think that students applying from outside Clemson therefore have to have in their undergraduate transcript strong

evidence of undergraduate lab experience to get in and be assigned an adviser. Hence, a biology student who wants to get into graduate work has to essentially choose the research direction for their graduate work sometime in the junior and senior year. So there is a large amount of pressure on students with graduate work interest to sign up for these sorts of lab experiences. The only way a student can hedge their bets is to sign up for multiple lab experiences but that of course takes even more credit hours.

- ▲ The only time that a biology student can easily add mathematical and computational training is in their Freshman year via a required course. When MTHSC 111 – the second semester calculus for biologists course – was required by some majors in biology, we saw about 100 students per year which is about 25% of the new biology major students per year. Note the biology department is huge with 1600 majors of many types. Although we have developed other interdisciplinary mathematics, computation and biology courses aimed at the sophomore to senior level, we have never been able to offer them to more than 1 - 3 students a semester as an overload. And to take them, my interested students had to overload at 21 hours or so.
- ▲ The last thing about the biology majors that is a common theme is that many of them are truly terrified of mathematics and computers. They can even be very good at mathematics, but the terror is still there. We also often have freshman with great SATs etc who come into the calculus for biologist class and

don't know how to use word to write a report. They figure it out soon enough but it is interesting that the transcript does not show this. So one of our tasks is to find non-threatening ways to get the students to embrace the mathematics, the computer work and learn how to integrate it with the science.

The New First Semester Calculus Class for Biologists

In this course, we want the students to learn how to use mathematics and what is called computation to help them understand how to study biological sciences. The problem, of course, is the mathematics and computer science part seem to overwhelm all of them and keep them from seeing how helpful it is to allow those extra points of view. Now Physics is a big field that has been traditionally very mathematical and physics students have similar complaints about losing sight of their science by being narrowly focused on the quantitative underpinnings. In this course, we try hard to avoid that trap, but make no mistake. We expect the students are all willing to go on the journey eagerly and work hard to achieve the goals we set out. Of course, freshman students are dealing with many things and so not all will want to work this hard! Nevertheless, we can have set simple goals.

- ▲ Learn enough Calculus to allow them to think clearly about biological models. This means they have to learn about how to use functions to model the data they find in their experiments. This is the area of study we call Biological Modeling. Then they have to make assumptions about how the things in their data that varies depend on each other. We typically call these things

variables. For this course, we will limit ourselves to two variables most of the time, but towards the end we look at relationships between more than two things. But remember, we are the ones who look at the data we measure and make this call. Our intellect makes the decisions on how our variables depend on one other. Usually how variables change over time is important to us and that leads us to think about that idea more abstractly. This leads to the idea of the derivative of a function. This idea is a nice abstraction of stuff we do all the time in our physical world. We notice how things change! In fact, we tend to not notice things that stay the same. Think about the shirt or blouse you are wearing. When you first put it on, you might notice how it feels on your skin, but our sensory subsystems for skin pressure and so forth quickly stop paying attention. Instead, it is change in pressure we notice. So we need ways to model such changes and that is the idea of a derivative. If we were looking at data on how an animal was eating over a period of weeks, we might want to add up how the animal has eaten over that time period. It is pretty easy to see that if we added up the food intake each day that would in general give an answer a bit different from what we would get if we measured food intake every twelve hours and then added. And what about measurements taken each hour and added? Or measurements taken each minute and added? This progression of additions over different time scales leads naturally to a new idea: that of the integration of a function. Of course, these three concepts:

function, differentiation and integration have lots of nuance the students have to work through. But these are all tools they can use to help us model the data we measure. We intertwine these modeling ideas with the learning of basic Calculus ideas so that the students always see why they are learning these new things. We also introduce computational ideas early using MatLab so that the students can get comfortable right away with tools that can help them in cases where they just can't solve the equations by hand. We typically use a mixture of computer work and mathematics to gain insight. This is a very profitable way of gaining insight and we hope to train the students so well in this that they carry it forward to other work they do in the future.

- ✧ Once we have basic calculus ideas down, we can start modeling biology in earnest. We typically do this in the beginning with what are called differential equations which are just equations where some of the variables involve derivatives. We can model protein synthesis in various ways with these ideas quite nicely. We can also use our tools to model large-scale ideas such as domestication rates in wild wheat and barley. And many others, of course. We will learn enough in this course to get you started and you will find you can build models of your own soon enough using what you learn in this one semester course.
- ✧ We also want to be able to build models of biologically relevant stuff even if we can't solve them with our calculus tools. This leads us to use computational techniques. In this

course, we will be using MatLab throughout and we show how to use it to help solve problems that are way too hard to solve by hand techniques. Using MatLab we can run what are called simulations to solve the differential equation models and help us understand how the variables we choose to focus on interact over appropriate time scales even when we can't solve the models using pencil and paper.

- △ Finally, we allow our focus to broaden to look at more than two variables of interest. This will lead us to look at what is called partial derivatives, which are really quite simple. We just take the usual derivative thinking of one variable at a time as being allowed to change. We will find the mechanics of this is very simple and we will do just enough theoretical stuff to help the students understand what they are really doing. Having more than two variables will allow them to look at their biological data in more sophisticated ways. We can only scratch the surface of this here, but students can take more courses and learn more. And we encourage them to do so! Biology, Mathematics and Computation are merging more and more and studying all three areas is a wise thing to do for their future.

Our Design Philosophy

As discussed earlier, our philosophy is that all parts of the course must be integrated, so we don't want to use mathematics, science or computer approaches for their own intrinsic value. We want to be generalists and always look for connective approaches. Also, models should be carefully chosen to illustrate the basic idea that we know far too much detail about virtually any biologically

based system we can think of. Hence, we must learn to throw away information in the search of the appropriate abstraction. The resulting ideas can then be phrased in terms of mathematics and simulated or solved with computer-based tools. However, the results are not useful, and must be discarded and the model changed, if the predictions and illuminating insights we gain from the model are incorrect. We must always remember that throwing away information allows for the possibility of mistakes. This is a hard lesson to learn, but important. Now many of us are trying to build an interface between biology, mathematics and computation. There is a recent article which discusses the issues involved and we encourage you to read it ("Interfacing Mathematics and Biology: A Discussion on Training, Research, Collaboration, and Funding" by Laura Miller and Silas Alben published in *Integrative and Comparative Biology* in 2012) (see Miller and Alben, 2012). The paper discusses what happened at a workshop on this interface, which was held at the 2012 annual meeting of the Society for Integrative and Comparative Biology. The broad goal of much of this recent activity has been to promote new collaborations between biologists, physical scientists, and mathematicians, to inspire the next generation of biology students to use quantitative approaches and to use applications in the life sciences to fuel the development of new mathematical and numerical techniques. The common challenges that have emerged from these discussions center on the best practices for training students and the need to develop mechanisms that foster multidisciplinary collaborations.

Ideally, students would take the required first semester Starting Calculus for Biologists as we teach it in this course and follow it up with the second semester Calculus for Biologists. Here these are the

course MTHSC 106 -Bio and MTHSC 111. The second course is not required but if students take it they will have a reasonably broad training in how to use mathematics and computation to help them in biology all the way through multiple variable differential equation models and enough parts of advanced mathematical training to serve them well. We would then recommend you take another course on more multivariable techniques for building models which is our More Calculus for Biologists: Partial Differential Equation Models (Peterson, 2012). The latter two courses we have taught almost every semester for about five years to small numbers of students but we always hope for more interest! The point is to for the students take the tools we are teaching and use them in their own work. Unfortunately, there are not enough of traditional biology teachers using these tools. However, that does not mean their use isn't the future. It just means it is always hard to integrate interdisciplinary material into traditional courses. The biology teachers are probably as afraid of mathematics and computation as the students are so it is only natural that it is hard to get the ball rolling. But we think it is very important to try to get this off the ground as future work in biological sciences is clearly tied to increased use of mathematics and computation. A standard criticism of being more interdisciplinary in approach is that if we teach students that way, they lose depth. So the challenges here are deep and require focus and work from professionals in all areas. As the paper says

"[t]o address these challenges, a variety of educational initiatives, funding programs, and institutes focused on mathematics and biology have been established over the past decade....An important theme in the discussion was the training and mentoring of researchers at the interface of

mathematics, engineering and biology. The panel discussed the ideal timing of a switch from a more traditional disciplinary education to a more interdisciplinary education – at the undergraduate level, the graduate level, or beyond? There was a general concern expressed about interdisciplinary students gaining breadth at the expense of depth. Less depth in a traditional field can be a significant disadvantage when applying to, and completing the requirements for a graduate degree in a particular field. However, faculty pursuing interdisciplinary research are more likely to admit students who have shown an interest in previous interdisciplinary work. Ultimately, success in coursework and research is strongly enhanced by following one's intellectual interests. Pursuing research that overlaps with the priority research areas of faculty and funding opportunities is one of the practical realities of training students".

Clearly, we are still working out how to do this. For example, one of my former students who is just now graduating was interested in interdisciplinary work and ended up doing a dual major in biochemistry and biology. He took all of our biological mathematics courses and did additional work with us on modeling brain networks and programming. He had to work very hard at finding the right graduate school. Most graduate schools are still not so keen on interdisciplinary work. He found that he had to be upfront about his need to wear multiple hats and not be typecast into one area or another. He found three likely candidates and is going to start in the Fall at the University of Washington in their NIH funded training program for medical researchers. He will be able to direct how his research focuses with a team's backing, which is what he wanted. To finish with this student's story, here is an example of how

the mathematics, computation and biology worked together for him. At one point in his senior research, he needed primers to bind to the DNA he was working on. It was hard to find and order the right ones as the organism he was working on was just in the process of having its genome annotated. He contacted the group doing that research and they shared the program they were using with him. He was able to modify the code of that program which was written in MatLab to search for the primers he needed. So these tools we are going to be talking about are useful! The training we are trying to do here is also being done at other places. Indeed, as the paper says

"At the undergraduate level, colleges and universities are offering increasing numbers of courses and degree programs that cross the interface of mathematics and biology. The panelists and workshop attendees generally agreed that these courses were excellent mechanisms to pique student interest in interdisciplinary work and that undergraduate education often allows students the flexibility for students to develop a solid background in more than one field. One of the most common courses being developed is BioCalculus (i.e., Calculus for Life Scientists). This course typically focuses on covering standard calculus material using applications to biology. More and more colleges and universities are also offering upper level courses such as Quantitative Biology (from the biology side) or Mathematical Biology (from the mathematics side)".

So the type of course we are offering here is not just unique to Clemson. It is a more general phenomenon. However, there is much more work to be done. One of the biggest problems is that the mathematics teachers usually do not have biological training and the biology teachers lack the

mathematical training so it is hard for most teachers to be comfortable in using ideas and tools outside of their discipline. Here, as the paper says

"[t]he panel and workshop group generally agreed that more curriculum development is needed at the interface of mathematics and biology. Parallels can be drawn to some degree between physics and mathematics. These fields have a long history of intersecting research and education. Physics majors take a significant number of mathematics courses, and substantial mathematics is included in many physics courses. Applied mathematics courses often are motivated by examples from physics. A limitation in mathematical training is due to the fact that while students may take a course in mathematical or quantitative biology, these ideas are not reinforced in other courses. If a freshman takes a course in BioCalculus, for example, but does not see many applications of mathematics in the courses that follow, this training likely will not be retained. A consensus was reached during the discussion that publicly available lesson plans that easily could be incorporated into standard classes by non experts have the potential to greatly enhance training at the interface. Repositories of biological examples in mathematics should be available for mathematicians with little or no biology training. There is a similar need for straightforward applications of mathematics and computation to standard material in the biological sciences".

Then, they note

"One approach to this problem is to design courses that generally address how to develop mathematical models in biology. The construction of original mathematical models for new biological problems can be both tractable and

challenging to many students at all levels".

and this is one of our guiding principles!

Insights From Other Fields

A very mathematical part of Physics is called Quantum Field Theory or just QFT for short. It is very hard to train new physicists in this area as it requires hard and difficult mathematics to work through the problems. However, it is easy for the teachers and masters of this area to get lost in the beauty and wonder of the mathematical manipulations and forget that all the models come from physics. Just to give you a feeling for this, we thought you should see some reviews of the new textbook *Quantum Field Theory in a Nutshell: Second Edition* by A. Zee published by Princeton University Press in 2013. These reviews can be found on the Amazon web page you see when you look at Zee's book. Zee's book is well received because it places the Physics first and the mathematical detail in a subservient position. As the first review says

Review by M. Haque: One problem with learning QFT is that it is so easy to get lost in the mathematical details that the core physics concepts often get obscured. In my opinion, Tony Zee overcomes this particular problem quite successfully. He keeps algebra to a bare minimum, and tries to find the shortest route to the physics ideas. He chooses examples that illustrate concepts in the fastest possible way. Wholeheartedly recommended.

This is why we are trying hard to illustrate how to use the mathematics and computation in biology with carefully chosen examples and models. They give insight! Now Zee does have one advantage we don't have. By the time students get to

QFT, they have had years of mathematical training so Zee can assume a lot of basic expertise. Of course, we don't have that but the basic principles are the same. Focus on the science and let the mathematics and computation serve that. The next review states how Zee's emphasis on ideas is really helpful.

Review by Alexander Scott: From my experiences in quantum field theory: [there are different types of books on QFT:] The kind that you can read, the kind that work out examples, and the kind that your professors want you to understand. The last are [texts] that dummies like me in a QFT class will never be able to use ("dummies in a QFT class" may sound like an oxymoron, but we're not all geniuses...). The kind of texts that works out examples ... have been invaluable to me, but I still have not always been able to understand the IDEAS contained in the mathematics. "QFT in a Nutshell" heralds the introduction of a book on quantum field theory that you can sit down and read. My professor's lectures made much more sense as I followed along in this book, because concepts were actually EXPLAINED, not just worked out. I still recommend having all three types of texts, but I am glad that now I have three types and not just the last two.

So, explanation is key! In our course, we will always work hard at getting the students to understand thoroughly the ideas. We think memorizing formulae and thinking of the mathematics as some sort of black box they just plug things into is a very bad way to train scientists and critical thinkers. Note how the reviewers of the QFT book, who are all physicists in training, repeatedly state it is the underlying ideas that count. That point is just as important in biology as it is in

physics. Let us leave you with one final review

Review by Mobius I was tempted to give this book four stars, simply to stand out among the sea of five star reviews, but I cannot, for this book truly is deserving of five stars. This is indeed a wonderful book, though it is not the mythic "one field theory text you will ever need" or the book that can make Sarah Palin understand instantons. This book covers quite a bit of ground, but that does not mean it is shallow. I've read some crap textbooks whose authors try to cram every topic under the sun into the table of contents, but do nothing to convey any real understanding... This book is at the other end of the spectrum. In physics identifying the truly interesting questions usually proves to be more difficult than performing the calculations, and what this book does really well is show what the interesting questions are and why they are interesting. If the calculational details Zee presents are too sparse, and I think they are in a few places, you can always find more information on the interwebs.

Hold onto that thought: identifying the truly interesting questions is very difficult. Another way of looking at this is that all interesting questions in science require complicated mathematics that can't be easily solved without concomitant computational work. Our aim in this course is to get you started on learning how to do this. Now let's switch gears and go from Physics to Climate Modeling. Here are some quotes from a new textbook on this subject: Principles of Planetary Climate by Raymond Pierrehumbert published by Cambridge University Press in 2010. Climate models are extremely interdisciplinary. As he says

"When it comes to understanding the whys and wherefores of climate, there is an infinite amount one needs to know,

but life affords only a finite time in which to learn it; the time available before ones fellowship runs out and a PhD thesis must be produced affords still less. Inevitably, the student who wishes to get launched on significant interdisciplinary problems must begin with a somewhat hazy sketch of the relevant physics, and fill in the gaps as time goes on. This book [our book too!] is an attempt to provide the student with a sturdy scaffolding which a deeper understanding may be built on. The climate system is made up of building blocks which in themselves are based on elementary physical principles, but which have surprising and profound collective behavior when allowed to interact on the planetary scale. In this sense, the "climate game" is rather like to game of Go, where interesting structure emerges from the interaction of simple rules on a big playing field, rather than complexity in the rules themselves. ... A guiding principle is that new ideas come from profound analysis of simple models – thinking deeply about simple things. The goal is to teach students how to build simple models of diverse planetary phenomena, and to provide the tools necessary to analyze their behavior".

We completely agree. The focus should be on a deep analysis of relatively simple models that we think very carefully about. Always remember that our goal is explanatory insight!

How Should A Student Study?

Since this course is a lot different from traditional mathematics courses you have taken, it is comforting to hear what the authors of another text that tries to combine mathematics and biology has to say. The text is "Mathematical Models of Social Evolution: A Guide For the Perplexed by Richard McElreath

and Robert Boyd published by the University of Chicago Press in 2007. They are teaching evolutionary models to biologists, anthropologists and psychologists who at best have had a calculus course a long time in the past. They state the problem very nicely

"Imagine a field in which nearly all important theory is written in Latin, but most researchers can barely read Latin and certainly cannot speak it. Everyone cites the Latin papers, and a few even struggle through them for implications. However, most rely upon a tiny cabal of fluent Latin-speakers to develop and vet important theory. Things aren't quite so bad as this in evolutionary biology [think our combination of mathematics, biology and computation here instead!]. Like all good caricature, it exaggerates but also contains a grain of truth. Most of the important theory developed in the last 50 years is at least partly in the form of mathematics, the "Latin" of the field, yet few animal behaviorists and behavioral ecologists understand formal evolutionary models. The problem is more acute among those who take an evolutionary approach to human behavior, as students in anthropology and psychology are customarily even less numerate than their biology colleagues. We would like to see the average student and researcher in animal behavior, behavioral ecology, and evolutionary approaches to human behavior [think biological scientists] become more fluent in the "Latin" of our fields. Increased fluency will help empiricists better appreciate the power and limits of the theory, and more sophisticated consumers will encourage theorists to address issues of empirical importance. Both of us teach courses to this end, and this book arose from our experiences teaching anxious, eager, and hard-working students the basic tools and results of theoretical evolutionary ecology."

They note the most common problem is that textbooks are too mathematical at the expense of the science. So the key thing is many examples and worked out steps. They have suggestions for you!

"While existing theory texts are generally excellent, they often assume too much mathematical background. Typical students in animal behavior, behavioral ecology, anthropology or psychology had one semester of calculus long ago. It was hard and didn't seem to have much to do with their interests, and, as a result, they have forgotten most of it. Their algebra skills have atrophied from disuse, and even factoring a polynomial is only an ancient memory, as if from a past life. They have never had proper training in probability or dynamical systems. In our experience, these students need more hand holding to get them started. This book does more hand-holding than most, but ultimately learning mathematical theory is just as hard as learning a foreign language. To this end, we have some suggestions. In order to get the full use of this book, the reader should

1. Read the book in order. Each chapter builds on the last. ...
2. Work through the examples within each chapter. Math is like karate: it must be learned by doing. If you really want to understand this stuff, you should work through every derivation and understand every step. [So] read the chapters at two levels, for general understanding and for skill development.
3. Work all the problems. ...
4. Be patient, both with the material and yourself. Learning to understand and build formal evolutionary models is much like learning a language. This book is a first course, and it can help the reader understand the grammar and essential

vocabulary. It is even a passable pocket dictionary. However, only practice and use of the language will build fluency. Students sometimes jump to the conclusion that they are stupid because they do not immediately understand a theoretical paper of interest. This is not justified. No one quickly learns to comprehend and produce mathematical arguments, any more than one can quickly become fluent in Latin".

They let you know that the student needs a lot of practice at working through all the steps in a derivation so that they really understand.

"This book has lots of algebra. The reason is that beginning students need it. If you really want to learn this material, you have to follow the derivations one mathematical step at a time. Students that haven't done much math is a while often have a shaky grasp on how to do the algebra; they make lots of mistakes, and even more important, don't have much information about how to get from point A to point B is a mathematical argument. All this means that they can find themselves stuck, unable to derive the next result, and unsure of whether they don't understand something fundamental or the obstacle is just a mathematical trick or algebraic error. Many years of teaching this material convinces us that the best remedy is to show lots of intermediate steps in derivations".

We will follow this plan too but we expect that the students work hard to understand all the steps so that their growth path is on target to helping them become a modern biologist. Finally, they talk about how we use computation in our modeling work.

Their comments are very true. We know many mathematicians who study biology, chemistry, ecology or physics by having the equations that some other group has decided provide a model handed to them without understanding how the model is derived. And they don't want to understand that! They simply put a thin veneer of science into their mathematics. Their work is usually impossible for scientists to use as it is divorced from the science. The same is true about computational approaches. All of these things need to be fully integrated with the science. As they say

"There is a growing number of modelers who know very little about analytic methods. Instead, these researchers focus on computer simulations of complex systems. When computers were slow and memory was tight, simulation was not a realistic option. Without analytic methods, it would have taken years to simulate even moderately complex systems. With the rocketing ascent of computer speed and plummeting price of hardware, it has become increasingly easy to simulate very complex systems. This makes it tempting to give up on analytic methods, since most people find them difficult to learn and understand. There are several reasons why simulations are poor substitutes for analytic models.

Equations Talk: Equations – given the proper training – really do speak to you. They provide intuitions about the reasons an evolutionary [think more general biological models!] system behaves the way it does, and these reasons can be read from the expressions that define the dynamics and resting states of the system. Analytic models therefore tell us things that we must infer, often with great difficulty, from simulation results. Analytic models can provide proofs, while simulations only provide a collection of examples.

Sensitivity Analysis: It is difficult to explore the sensitivity of simulations to changes in parameter values. Parameters are quantities that specify assumptions of the model for a given run of the simulation – things like population size, mutation rate, and the value of a resource. In analytic models, the effects of these changes can be read directly from equations or by using various analytic techniques. In simulations, there are no analogous results. Instead the analyst has to run large numbers of simulations, varying the parameters in all combinations. For a small number of parameters, this may not be so bad. But let's assume a model has four parameters of interest, each of which has only 10 interesting values. Then we require 10⁴ simulations. If there are any stochastic effects in the model, we will need maybe 100 or 1000 or 10,000 times as many....[M]anaging and interpreting the large amounts of data generated from the rest of the combinations can be a giant project, and this data-management problem will remain no matter how fast computers become in the future. Technology cannot save us here. When simple analytic methods can produce the same results, simulation should be avoided, both for economy and sanity.

Computer Programs are hard to communicate and verify: There is as yet no standard way to communicate the structure of a simulation, especially a complicated “agent-based” simulation, in which each organism or other entity is kept track of independently. Often, key aspects of the model are never mentioned at all. Subtle and important details of how organisms reproduce or interact have benefited from generations

of notational standardization, and even unmentioned assumptions can be read from expressions in the text. Thus it is much easier for other researchers to verify and reproduce modeling results in the analytic case. Bugs are all too common, and simulations are rarely replicated, so this is not a minor virtue.

Overspecification: The apparent ease of simulation often tempts the modeler to put in every variable which might matter, leading to complicated and uninterpretable models of an already complicated world. Surprising results can emerge from simulations, effects we cannot explain. In these cases, it is hard to tell what exactly the models have taught us. We had a world we didn't understand and now we have added a model we don't understand. If the temptation to overspecify is resisted, however, simulation and analytic methods complement each other. Each is probably most useful when practiced along side each other. There are plenty of important problems for which it is simply impossible to derive analytic results. In these cases, simulation is the only solution. And many important analytic expressions can be specified entirely as mathematical expressions but cannot be solved, except numerically. For these reasons, we would prefer formal and simulation models be learned side by side.”

We hope by the end of this course, to convince the students that equations do talk and to help them understand what they are saying! And we hope they enjoy the journey. We have written a text using these principles for the new version of first semester calculus for biologists (Peterson (20) 2013).

A Typical Syllabus

A typical syllabus for this course is Table 6. We don't show it but we have three exams during the semester.

Lecture	Topic	Lecture	Topic
1	Algebra and Viability Selection	28	Approximating functions
2	Viability update equations	29	The Mean Value Theorem, Rolle's Theorem
3	Introducing MatLab for graphs	30	Quadratic approximation
4	Limiting behavior: roots and polys	31	Differences in Exponentials
5	Limiting behavior: continuity and derivatives	32	Extremals
6	Limiting behavior: integration	33	Cooling Models
7	Continuity	34	Cancer Model I
8	Derivatives and the Product rule	35	Cancer Model II
9	The Quotient and Chain rules	36	Euler's Method I
10	Sin and cos stuff	37	Euler's Method II
11	Antiderivatives	38	Logistic models
12	Trig Antiderivatives and Substitution I	39	Advanced protein models I
13	Substitution II	40	Advanced protein models II
14	Riemann sums	41	Runga-Kutte methods
15	Riemann integrals and FToC	42	Matrices, Vectors etc
16	FToC again, CFToC	43	Drawing Surfaces
17	Substitution III	44	Partial Derivatives
18	ln and exp	45	Tangent Planes
19	ln and exp Derivatives and Antiderivatives	46	Second order partials
20	ln properties	47	Tangent Plane error
21	exp properties	48	Extremals
22	Simple Rate models	49	Regression lines
23	Half lives, doubling times	50	Shared Common Good models
24	Protein Synthesis	51	Hamilton's rule
25	Signalling and Transcription Error I	52	Gene Survival
26	Transcription Error II, Logistics Models One	53	Additive Fitness and Additive Genetics
27	Logistics Models Two	54	An optimization approach

Table 6: A typical syllabus for MATHSC 106-Bio

This is similar to what we have used for the last seven years when we teach the follow up course to this one, MTHSC 111, A second Course on Calculus for Biologists.

A Proposal For Mathematics Usage Each Year

First, let's note the problems inherent with the goals above. To get students involved from the freshman year onward therefore require altering some aspects of the program of study. A freshman and sophomore program of study with some enhancements is given in Table 7.

Year	Course	Description
I (F)	BIOL 110 R (5)	Biology I
	BIOSC 101 (1)	Frontiers in Bio I
	CH 101 (4)	Chemistry I
	COMM 150 (3)	Communication
	MTHSC 106–Bio MatLab (4)	Calc
	Total 17	
	I (S)	BIOL 111 Add(C,M,R) (5)
BIOSC 102 (1)		Frontiers in Bio II
CH 102 (4)		Chemistry II
ENGL 103 (3)		Composition
EX ST 301 (3)		Statistics I
Total 16		Organic Chemistry
II (F)		CH 223, 227 (4)
	BIOSC 302, 303 Add(C,M,R) (4)	Biochemistry
	BIOCH 301, 302 (4)	
	BIOL/ BIOSC course (4)	
	Total 16	
II (S)	BIOSC 443, 444 Add(C,M,R) (5)	Ecology and Lab
	BIOL/ BIOSC course (4)	
	BIOSC 304, 308 (4)	Plant Diversity
	GEN 300, 301 (4)	Genetics
	Total 16	

Table 7: The Freshman and Sophomore Year altered B.S. with the addition of quantitative modules to BIOSC 302, 303 and BIOSC 443, 444.

In this table, F and S denote the Fall and Spring semester, respectively and the number in parenthesis behind the course is the number of credit hours. If all we can expect is one semester of mathematics and one semester of statistics, what can we do to increase literacy for all four years? We are now beginning to add the use of the computer language for statistics, **R**, in BIOL 110. Since the starting calculus for biologists course, MTHSC 106-Bio, gives students beginning competency in MatLab, the courses together in the freshman year give a very good computational foundation. The use of **R** also prepares the students for more sophisticated statistics so they can do more with the statistics knowledge they get from their one statistics class. If no more mathematics, computation and statistics is taken, the first two years could look like Table 7. Note we are putting the mandatory statistics course in Spring of the freshman year. Now Biol 111 continues to have a quantitative component and

if all students are expected to have MTHSC 106-Bio as a prerequisite, it would be easy to add calculus and computational modules using MatLab to BIOL 111. In the Fall of the sophomore year, calculus, computation using MatLab and statistics modules using **R** are added to BIOSC 302, 303 (Animal Diversity) so that the use of quantitative methods is continued. In the Spring of the Sophomore year, quantitative methods using calculus, MatLab and **R** are added as modules to BIOSC 443, 444 (Ecology). At this point, all students see the potent mix of mathematics, computation and statistics in each semester of the first two years. The phrase **Add(C,M,R)** means to add modules using calculus, MatLab and R to the course it follows.

To continue the use of quantitative methods across the board in the full undergraduate degree, consider Table 8.

Year	Course	Description
III (F)	BIOSC 335 Add(C,M,R) (3)	Evol. Bio.
	ENGL 315 (3)	Science Writing
	BIOL or BIOSC course (3)	
	PHYS 122, 124 (4)	Physics I and Lab.
	BIOSC 401, 402 Add(C,M,R) (4)	Physiology
III (S)	Total 17	
	BIOL or BIOSC course (4)	
	BIOSC 461, 462 Add(C,M,R) (5)	Cell Bio. and Lab
	PHYS 221, 223 (4)	Physics II and Lab.
	Social Science (3)	
IV (F)	Total 16	
	BIOSC 493 (2)	Senior Seminar
	GEN 440 Add(C,M,R) (3)	Bioinformatics
	Arts and Humanities (3)	Literature
	BIOSC 3xx-4xx (7)	More > 300 Bio.

Year	Course	Description
IV (S)	Total 15	
	BIOSC 491 (1)	Under. Research
	Arts and Humanities (3)	Not Lit.
	BIO 3xx-4xx (5)	More > 300 Bio.
	Social Science (3)	
	Total 12	

Table 8: The Junior and Senior Year altered B.S. with the addition of quantitative modules to BIOSC 302,303 and BIOSC 443, 444.

We add mathematics, computation and statistical modules to BIOSC 335 (Evolutionary Biology) and BIOSC 401, 402 (Physiology) in the Fall of the Junior year. At this point, there is no additional formal mathematics coursework and even a second statistics course such as EX ST 311 is optional. We also add mathematics, computation and statistical modules to BIOSC 461, 462 (Cell Biology) in the Spring of the Junior year. The students finish the junior year having had three consecutive years where they routinely use tools from calculus, computation and statistics to help them understand biology. We finish the senior year, which has a lot of flexibility, by adding quantitative modules to GEN 440 (Bioinformatics). A motivated student could then add BIOSC 428 and MTHSC 390 to their

senior year experience although it is not mandatory. The resulting prerequisite chain is shown in Figure 1. This approach to creating a full four year environment for the inculcation of mathematics and computation as part of a practicing biologist's toolkit works off of the basic foundation of one semester of calculus and one semester of statistics, but by introducing the use of R and MatLab in the Freshmen year and adding modules using these ideas to six critical biology courses, we create a very unified environment of use. If at a later date, the second semester of calculus was reinstated as a requirement, even more could be done, of course.

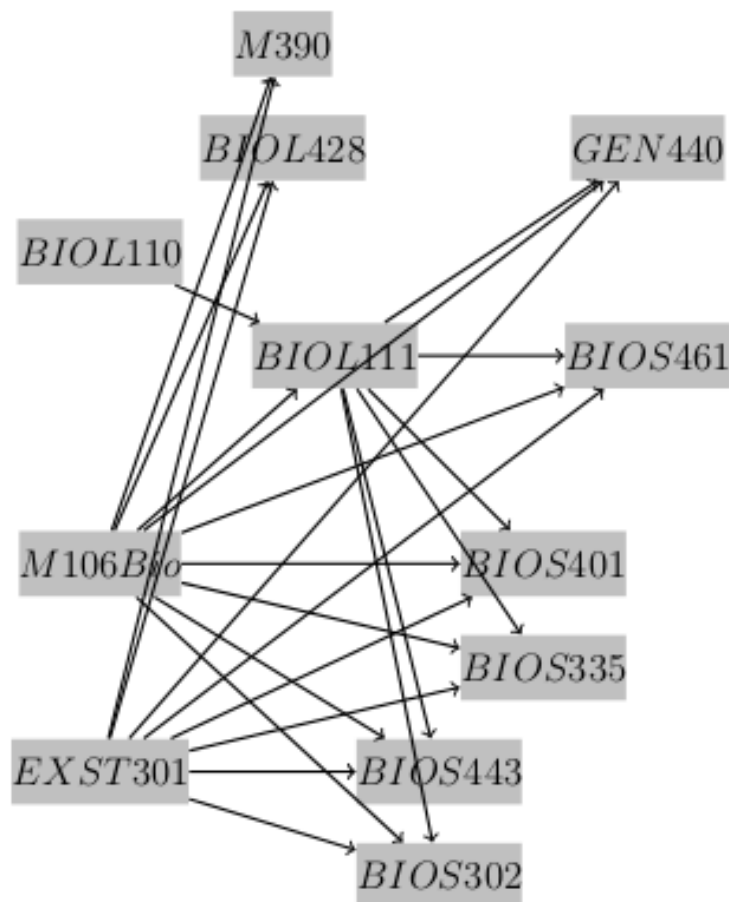


Figure 1: Mathematics Usage Graph In Biology Curriculum. MATHSC 106-Bio is a prerequisite for six biology courses. Each of these courses can use MatLab and R in their modules.

If only one semester of calculus is required, the course we have developed covers all the appropriate parts of calculus one, crucial one variable ordinary differential equation biological models and the critical amount of two variable calculus theory so that the use of partial differentiation and first order approximations for models with two variables can be understood. We also spend much time on models that range from low-level models such as protein transcription to high-level models such as the spread of altruism. In addition, we train the students in the use of MatLab for computation by introducing numerical methods for solving the models. We also train them in the proper way to write reports that mix mathematics, computation and science in a standard word processing document such as Word. However, if a second

semester of calculus were required, then the second semester would add additional training in two variable systems that are both linear and nonlinear. They would study carefully predator-prey systems, two interacting protein systems, the basic SIR model for the spread of infection and a cancer model based on the loss of the alleles of a tumor suppressor gene. They would also learn about more sophisticated mathematics concepts such as eigenvalues and eigenvectors of matrices and additional calculus tools. If all biology students were required to take the two-semester sequence we have laid out here, a significant amount of mathematical and computational training would be available to use in courses in the biological sciences. The plan outlined here requires the integration of modules using mathematics and computation into six courses in biology: BIOSC 443

(Ecology), BIOSC 302 Animal Diversity), BIOSC 335 (Evolutionary Biology), BIOSC401 (Physiology), BIOSC 461 (Cell Biology) and GEN 440 (Bioinformatics). If two modules were added per class, this would require the development of twelve modules. As discussed earlier, each module requires about 4 - 6 weeks of effort. Hence, we and possible colleagues in mathematics could work with the biology department to develop such material over the course of approximately one year and a summer with adequate support via a one course teaching reduction. The payoff would be quite substantial though and well worth the effort.

A Discussion of General Education

It is very important to capture freshman and sophomore interest in their course work and to design the classroom experiences so that the students who enter the courses stay for the full semester and learn the material well enough to achieve a good grade. This is a problem common to all universities and there are a variety of approaches to improve what is known as the DFW rate. This is the percentage of students in a course that drop, fail or withdraw. It is a measure, of sorts, of pedagogical success. This is a very complex issue and problem and there are a number of tools that have been applied to improve the DFW rate. In an effort to help students in the engineering calculus sequence succeed, many departments at universities in this country have initiated the teaching of all “student-centered, reduced-lecture” teaching formats. This format is modeled on North Carolina State’s SCALE-UP program for its physics courses. Briefly, using this format, courses are taught in rooms containing five round tables, each of which seats nine students. This limits the size of each section to 45 students. During a typical 50-minute class meeting, the instructor reviews material from the previous meeting and then spends between 20 and 25 minutes discussing the day’s instructional objectives, providing examples and modeling solutions. Finally, the students are divided into groups of three and

given “learning activities” that they are expected to complete before the end of class. To assist these students, the instructor and two graduate students circulate around the room offering advice and encouragement. Students are then assigned homework problems that are collected and graded at the end of the week. The objective in this effort is to increase the number of students who earn an A, B or C in the course. Table 9 shows data on this issue for the Clemson University calculus one course, MTHSC 106. It shows how the percentage of students who earned an A, B or C during the Fall 2005 Semester – that is, the year before the made this change – and compares it with the percentage of students who earned an A, B or C in MTHSC 106 Calculus I in the years after scale up was implemented. This sort of improvement is typical when scale up is implemented in the large multi section courses such as are offered, by necessity, in mathematics, physics and so forth.

Semester	Percentage A, B or C
Fall 2005	56.4
Fall 2006	77.2
Fall 2007	81.1
Fall 2008	81.8

Table 9: The Percentage of A, B and C grades in Engineering Calculus MTHSC 106 and MTHSC 108

Our approach to both the first semester calculus course for biologist, MTHSC 106-Bio and the second semester calculus course for biologists, MTHSC 111, does not follow “student-centered, reduced lecture” format of SCALE-UP as the needs of the class are different. One of our major goals is to provide an integration of mathematical and computational tools into the traditional biological sciences curriculum. Hence, we focus of putting many threads together simultaneously in order to present whole models. This necessitates longer and more involved lectures and homework

exercises that combine many separate threads into an integrated whole. The biology students in MTHSC 111 thus see how the mathematical and computational tools we ask them to learn will be used in models throughout the entire course. This integrated approach has had a positive impact on both the interest of the biology students and the retention of biological sciences students in their major. As mentioned above, one indicator of these is the Drop/ Fail/

Withdraw or DFW rate for the class. In Figure 2, we compare the DFW rate for data from our second semester calculus for biologists courses with the regular science and engineering course. We achieve improvements similar to SCALEUP with a different suite of tools. Hence, we find the tool suite we are using to train students in mathematics, computation and modeling is quite effective.

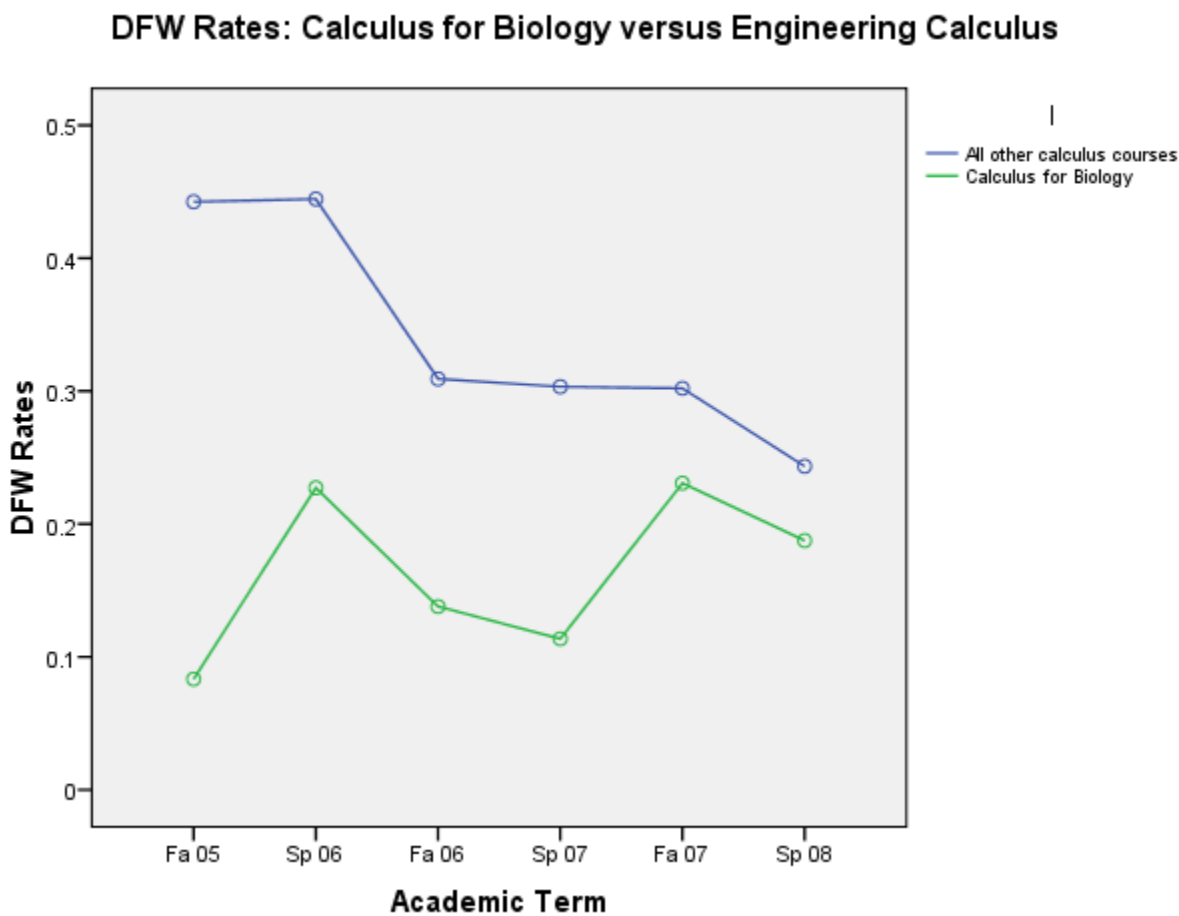


Figure 2: Comparison of DFW Rates for MTHSC 111 and MTHSC 108

What Is Our Product?

The courses we have been talking about are, in essence, interdisciplinary courses and if we are introducing courses like this at the freshman level, we should back up and think hard about what are assumptions are. There are many questions. What is our product? If one teaches at a research university the product is very mixed. In terms of degree programs one has:

- ♣ The undergraduate degree which can be terminal so that the student attempts to enter the work force and begin to assimilate into society. However, such a student can also feedforward into a graduate program to find additional training.
- ♣ The master's level graduate degree which is terminal with the graduating student seeking employment. Again, there are students who use this degree as an entry into the Ph. D. level programs.
- ♣ the Ph. D. program which can also be terminal with the student looking for work in their area. However, even at this level, it can be used as a stepping-stone towards more advanced training. To obtain a post in a Ph. D. granting institution in the sciences and many other areas, a student now must first obtain a post-doctoral appointment for approximately three years to show the proper seasoning before they can apply for a permanent post. Hence, we have Ph. D. students feeding forward to Postdoctoral programs.
- ♣ The Postdoctoral program in which the student works closely with an established researcher to get more experience in what constitutes research in their field.

The way one would design course work is different for these targets. One can say similar things about students who train for professional programs such as that of a medical or dental school and so forth. After the undergraduate degree, there is medical school, a residency and so forth before the student is fully vetted. In terms of time, these long training programs are similar to those in guilds where a beginner apprenticed to a master craftsman in the chosen area. After approximately 10 - 15 years of work, the apprentice would be certified a master and would then be able to open a business of their own. However, guild apprenticeship is also very different in that there is one master who does the teaching and in a modern university, there are dozens involved in the student's training; postdoctoral training with one mentor is, of course, closer to the spirit of the guild apprenticeship. To do a good job with freshman interdisciplinary courses, one therefore needs to understand just what the product should be. A common thread throughout the education process is the idea that one should inculcate in students the ability to think and reason in new situations. This means to challenge them to help them grow intellectually. But challenge inevitably means a higher risk of getting less than an A in a course. In today's climate, freshmen are already worried about getting into law and medical school. One routinely sees people drop courses now just because they are working at a B level. As a freshman, they feel that one B will be the thing that keeps them from medical school. So many of the freshman do not want intellectual challenge; instead, they want a painless (i.e. not too much homework, not too many projects etc.) path to that A. So what is our perspective on these general issues? We believe the product should be a student who can understand the consequences of assumptions. We all build

models of the world around us whether we use mathematical, psychological, political, biological and so forth tools to do this. All such models have built in assumptions and we must train our students to think for themselves. They must question the abstractions of the messiness of reality that led to the model and be prepared to adjust the modeling process if the world they experience is different from what the model leads them to expect. There are three primary sources of error when we build models:

- ⤴ The error we make when we abstract from reality; we make choices about which things we are measuring are important. We make further choices about how these things relate to one another. Perhaps we model this with mathematics, diagrams, words etc; whatever we choose to do, there is error we make. This is called **Model** error.
- ⤴ The error we make when we use computational tools to solve our abstract models. This error arises because we typically must replace the model we came up with in the first step with an approximate model that we can be implemented on a computer. This is called **Truncation** error.
- ⤴ The last error is the one we make because we cannot store numbers exactly in any computer system. Hence, there is always a loss of accuracy because of this. This is called **Round Off** error.

All three of these errors are always present and so the question is how do we know the solutions our models suggest relate to the real world? We must take the modeling results and go back to original data to make sure the model has relevance. We agree with the original financial modeler's manifesto (Derman and Wilmott, 2009) which takes the shape of the following Hippocratic Oath. We have changed one small thing in the list of oaths. In the second item, we have replaced the original

word value by the more generic term variables of interest, which is a better fit for our interests.

- ⤴ I will remember that I didn't make the world, and it doesn't satisfy my equations.
- ⤴ Though I will use models boldly to estimate variables of interest, I will not be overly impressed by mathematics.
- ⤴ I will never sacrifice reality for elegance without explaining why I have done so.
- ⤴ Nor will I give the people who use my model false comfort about its accuracy. Instead, I will make explicit its assumptions and oversights.
- ⤴ I understand that my work may have enormous effects on society and the economy, many of them beyond my comprehension.

There is much food for thought in the above lines and all of us who strive to develop models should remember them. We are all aware of how poor assumptions in financial models led to our current ruinous state. Indeed in our own work, many times managers and others who oversee what we are doing have wanted the false comfort the oaths warn against. We should always be mindful not to give in to these demands and we must train our students to think deeply about assumptions at all times. In addition, we must find a way to get all the students intellectually engaged in our interdisciplinary course. In traditional engineering mathematics courses, students are eventually going on to other courses that need all the things we are teaching. The engineering, physics and other quantitative science students do not mind learning this material even though they won't use it in their own problem domain for several years. The biology students are not like this at all. They typically want to take the first and perhaps second semester of calculus because they knew they would never use this material again. Despite all of our effort in the design and implementation of the Calculus for Biologist courses, this is still true to a large

extent. Once the students take Calculus for Biologists, at the present, there are no followup courses other than the ones we have designed in biology that use the material. Hence, the biology majors do not see this material used on a regular basis. Instead, they see a dead end and a real impediment to their medical school application. An interdisciplinary course must somehow have relevance in addition to challenge in order to keep our students involved. A good example is from the world of Processing (Reas and Fry (21) 2007). The artists Reas and Fry developed a programming language for artists starting about 10 years ago which is currently used by about 200,000 people (at least) over the world. Reas and Fry were not classically trained mathematicians or computer scientists, but they felt there was a lack of computer tools that could be applied to the artistic process. So they implemented Processing. Moreover, Processing allows anyone to design and build hardware for use in art easily within the program (see the Arduino platform (Banzi (3) 2008) and ideas on programming interactivity (Noble (17) 2009)). They teach semester courses using these tools in which the students in the class learn the stuff they need to build art and then actually do art in the second phase of the class. The thing is that the students are intellectually engaged. If Reas and Fry can capture the interest of art students who usually don't care for quantitative tools such as programming languages, mathematics and so forth, we feel we can do this also. Hence, the interdisciplinary course we field must apply what they learn to build something. It can be hardware, a software model or a probing discussion of ideas on the edge of what we know. We feel this is essential to grabbing and maintaining student interest. After all, we want to have all the students take this one course. So it has to mean something to them.

Conclusion

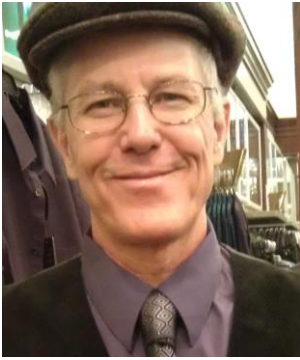
We have successfully added a reasonable implementation of two interdisciplinary courses, *Math-One-Biology* and *Math-Two-*

Biology as replacements for traditional engineering based calculus courses in a biology major. The *Math-Two-Biology* has been taught to approximately 800 (about 100 per year) students since 2006 when it was required. A recent change in how the biology major is structured has made *Math-Two-Biology* optional and hence enrollments have dropped severely. However, a new course *Math-One-Biology* has been designed which is a replacement for the traditional calculus one course and is now being deployed. The enrollment in the new course will probably be in the 100 - 120 per year range so we are mildly increasing the number of students we see with this change. This will allow these interdisciplinary ideas to take hold early. Also, our lectures for these courses as down loadable slides are available at www.ces.clemson.edu/~petersj/startingcalcforbio.html for *Math-One-Biology* and at www.ces.clemson.edu/~petersj/calc-bio-online.html for *Math-Two-Biology*. These sites also include the MatLab files needed for the courses.

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Cell Lines as a Model for Immune Cells in Research and Didactics

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The immune system is one of the most important systems in an animals' body. It is responsible for eradicating pathogens and maintaining the overall condition of the cells. Working on immune system cells can be tricky and expensive as it involves a collection of the cells from the blood. One way to overcome these difficulties is to use cell lines that act as a model for the immune cells. Cell lines are homogenous cell cultures that are normally derived from one single donor cell. Such cells are then immortalized so they can divide almost indefinitely. They have both their disadvantages and advantages in research as well as in didactics. Cell lines provide low genetic variability, because they originated from single cell. They are easy and inexpensive to culture. It is easy to demonstrate or to study various immunological processes like antigen presentation, phagocytosis, activation or differentiation of the specific cells. The yield of the cells is very high and depends only on the needs of the researcher. But in the end they act only as a model. The fact that they are derived from only one individual and they often had been manipulated (i.e., immortalized) means that they differ in functions and properties from regular cells. To summarize, cell lines are often used in clinical and basic research. The majority of Bachelor or Master students can easily maintain such cell lines and perform their own experiments with them. Thus, very complicated immunological process is no longer limited to qualified, well equipped personnel nor requires high amounts of funding.

Układ odpornościowy jest jednym z najważniejszych systemów w organizmie zwierząt. Jest on odpowiedzialny za zwalczanie patogenów i utrzymanie ogólnego dobrego stanu komórek. Praca na komórkach układu odpornościowego może być trudna i kosztowna, ponieważ wymaga pobrania komórek z krwi obwodowej. Jednym ze sposobów przezwyciężenia tych problemów jest użycie linii komórkowych, które działają, jako model dla komórek układu odpornościowego. Linie komórkowe są to jednorodne hodowle komórkowe zazwyczaj pochodzące z tych samych komórek jednego dawcy. Takie komórki są następnie unieśmiertelnione, dzięki czemu mogą dzielić się niemal w nieskończoność. Mają one zarówno swoje wady i zalety w zakresie badań, jak również w dydaktyce. Linie komórkowe zapewniają niską zmienność genetyczną, ponieważ pochodzą od jednego dawcy. Są łatwe i tanie w hodowli i nie wymagają szczegółowej wiedzy czy intensywnego treningu. Łatwo pokazać na nich różne procesy immunologiczne, takie jak prezentacja antygeny, fagocytoza, aktywacja i różnicowanie poszczególnych komórek. Wydajność linii komórkowych jest bardzo wysoki, a liczba pozyskanych komórek zależy tylko od potrzeb badacza. Jednakże linie komórkowe działają jedynie jako model. Fakt, że pochodzą one tylko od jednej osoby, a często były genetycznie manipulowane z (np. unieśmiertelnione), oznacza, że różnią się w funkcjach i właściwościach od zwykłych komórek. Podsumowując, linie komórkowe są często stosowane w badaniach klinicznych i podstawowych. Większość licencjuszy lub magistrantów może łatwo i samodzielnie utrzymać takie linie komórkowe i przeprowadzić na nich własne eksperymenty. Studiowanie skomplikowanych procesów biologicznych nie jest już ograniczone do wykwalifikowanego, dobrze wyposażonego personelu i nie wymaga dużych ilości funduszy.

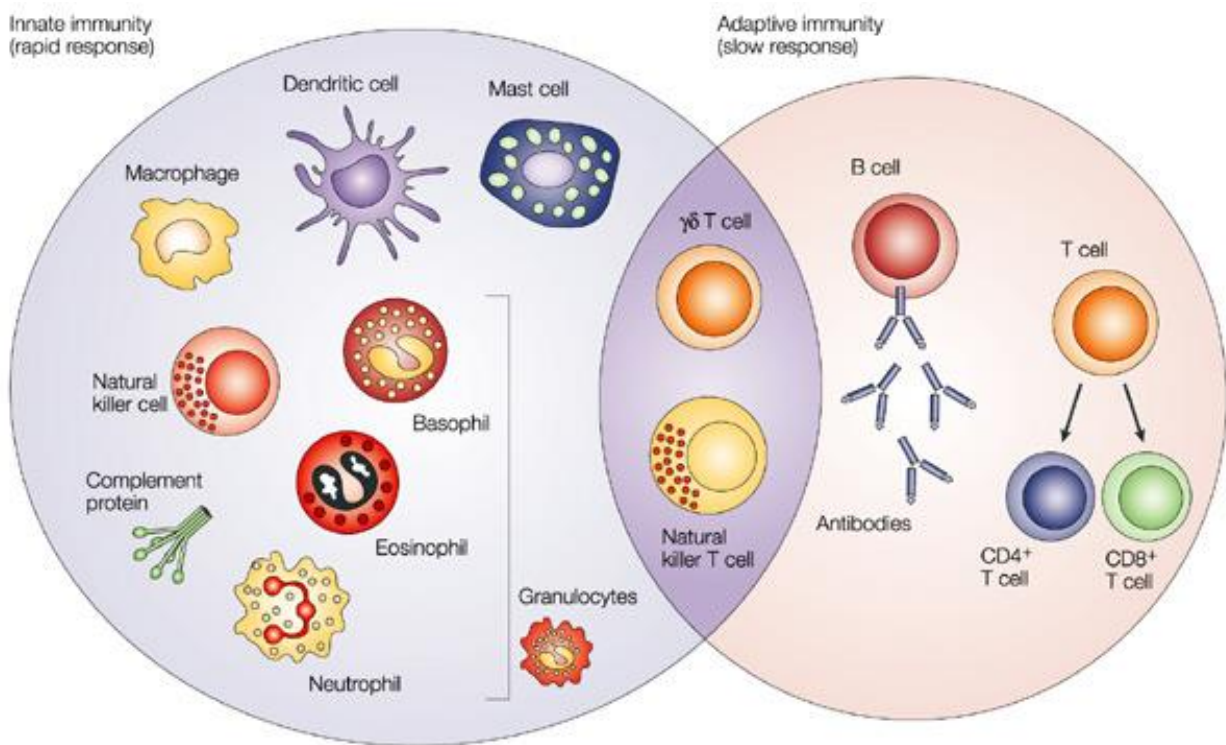
Keywords: biology, science, laboratory techniques, cell lines, immunology, higher education

Immune system

The immune system is one of the most important systems in an animals' body. It is responsible for eradicating pathogens and dead or cancerous cells. In order to perform its functions properly, immune systems recruit various type of cells. Each cell is responsible for a specific task.

The immune system in general can be divided into innate and adaptive immune systems. The difference between them is the degree of their specificity. The innate immune system is the oldest defense system in terms of evolution. Almost all

living higher organisms have this kind of protection. The defense mechanisms deployed by the innate immune system are non-specific and are characterized by a generic response and no long-term memory formation. In contrast to the innate system, the adaptive immune system is evolutionarily much younger (it evolved in vertebrates) and is characterized by high specificity and efficacy. (Goldsby *et al.*, 2003) Cell types involved in both adaptive and innate immunity are presented in Figure 1.



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Figure 1. Cell types involved in immune response (from Dranoff, 2004)

Defensive mechanisms of the innate immune system

Inflammation

As was mentioned above, the innate immune system starts generic responses to non-specific pathogens. The main mechanism deployed is an inflammation, an alarm state of an organism. Inflammation is characterized by five main symptoms: fever, swelling, redness, loss of function, and pain. Those are caused by various proteins secreted by immune cells and function as a danger signal that something wrong is happening in the organism. The swelling and redness is caused by increased blood flow due to vasodilatation. This migration of the immune cells to the site of the inflammation is dependent upon this increased blood flow. The vasodilatation is caused by histamine, a protein secreted by *mast cells*. The fever and pain is caused by a specific compound called prostaglandin. The synthesis of prostaglandins is inhibited by popular anti-inflammatory drugs like ibuprofen, salicylic acid or paracetamol (Goldsby *et al.*, 2003).

Phagocytosis

Over evolutionary time, some cells differentiate into forms able to phagocytize pathogens. Special cells called phagocytes are able to digest large objects like bacteria or protist. The phagocytosis is activated by recognition of some generic molecular patterns on the extracellular surface of microorganisms. For example, bacteria are often recognized by the mannose residues in their cell walls and membranes. The immune cells with ability to phagocytize are *macrophages*, *neutrophils* and *dendritic cells*.

Cell killers

In some cases the cells of our own body turn against us. Whether it is caused by viral or cancerous transformation, it is an imminent threat for the organism. In this situation a special type of cells are

deployed called *natural killer cells*. They are responsible for detecting and destroying diseased or non-self cells. On the surface of almost all cells, the MHC (major histocompatibility complex molecules) are present. Each person has a unique set of those receptors and cells like NK cells are able to recognize self from non-self cells.

Defensive mechanisms of the adaptive immune system

Vertebrates evolved an additional layer of defense in the form of the adaptive immune system. The immune system adapted by matching mutating and evolving microorganisms. Special type of cells is responsible for detecting specific antigens (particles that cause immune response; mainly proteins). Those cells perform tasks of a border patrol. They act as sentinels, alarming the immune system of detected pathogens. They are called antigen presenting cells as they digest the antigen and then stimulate (present) effector cells – lymphocytes. Lymphocytes act as the primary defense mechanism of our immune system. They are responsible for production of antibodies (small proteins which neutralize antigens). Examples of antigen presenting cells are *dendritic cells*, *monocytes* and *macrophages*.

Lymphocytes

Lymphocytes consist of two major groups: B cells and T cells. B cells are responsible for production of antibodies. During infection, they detect pathogens and start producing different subsets of antibodies. There are 5 known classes of antibodies, each performing specific functions (IgA, IgD, IgE, IgG and IgM). In the course of immune response the B cells often switch from producing antibodies from all-purpose to more specific ones. It is called antibody class switching. While B cells are only responsible for producing antibodies, the function of T cells varies. T cells can be either involved in helping B

cells in detecting specific antigens (T helper cells), regulation of the immune response (regulatory T cells), destroying diseased or infected cells (cytotoxic T cells). Together they form a sophisticated network of mutual interactions that protects our bodies from pathogens.

Cross talk – cell interaction

When the cells perform their task efficiently, they communicate well with each other. This is achieved through the interaction of various surface receptors that are distinctive for each cell type. These interactions can involve detecting pathogens (by antigen presenting cells – the border patrol of our body), distinguishing non-self from self cells (e.g., in case of transplantation or blood transfusion), activation or motion coordination (e.g., by guiding the cells into the inflammation site). The immune cells derive from different organs. The thymus, which is situated just over the heart is involved in the maturation of T lymphocytes. The cells originated from there are called of a *lymphoid lineage*. The cells derived from bone marrow (tissue found in the interior of some bones) are called a *myeloid lineage*. Those are erythrocytes, platelets (involved in the blood clotting), granulocytes, B lymphocytes, monocytes, and macrophages.

Didactics and research

The immunological web of interactions is a constant object of interest of many researchers all over the world. But such research is quite difficult and expensive. As was shown, the immune system consists of many different, distinctive cell types. In order to perform any research, especially on human cells, one has to collect all of them (e.g., from donor blood) and distinguish or even physically separate them. This process requires a lot of knowledge, experience, and funds. The same goes for immunology didactics. The standard route of teaching in the field of

immunology involves working on murine models. The organs and cells have to be collected by students from euthanatized mice. It brings both ethical concerns and requires a lot of training of the students, which is hardly achievable during the normal length of a course. In order to overcome those difficulties, various cell lines can be used as models for specific types of immune cells.

Cell lines

A cell line is a population of cells, typically of the same function and origin. Normal cells cannot divide indefinitely due to the process of senescence (cell aging). But through some laboratory methods, we are able to transform them into an immortalized state such that they can divide for prolonged periods *in vitro* (Sugimoto *et al.*, 1999). The main methods involved in immortalization of the cells are:

- inducing spontaneous mutations that affect the regulation of the cell cycle
- transformation by using virus vectors (e.g., Epstein Barr Virus)
- isolating the cells from naturally occurring tumors (e.g., from a patient suffering from leukemia) (Sugimoto *et al.*, 1999; Utikal *et al.*, 2009)

The standard process involved in the establishing primary cell culture starts by taking a tissue sample. Then the tissue is homogenized both physically and biochemically (by proteolytic enzymes) to isolate single cells. The cells are submerged and cultured in a special aqueous nutrition medium in small plastic flasks. Thanks to increased longevity, it is easy to overgrow the cells so they fill all available space and use up all of the nutrition. Then the cells need to be subcultured to give them room for continued growth. This is most often done by gently removing the cells from a flask (e.g. through centrifugation) and replacing the old medium with fresh medium (Utikal *et al.*, 2009).

The cultured cells differ in their morphology depending on the type of the cell we are working with. There are three main morphologies (Utikal *et al.*, 2009):

- epithelial-like-cells polygonal in shape that attach to the flask surface
- lymphoblast-like-spherical cells which are growing in the suspension
- fibroblast-like- elongated cells that are attached to the flask surface

Most cell lines used in immunology research will be of the lymphoblast morphology.

Cell lines have both their advantages and disadvantages for both education and research:

- They can be grown almost indefinitely.
- They do not require specialist knowledge (apart from basic cell culture skills); even minimally trained person all can maintain the culture.
- They are inexpensive to culture.
- They can act as *in vitro* models for different type of cells. It is easy to demonstrate or to study various processes like antigen presentation, phagocytosis, activation, or differentiation of the specific cells.
- Cell lines provide low variability of the samples because they originated from single cell, whereas cells collected from blood will differ greatly because of the personal variability of different people.
- They can be easily frozen to be kept almost forever (e.g., for further studies or next year didactics).
- The fact that they are derived from only one individual and they had been immortalized (e.g. through the induction of mutations) means they differ in functions and properties from regular cells.

Application of Cell lines in didactics

The aforementioned properties of cell cultures make them an ideal tool for higher education didactics. During a biology course, different aspects of cell functioning can be presented, not necessarily exclusive for immunology; e.g., it can be phagocytosis, cell signaling, cell biology or cell interactions. Another application of cell lines is for lab projects of bachelor and master students. After brief training in cell culture techniques, students are able to perform their own experiments. The high yield of the cells allows a trial and error approach where students can test the hypothesis on their own. There is no risk of losing your material to a mistake as the cells can be grown back (e.g., from frozen stock). The work can be maintained solely on cell lines so there is no health risk involved (the cells are tested for viruses), as opposed to working on human blood. Moreover, research on cell lines tends to be focused on specific cellular mechanisms. There is no distraction from work in the form of obtaining, isolating the cells, or distinguishing different cell subsets.

Below there is short description of several immunological processes that can be studied with cell lines.

Phagocytosis

Phagocytosis can be observed by exposing phagocytes (cells that can perform phagocytosis) to some noticeable material like red cells, iron particles or latex beads. Erythrocytes are often used in such experiments. In order to enhance the phagocytosis, the red cells are often coated with antibodies (it is a signal for phagocytosis). Currently, more novel methods are available. It is possible to coat internalized molecules with some fluorescent dye. The digested particles will be visible in a fluorescent or confocal microscope image.

Antigen presentation

During this process, antigen presenting cells activate T cells. Antigens are presented on MHC molecules and recognized by T lymphocytes. But under normal conditions that signal is not sufficient for activation. A second signal called a costimulatory is required in which CD28 receptors on T cells interact with B7 receptors on antigen presenting cells. In order to study this process, a mixed leukocyte reaction is performed. On 96-well culture plates, both APC and T cells are cultured in different ratios (usually with the lymphocytes in larger quantities than the APC). After a few days, we can measure the activation of T cells (increase in the expression of some surface receptors like CD69). Also, we can determine whether the lymphocytes have received the proper costimulatory signal (without it the cells become anergic – they are unable to produce IL-2 and cannot proliferate). Lastly, we can measure the proliferation rate of lymphocytes. The stronger the signal, the greater proliferation we will get. To estimate the division rate, we can use a simple fluorescent dye. The cells absorb it and during each division they will lose half of it as it is passed to daughter cells. Then, we can analyze the fluorescence signal in a flow cytometer to count how many cell divisions had occurred.

Cytotoxicity assay

In this method, we can observe the cytotoxic properties of some cells (like cytotoxic T cells or NK cells). Firstly, we need our target cells (e.g., K562 cells). Then, we need to tag the cytoplasm of the cells with some kind of marker. Thereafter, the co-culture of target cells and cytotoxic cells need to be prepared. In this process, the target cells will be killed by destruction of their cell membrane and the marker will be released to the environment. By detecting the amount of the marker in the cell culture supernatant (the more marker there was, the more intensive the cytotoxic reaction that has occurred) we can estimate

the intensity of cytotoxicity. The most commonly used method to tag cells is to stain them with radioactive chromium. Once released through a pierced membrane, it was possible to evaluate the amount of radiation in the supernatant. In recent years, more commonly a fluorescent dye is being used instead of the radioactive chromium. The fluorescence in the supernatant from the culture can be measured by a fluorescence detector.

Cell lines in immunology

As was described earlier, the immune system consists of several types of cells, each distinctive in their properties and functions. Using cell lines allows focusing on one specific aspect of the immune system. In this article, only human cell lines will be discussed.

Lymphoid lineage cell lines

In this category, there are almost exclusively T lymphocytes.

Jurkat cell line

Jurkat cells are immortalized cell lines of T lymphocytes derived from the peripheral blood of a young boy suffering from lymphoblastic leukemia (Schneider *et al.*, 1977). They are often used in the research as a model to study acute leukemia, cell signaling, expression of different surface receptors, or studying mechanisms of action of anti-cancer drugs and radiation. They are activated by directly manipulating their signaling pathway with [phorbol 12-myristate 13-acetate](#) (commonly known as PMA) (Xu *et al.*, 2005)

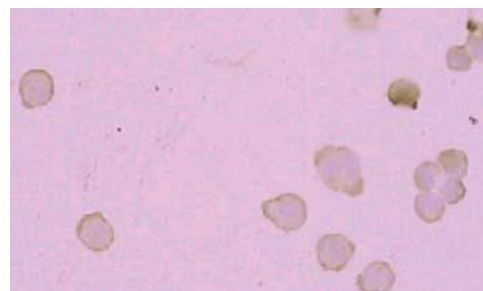


Fig. 2. Jurkat cells from (Xu *et al.*, 2005)

Application in didactics:

- studying T cell signaling (e.g., activation)
- studying secretion of IL-2
- methods for detecting cytokines (Jurkat cells are able to secrete IL-2)

Myeloid lineage cell lines

Myeloid cells originate from bone marrow. They can perform various functions from blood clotting to immune response regulation and antigen presentation. Frequently these cell lines are used in research of a myeloid lineage (Table I). It is important to mention that myeloid cell

lines are often susceptible to cytokines (local immune hormones) and it is difficult to trace cell signaling or study the response to cytokines. In order to differentiate such cells, direct manipulation in intracellular signaling is often required, usually through treatment with [phorbol 12-myristate 13-acetate](#) (PMA). There are some myeloid lineage cell lines that are able to respond to cytokines, but they require additional components in the medium (most commonly cytokines) (Santegoets *et al.*, 2008).

Table I. Cell lines used in immunology

Cell line	Model for:	Advantages	Disadvantages	Applications
Jurkat	T cells	good model for T cells secretes and responds to IL-2	-	T cell signaling methods for detecting cytokines
THP-1	monocytes macrophages	easy and inexpensive	not responsive to cytokines	microscopy, phagocytosis
TF-1	myeloid progenitor	responsive to cytokines	can be expensive to culture	cell signaling, response to cytokines
HL-60	monocytes macrophages neutrophils eosinophiles	multipotent easy and inexpensive	limited responsiveness to cytokines	differentiation of the cells
KG-1	dendritic cells	easy and inexpensive	limited responsiveness to cytokines	antigen presentation, phagocytosis
MUTZ-3	dendritic cells	responsive to cytokines; best model	quite difficult and expensive to culture	antigen presentation, phagocytosis, response to cytokines, differentiation of dendritic cells
K562	erythroblasts erythrocytes	they do not express MHC	limited application	cytotoxicity assays
NK-92	natural killer cells	good model for NK cells	IL-2 dependent growth	cytotoxicity assays, self – non self discrimination
CL-01	B cells	has almost all properties of native B cells	transformed with EBV	antibody production and secretion, gene regulation of B cells

THP-1 cell line

The THP-1 cell line is a human monocyte cell line that was derived from an acute monocytic leukemia patient. They are big round cells, ideal for analysis under the fluorescence or confocal microscope. By direct manipulation of intercellular signaling (e.g., by PMA), they can differentiate into macrophage like cells (Tsuchiya *et al.*, 1980).

Application in didactics:

- studying phagocytosis (latex beads or erythrocytes)
- studying monocytes
- studying macrophages; they differentiate into macrophage-like cells after treatment with PMA

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Designation: THP-1

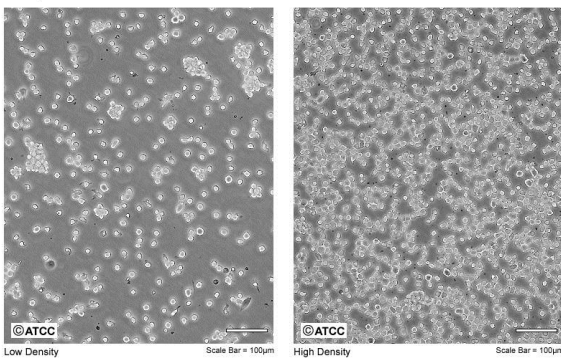


Figure 3. THP-1 cells; fresh culture on left, overgrown on right from

http://www.lgcstandards-atcc.org/?geo_country=pl

TF-1 cell line

The TF-1 cell line is a progenitor cell line. This means that it is not fully differentiated and does not perform a specific function. It was derived from the bone marrow of a patient suffering from pancytopenia (low number of white and red cells as well as platelets). It is responsive to cytokines, but for the survival of the cells, addition of GM-CSF (granulocyte-macrophage colony-stimulating factor) and IL-3 to the medium is required (Yang *et al.*, 2004).

Application in didactics:

- studying cellular response to different cytokines
- studying cell signaling (most notably the cytokine signaling mechanisms)

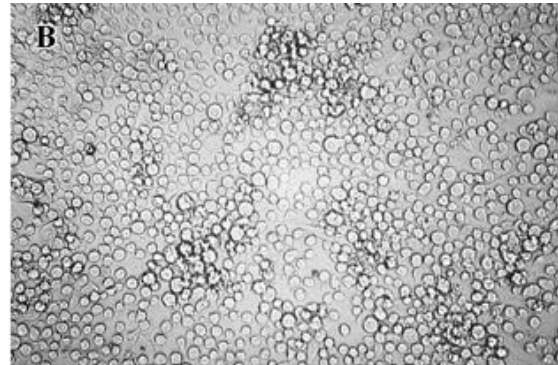


Figure 4. TF-1 cell line from (Kitamura *et al.*, 1989)

HL-60 cell line

It is a myeloid progenitor cell line that can act as a model for granulocytes (most notably neutrophils) monocytes or macrophages. In order to obtain these specific types of cells, the HL-60 cell line needs to be differentiated. Addition of DMSO (Dimethyl sulfoxide) or retinoic acid will result in the formation of granulocyte-like cells. Treatment with PMA results in the differentiation of the HL-60 cell line into monocyte- or macrophage-like cells. It is possible to obtain a specific type of granulocytes - eosinophiles (granulocytes involved in allergic and parasitic response) - by stimulating cells with GM-CSF (Gallagher *et al.*, 1979).

Application in didactics:

- studies of the various differentiation processes (they are multipotent cells)
- studying the functions and properties of eosinophiles

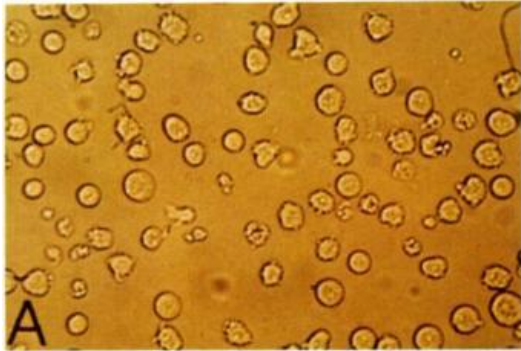


Figure 5. HL-60 cells from (Gallagher *et al.*, 1979)

KG-1 cell line

The myeloid cell line KG-1 was obtained from a patient suffering from acute myeloid leukemia. These cells, upon stimulation with an activating agent (such as PMA and ionomycin), differentiate into the so called dendritic-like cells that exhibit many features and functions of dendritic cells and are characterized by a distinctive morphology (they form characteristic cytoplasmic projections) and increased adhesion. The line KG-1 has low sensitivity to cytokines (such as TNF- α – cytokine called tumor necrosis factor α). They have a low ability of phagocytosis and mediocre efficacy in the activation of T cells (Teobald *et al.*, 2007; Koeffler *et al.*, 1980).

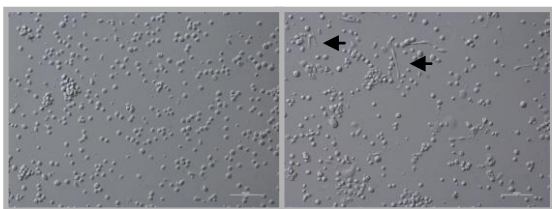


Figure 6. Undifferentiated KG-1 cells on the left; differentiated dendritic-like cells on right (cytoplasmic projections pointed with arrows) (photo by Michal Zarzycki)

Applications in didactics:

- studying the functions and properties of dendritic cells
- phagocytosis
- antigen presentation and T-cell activation

MUTZ-3 cell line

The MUTZ-3 is a cell line that is derived from a patient with acute myelomonocytic

leukemia and exhibits properties of monocytes. The line is cytokine dependant for its survival; it requires IL-3 or GM-CSF in the medium. After stimulating the cells with GM-CSF and IL-4, they differentiate into dendritic cells in the same manner as it happens during differentiation of human monocytes into dendritic cells *in vitro*. The line is quite expensive and difficult to culture, but is one of the best models of human dendritic cells (Hu, *et al.* 1996; Masterson, *et al.* 2002; Rasaiyaah, *et al.* 2009).

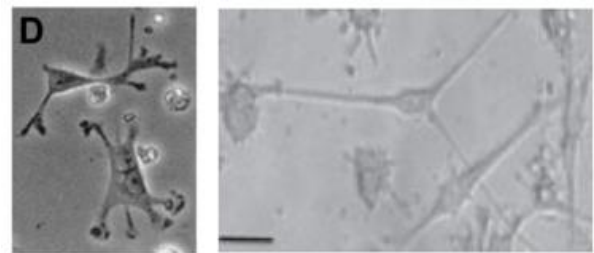


Figure 7. Differentiated MUTZ-3 cells with dendritic cells morphology left picture from (Masterson *et al.*, 2002) and right from (Rasaiyaah *et al.*, 2009)

Applications in didactics:

- studying the functions and properties of different subsets of dendritic cells (e.g. dermal cells, Langerhans cells)
- phagocytosis
- antigen presentation and T-cell activation
- cytokine responses
- differentiation process

K562 cell line

The K562 is a myeloid leukemia cell line. Cells can spontaneously gain properties of early stage erythrocytes. They do not express the MHC (major histocompatibility complex) molecules. That means that the natural killer cells (NK cells) will identify them as non-self cells and destroy them. (Lozzio *et al.*, 1975; Klingemann *et al.*, 1996; Zhang *et al.*, 2007)

Application in didactics:

- cytotoxicity assays with NK cells
- studying the early stages of red cells differentiation

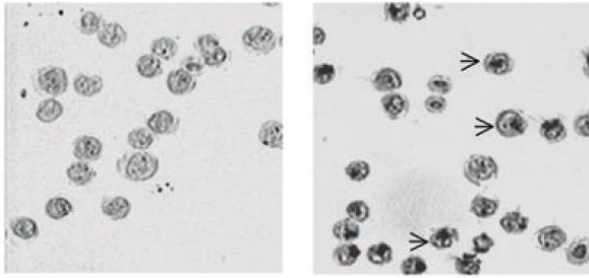


Figure 8. K562 cells; undifferentiated culture on left, differentiated erythrocytes on right from (Zhang *et al.*, 2007)

NK-92 cell line

The NK-92 is yet another myeloid leukemia cell line that displays properties of activated NK-cells. IL-2 is necessary for these cells to grow; they die within 72h when deprived of IL-2 (Klingemann *et al.*, 1996; Gong *et al.*, 1994; Edsparr *et al.*, 2009).

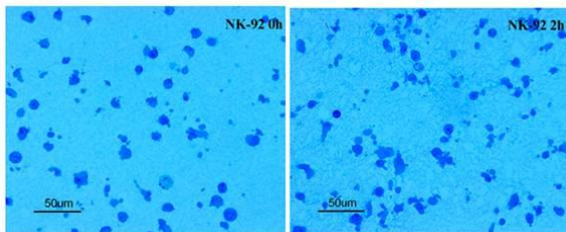


Figure 9. NK-92 cells shown during different life span from (Edsparr *et al.*, 2009)

Application in didactics:

- studying the properties and functions of NK-cells
- cytotoxicity assays with K562 cell line

CL-01 cell line

The CL-01 cell line is a B lymphocyte cell line, which was immortalized through transformation with Epstein Barr Virus. The cells display the same properties as native B cells. They can undergo hypermutation in the area of antibody genes, are capable of antibody class switching, and complete differentiation *in vitro* (Cerutti *et al.*, 1998; Zan *et al.*, 1999).

Application in didactics:

- studying the mechanisms of B cell differentiation and survival during antibody responses
- antibody production and secretion
- studying gene regulation of B cells
- studying antibody class switching

Summary

To summarize, cell lines are often used as models for studying human diseases, abnormal cell functions, or basic science. One of the greatest advantages of these cell lines is that the majority of Bachelor or Master students could easily maintain such cell lines and perform their own experiments with them. They require minimal training, are easily accessible, and allow performing and learning various biological processes. An important issue when conducting research is funding. Thanks to the almost indefinite growth, the cell lines are very cheap. Apart from the initial purchase cost, only fresh medium is required to keep them growing in terms of money. There is also the possibility to freeze the cells so just they are kept for later, e.g. next academic year.

An additional benefit of using cell lines is that they are available at any given moment in almost any necessary quantity. One exception is when the cells are thawed out from the frozen stock. It is worth keeping in mind that they need around 1-2 weeks to accommodate to a new environment.

Cell lines provide an excellent tool for research and didactics. Students can try different new techniques and investigate cell functioning. Cell culture techniques are required in today's biological science, so giving an opportunity for students to use this method in their projects will be of a great benefit. Finally, our conclusion is that studying a very complicated biological process is no longer limited to qualified, well-equipped personnel, and no longer

requires high amounts of funding, thanks to the availability of cell lines.

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A Constructivist Learning Environment in Science Classes at Polish, Turkish and Bulgarian High Schools

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This cross-national research study is entitled: "In the past and now: Constructivist practices in teaching chemistry - Bulgaria, Balkans and Europe. The purpose of the research was to assess science secondary classroom environment in terms of constructivist approaches, specifically to explore the high school science classroom of a constructivist teacher and examine how constructivist-based teaching influences students' learning of chemistry in Bulgarian and neighboring schools. The study was conducted at international and state schools in Tirana (Albania), Pristina (Kosovo), Bucharest (Romania), Bielsko - Biala and Warsaw (Poland), Vienna (Austria) and Istanbul (Turkey). The questionnaires have been given to 1127 secondary school students and 27 teachers. The data collection methods for students were three surveys: What is happening in this class? (WIHIC); Constructivist Learning Environment Survey (CLES); and Modified Attitude Scale Modeled on Test of Science Related Attitudes (TOSRA). For teachers, we used the Teacher Pedagogical Philosophy Interview (TPPI). The results show that the majority of the surveyed teachers practise a blended, traditional-constructivist type teaching. Their students also placed them into this category. In this study, the survey results from Polish, Turkish and Bulgarian schools have been analyzed in more detail.

Това проучване е част от международно изследване, озаглавено „В миналото и сега: Конструктивистки практики в обучението по химия - България, Балканите и Европа“. Целта на изследването е да се оцени учебната среда в природните науки в гимназиалните класове от гледна точка на конструктивисткия подход, да се опознае гимназиалната природонаучна класна стая на конструктивисткия учител и да се разгледа как конструктивистко - базирано преподаване влияе върху учениците и тяхното обучение по химия не само в българските училища, но и в съседните страни. Проучването е проведено в международни и държавни училища в Тирана (Албания), Прищина (Косово), Букурещ (Румъния), Биелско - Бяла и Варшава (Полша), Виена (Австрия) и Истанбул (Турция). Досега въпросниците са били дадени на 1127 ученици от средните училища и 27 техни учители. Методите за събиране на данни за учениците са три анкети - Какво се случва в този клас? (WIHIC), Изследване на конструктивистка учебна среда (CLES) и модифицирана скала на нагласите моделирана върху теста за научните нагласите (TOSRA) и за учителите: философско – педагогическа анкета (TPPI).

Тъй като проучването за нагласите на учителите по природни науки към конструктивистка учебна среда вече е реализирано в България, резултатите от наличните изследвания са били използвани в това проучване. Резултатите показват, че по-голямата част от анкетираните учители практикуват смесен, традиционно- конструктивистки тип обучение. Техните ученици, според проучването с CLES също ги причисляват към тази категория. В това проучване, резултатите от проучването от полски, турски и български училища са анализирани по-подробно.

Тази публикация е изготвена с финансовата помощ на Европейския социален фонд по проект № BG051PO001-3.3.06/0026. Илия Невенов Емилов носи цялата отговорност за съдържанието на настоящия документ, и при никакви обстоятелства не може да се приеме като официална позиция на Европейския съюз или на Софийски университет "Св. Климент Охридски", Факултет по педагогика.

Keywords: Constructivist teaching approach, science education, teaching chemistry, cross- national study

Introduction

The declining popularity of science among students, including chemistry, is a global trend (Toshev, 2007). The application of the constructivist approach is a better and more interesting way of teaching that can help students to understand abstract concepts in chemistry. Student learning in a constructivist-learning environment is one of the modern trends of continuous reforms in education and science (Tafrova-Grigorova, *et al.*, 2012). Constructivism in education seeks to address how people learn and the "nature" of knowledge. Constructivism considers knowledge as something that is acquired, and is constructed in the mind of the individual, and therefore cannot simply be transferred from one person to another. The new knowledge is built on the basis of prior knowledge and experience of the individual as a result of purposeful actions in a particular situation.

The most prominent representatives of the constructivist philosophy as the basis for learning and intellectual development of man are: Swiss psychologist, biologist and epistemologist Jean Piaget (1896-1980); the Russian psychologist Lev Vygotsky (1896-1934); and, the American philosopher, founder of functional psychology and education reformer John Dewey (1859-1952) (Tafrova-Grigorova *et al.*, 2012).

Jean Piaget (1929, 1950, and 1952) introduced the constructivist concepts of assimilation and accommodation, which describe the way students construct their own meaning as they experience the world. Jerome Bruner (1966, 1971, 1986, 1990, and 1996) built upon the constructivist philosophies of Dewey, Vygotsky, and Piaget as he explored the process and the culture of education (Wagner, 2008).

During the 20th century, Swiss scholar Piaget (1896-1980) was one of the most influential proponents of constructivism (Brooks, 1999). Piaget was concerned with cognitive development and how knowledge is formed.

On the other hand, according to social constructivism, learning takes place through interaction with other students and teachers around the world (Vygotsky, 1978). Lev Vygotsky is famous with the theory for cultural-historical activity of dependence of mental development. According to this theory, knowledge formation is impacted through social experience. According to Vygotsky, concepts are designed individually by each child. They can be spontaneous and daily, and are formed from everyday life experiences and scientific knowledge achieved through formal schooling. The "learning process happens with emergence of new structures and improvement of old ones" (Выготски, 2005).

Social constructivism emphasizes the importance of context for understanding what occurs in the world. Knowledge is a human product that does not exist in the world without social intervention. Humans must construct knowledge when engaged in social activities (Kim, 2001).

The psychologist Bruner (1915-) also influenced the theory of social constructivism. His theory, like Piaget's, was based on cognitive development studies. He believed that learning is an active, social process in which students construct new knowledge based on what they already know. Teachers should involve their students in active dialog and encourage their students to make their own discoveries (Bruner, 1966, 1973).

Psychologist Ernst von Glasersfeld (1917-2010) is typically associated with radical constructivism. It is termed radical since it

is so different from conventional constructivist learning theory, which assumes there is a reality that one must discover. With radical constructivism, knowledge does not fit an ontological reality; it is an individual ordering of the world based on personal experience (Busbea, 2006). Von Glasersfeld was influenced by the theories of Piaget. He also believes knowledge is actively received either through communication or through the senses and connects to previous knowledge (von Glasersfeld, 1989).

Nearly a century ago John Dewey (Dewey, 1915, 1916, 1938) laid out a progressive new approach to education. He believed that experience is the best education and created a system that would focus instead on learning-by-doing. If Dewey believed that all education is experience, then Lev Vygotsky (Vygotsky, 1978, 1986, 1997) believed that all experience is social. It follows then that all education is social (Wagner, 2008).

These theories have clear points of disagreement with each other. This paper will focus on both cognitive and social constructivist theories as they both contribute to understanding a constructivist science classroom environment.

Cross-National Studies

The research was conducted in six countries. In the present study the results from the previous Bulgarian investigations is discussed with the findings from Polish and Turkish science classroom environments. According to Barry Fraser (Fraser, 2012)

Science education research which crosses national boundaries offers much promise for generating new insights for at least two reasons. First, there usually is greater variation in variables of interest (e.g. teaching methods, student attitudes) in a

sample drawn from multiple countries than from a one-country sample. Second, taken - for - granted and familiar educational practices, beliefs and attitudes in one country can be exposed, made 'strange' and questioned when research involves two countries (p.1229).

Methodology of Research

Aim, questions and tasks

The **aim** of the study is to investigate the science classroom environments in Bulgarian and other European schools. For this purpose it is necessary to seek teachers' and students' views on the application of constructivist-based teaching and learning practices and thus to explore the high school science classroom environment.

The research questions are:

1. What are the students' perceptions of the science classroom?
2. What is the teachers' pedagogical philosophy of secondary science teachers?
3. Do the science teachers apply constructivist teaching approach in their classroom?
4. What are the current characteristics of constructivist approaches in Bulgarian, the Balkan and European schools?

The research tasks are:

1. To conduct a survey of samples of science teachers and their students in some European countries including some schools from the Balkans (Table I).
2. To explore patterns that emerged after close observations and careful documentation.
3. To analyze the survey results and to draw conclusions about constructivist-based teaching in high school science classroom environment.
4. To propose recommendations for future projects, initiatives and studies.

The research instruments

Different instruments have been used (QTI, SLEI, CLES, WIHIC, TPPI) by educational researches to identify the characteristics of constructivist learning environment (Tafrova-Grigorova *et al.*, 2012a). The instruments used to collect student data were: What is happening in this class? (WIHIC); Constructivist Learning Environment Survey (CLES); and, the Modified Attitude Scale Modeled on Test of Science Related Attitudes (TOSRA). For teachers, the Teacher Pedagogical Philosophy Interview (TPPI) was conducted. These instruments were chosen because other researchers have used them and their validity has been established.

In this study of the research for Polish and Turkish schools, the TOSRA and TPPI questionnaires were applied.

The Test of Science-Related Attitude, (TOSRA) (Fraser, 1981), is the most widely-used attitude instrument in science education research today (Fraser, *et al.*, 2009). TOSRA clearly defines each of the constructs to be measured by providing distinct subscales based on Klopfer's (1971) classification of students' attitudinal aims: (1) attitude to science and scientists, (2) attitude to inquiry, (3) adoption of scientific attitudes, (4) enjoyment of science learning experiences, (5) interest in science, and, (6) interest in a career in science. These six constructs are clearly defined and each represents a

different 'object' about which students are likely to form opinions (Fraser *et al.*, 2009).

In order to investigate the relationships between the learning environment and students' attitudes in the investigated countries, the TOSRA tool was selected. The final version of TOSRA measures seven distinct science-related attitudes among secondary school students: (1) Social Implications of Science; (2) Normality of Scientists; (3) Attitude to Scientific Inquiry; (4) Adoption of Scientific Attitudes; (5) Enjoyment of Science Lessons; (6) Leisure Interest in Science; and, (7) Career Interest in Science (Fraser, 1978 and 1981). This instrument is composed of seven scales and each scale is composed of 10 items. The response scale is a five-point Likert scale and has response categories ranging from Strongly Agree to Strongly Disagree. Teachers and researchers have found that the TOSRA is useful and easy to use for measuring and monitoring progress of science-related attitudes of individual students or whole classes of students. In particular, TOSRA also makes it possible for researchers and teachers to obtain a 'profile' of attitude scores for a particular group of students (Fraser, *et al.*, 2009). In the present study "Enjoyment of Science Lessons" scale with 10 items has been administered to students. The responses were given by on a three-level Likert scale: 1- Disagree, 2- Not sure, 3- Agree. Maximum score per item is 3 and total maximum score is 30.

Table 1. Number of surveyed students and teachers – distribution of the schools according to the countries.

Country	Students	Teachers
Albania	206	8
Austria	94	1
Kosovo	98	1
Poland	286	4
Romania	104	4
Turkey	339	9
Total	1127	27

Data on the composition of the teachers' sample is given in Table II. The distribution of the teachers by age, pedagogical internship and sex has been done in this way to comply with the total for the countries.

The Teachers Pedagogical Philosophy Interview (TPPI) is a questionnaire which was designed and developed by Richardson and Simmons (Richardson, 1994). The teachers' responses to the survey questions provide information on their views and perceptions of their role in science teaching as well as their relationships with students in the learning process (Tafrova-Grigorova *et al.*, 2012a). In order to obtain more detailed and concrete answers concerning teaching and learning methods, we adapted the TPPI by reducing it up to six questions (Boiadjieva, 2009).

These six questions can be divided into two groups. The first group of questions is related to their way of teaching. Respondents have to describe themselves as teachers and to highlight their professional qualities. The answers of the second group questions require information how both teachers and students learn.

The evaluation and scaling is discussed in the previous research (Tafrova-Grigorova, *et al.*, 2012a):

The 30 surveyed teachers answered questions in written individually and independently from each other. Each answer is evaluated by four experts. Three of them are university professors with experience in the field of chemical education and one is novice teacher (Tafrova-Grigorova, *et al.*, 2012a). Evaluation is determined by the scale presented in Table II. Experts independently ranked the teachers' responses from 1 to 5. Responses with a score of 4 or 5 relate to constructivist, inquiry-based and student-centered

classroom, 1 and 2 - to traditional teacher-centered teaching, 3 - to a transitional - between traditional and constructivist environment (Boiadjieva, 2009).

For the analysis of the surveys from the schools in Poland and Turkey, the same process and scale was adapted.

Background of research

The basic parameters of the study are the following:

- Time Frame: October 2012 - May 2013.
- Target group: high school students, science teachers (chemistry, biology and physics).
- Volume and composition of the sample: The study has been conducted at international schools and state schools in Tirana (Albania), Pristina (Kosovo), Bucharest (Romania), Bielsko-Biala and Warsaw (Poland), Vienna (Austria) and Istanbul (Turkey).
- The questionnaires have been given to 1127 secondary school students and 27 teachers. 286 Polish students and four Polish science teachers, and 339 Turkish students and nine Turkish science teachers participated in the study. In our previous research 30 teachers were surveyed from 28 schools of 9 areas of Bulgaria.

Procedure:

In Poland the survey was conducted in two cities: Bielsko-Biala and Warsaw. The school in Bielsko-Biala was a public school and the one in Warsaw an international school. In Bielsko-Biala, the WIHIC, CLES and TOSRA questionnaire was given to 195 students and one teacher answered the TPPI questions. In Warsaw, these questionnaires were administered to 81 students and three teachers. In Istanbul, Turkey 339 students and 9 teachers participated in the survey from four public

and one international school. The distribution of the students and teachers

are given in Table I and only students in Table III.

Table II. Composition of the teachers' sample.

Characteristics		Al	A	Ks	Pl	Ro	Tr	Total
Age	up to 30 years	4		1	2	3	1	11
	31 – 40 years	3			1	1	1	6
	41 – 50 years		1				6	7
	over 50 years				1		1	2
Pedagogical internship	up to 10 years	7		1	3	4	2	17
	11- 20 years		1		1		4	6
	21- 30 years						3	3
	over 30 years							
Sex	women	6	1		2	1	7	17
	men	1		1	2	3	2	9

Legend: Albania: Al, Austria: A, Kosovo: Ks, Poland: Pl, Romania: Ro, Turkey: Tr

In the formerly mentioned previous research on “Science Teacher’s attitudes towards constructivist environment: a Bulgarian case” a survey was conducted as a part of our research activities on the constructivist science teaching practices in the Bulgarian schools. The Teacher Pedagogical Philosophy Interview (TPPI) was applied as a research instrument by adapting and reducing it up to six questions. The sample of research consisted of 30 secondary science teachers at 28 schools from 9 areas of Bulgaria

General results of the present survey

Data resulting from the TPPI (administered to the teachers) and the TOSRA (administered to their students) will be discussed. From a total of 1127 students surveyed with the TOSRA questionnaire, there are 1040 valid students (Figure 1). The measures of the central tendency: mean score, median, mode and the standard deviation for the total of 10 items of all 1040 are calculated by the Statistical Package for the Social Sciences

(SPSS). The reliability is 0.870 according to Cronbach's Alpha. For the test of Homogeneity of Variances for TOSRA, the Levene statistic is 6.35. The ANOVA results for TOSRA is less than 0.05.

TOSRA mean score and standard deviation of the sample of 1040 students are shown in Table III.

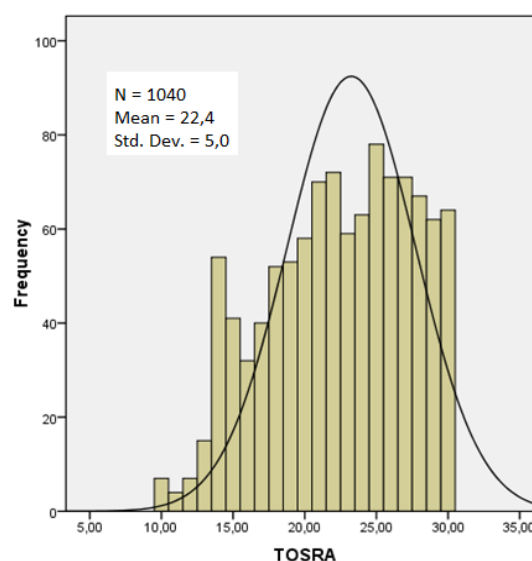


Figure 1. The distribution of the total scores for the ten TOSRA items.

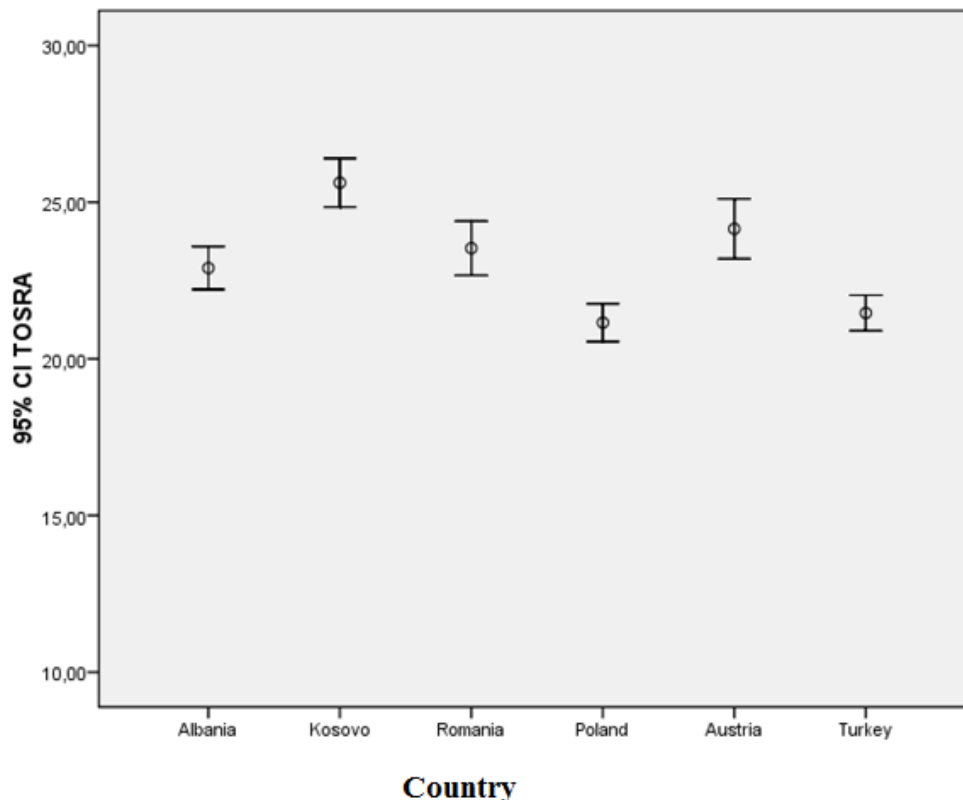


Figure 2. Mean total score of schools by countries for a confidence interval of 95%.

Table III. The distribution of Polish and Turkish students. Legend: 1,2,3 : High school classes; 1,2,3-JHS: Junior high school classes;10,11,12:High school classes. 1,2 and 3 refer to 10, 11 and 12 grades.

Country	City/School	Class	Number of students
Poland	Bielsko-Biala/Public School	1	-
		2	115
		3	80
	Warsaw/international school	1-JHS	14
		2-JHS	12
		3-JHS	16
		1	11
		2	23
Turkey	Istanbul – Beylikduzu/International School	10	57
		10	50
	Istanbul – Besiktas/ Public School -1	11	47
		12	27
		10	21
	Istanbul - Besiktas / Public School - 2	11	22
		12	24
		11	21
	Istanbul - Besiktas/ Public School -3	12	23
		11	20
12		27	
Istanbul - Besiktas/ Public School - 4	11	20	
	12	27	

Table IV. TOSRA mean score (\bar{x}) and standard deviation (s) of the sample of 1127 students.

	\bar{x}						s						All
	Al	A	Ks	Pl	Ro	Tr	Al	A	Ks	Pl	Ro	Tr	
Q1	2,40	2,46	2,77	1,91	2,42	1,92	0,72	0,73	0,52	0,69	0,74	0,76	0,69
Q2	2,15	2,45	2,47	1,95	2,29	2,08	0,75	0,67	0,69	0,78	0,73	0,79	0,74
Q3	2,28	2,48	2,66	2,11	2,46	2,11	0,80	0,66	0,56	0,77	0,72	0,83	0,72
Q4	2,19	2,38	2,47	2,06	2,36	2,19	0,81	0,82	0,75	0,88	0,79	0,83	0,81
Q5	2,82	2,63	2,88	2,66	2,70	2,80	0,41	0,63	0,36	0,60	0,59	0,47	0,51
Q6	2,91	2,83	2,90	2,81	2,80	2,86	0,33	0,41	0,30	0,48	0,51	0,41	0,41
Q7	1,21	2,53	2,59	2,10	2,28	2,01	0,74	0,69	0,62	0,76	0,73	0,78	0,72
Q8	2,01	2,24	2,53	1,83	2,10	1,87	0,75	0,77	0,69	0,78	0,80	0,78	0,76
Q9	1,66	1,76	1,94	1,65	1,84	1,70	0,74	0,80	0,81	0,79	0,77	0,84	0,79
Q10	2,18	2,31	2,42	2,05	2,25	1,95	0,72	0,65	0,75	0,74	0,74	0,79	0,73
\bar{x}	2,18	2,41	2,56	2,11	2,35	2,15							

Discussion

Polish and Turkish students gave nearly maximum scores to the question: “Finding out about new things is important,” the TOSRA. The standard deviation is low and close for both of the countries. This result shows that the great majority of the students from these countries unanimously wish to discover and acquire new scientific knowledge.

On the other hand Polish and Turkish students gave low scores to the question: “We should have more science lessons each week.” The students do not wish to have more lessons, but they would be happy if their present lessons were more interactive, attractive and interesting.

The highest value of the standard deviation for question number four, “Science is one of the most interesting school subjects,” the 286 Polish students and the 339 Turkish students are heterogeneous in their preferences and attitudes towards science.

The Polish and Turkish students have very close mean scores for all these 10 questions (see Table IV and Figure 2)

According to the teachers’ answers to the first question from the TPPI, “Describe yourself as a teacher”:

- 42% of them give priority to the interaction with students
- 26% of them describe themselves as professionals
- 16% of them put emphasis on personal qualities
- 16% of the teachers did not comment on this question.
- There is a tendency to have a student-centered science classroom.
- A teacher from Poland describes himself as “I am a teacher full of passion and commitment, I am professional and well prepared to teach.”
- A teacher from Turkey says, “I am a teacher who tries to keep up with the developments, and to carry out all the responsibilities desired by

regulations and am a normative teacher". In the constructivist classroom the students are active.

- The teacher is a mediator.

According to the data from the evaluation form:

- 1/3 of the Bulgarian teachers describe themselves as professionals
- almost 30 percent prioritize their interaction with students.
- About 1/4 put emphasis on personal qualities.
- Only three Bulgarian teachers do not assign themselves in teacher-centered teaching style, but they are so depicted by the actions of students.

To the second question, "What are your main strengths as a teacher?":

- 66 % of the teachers rely on the class inclusion of their students by making experiments, participating in projects, experience and games.
- 34 % of the teachers give priority to their professional and personal qualities.
- One of the Polish teachers says, "As I am preparing my PhD thesis, I am in the permanent contact with chemistry and I improve my chemical and pedagogical knowledge. Teaching chemistry in a new way through experiment and everyday applications allows students for better understanding world around, teach them of logical thinking and drawing conclusions."
- A Turkish teacher says, "To have a positive communication with the students, to be able to analyze their strengths and weaknesses."
- Over half of the Bulgarian teachers rated with a score of 3 which means that for them the good teacher combines the best qualities of a traditionalist and constructivist

teacher, because he is open to students.

- Four of the Bulgarian teachers rely on the skills and experience of their students.
- As in the previous question, about 1/4 of the teachers give priority to their personal qualities.

Questions number 3, 4, 5 and 6 seek responses on how teachers and their students learn. To the third question, "How do your students learn best?":

- 50 % think that their students learn best by interactive lessons, discovery learning, pair work, group work, discussions, doing and experiencing.
- The rest of the teachers think that their students learn by taking notes, writing, doing their homework and testing.
- 25 Bulgarian teachers explicitly state that their students learn mostly through their own actions and their interaction with the teacher, which is expressed in: "more exercises, inclusion in experimental work, problem solving," "an accessibly presented curriculum," "solving problems planned for the lesson," "and use of presentations to present the new curriculum."

To the next question, "How do you, as a teacher, learn best?":

- Some of the teachers answered "Similar as my students, I learn best by meeting chemistry in everyday life"
- One Turkish teacher said "I learn by using different sources, repeating, updating my knowledge and catching memorability in visual studies."
- On the other hand, there is a tendency of teachers to learn by taking notes, reading, watching

video clips or movies and solving problems.

- Almost half the Bulgarian teachers consider the use of visualization and further reading as a priority in their preparation and method of learning.
- Thirteen teachers (except the ones mentioned above) point out an important way for them to learn and exchange experience with colleagues is attending seminars, conferences, and training for additional qualifications.

These answers of the teachers are indicative for the trend in the change of the profile of the Bulgarian teacher in the direction of stepping out from the traditional role in the learning process.

To question five, “What are the characteristics of a good learner?”:

- One Turkish teacher says, “If a person can comment on the subject correctly, it means that he/she has learnt.”
- Most of the teachers consider that a good learner should be patient, good listener, open-minded for new ideas, striving to discover new things, analytical, logical and explorer.
- As the main features, Bulgarian teachers indicate “to be competent on various issues,” “not to reproduce, but to think and understand the studied material, “concentrated, thorough, persistent, and continuous in learning.”
- Half of the teachers indicate traits of the personality that are definitely formed in the constructivist learning environment. Views in this direction are: “to be motivated to explore new, unknown,” “to be able to lead the debate with facts and arguments,” “to be inquisitive and to evaluate the usefulness of knowledge,” “to decide cases and

to show initiative in activities carried out in class and outside it,” “to be willing to express.”

These answers from the teachers are a good sign of willingness and desire to form such qualities in their students. This can be realized differently from the traditional learning environment provided with new approaches and teaching methods

To the last question, “How do you know that your students understand the curriculum content?”:

- Almost all of the teachers who responded said that their students understood the curriculum content by asking questions, giving quizzes and tests.
- A Polish teacher responded, “I ask them if they understand, check them on organizing projects, quizzes and tests.”
- A Turkish teacher answered, “If I can get the desired answers in the quizzes, exams or the questions I ask, it means that they learnt well. At the same time, they should be able to apply what they learn in the classroom in their daily life.”
- Some of the teachers check during the lesson and some of them at the end of the lesson.
- Two of the teachers give small projects or experiments to check the studied material.
- As the basic criteria, half of the Bulgarian teachers indicate “ability to solve logic and test tasks to deal with practical exercises,” “to answer questions related to curriculum,” “to place the individual tasks,” “through lectures and discussions with students on learned curriculum content.”
- An important criterion for success to one-third of Bulgarian teachers

is the extent to which the students apply new knowledge in different situations.

Almost as many are the teachers for whom the results of examinations and tests are conclusive evidence for understanding the studied material.

Limitations

Cross-national studies are usually challenging since it is necessary to get permission from the authorities to be able to conduct them in schools. Also the schools should be chosen carefully to map the whole nation. Obviously, this process needs to be given a lot of time. In this research, the surveys were given to a limited number of schools from certain areas of the countries, therefore the results cannot be generalized to the whole country.

Factors that could affect the results

In this part, some data and arguments will be mentioned about the education system and curriculum in these three countries, as the system and the requirements of the state may affect the teachers' behavior and practice.

First, the surveyed schools in Istanbul, Turkey are representative of prestigious schools. The students are enrolled into these schools after a national entrance exam. The average scores of the accepted students are very high. Most of the students in these schools prefer to be in a science class, because in order to be an engineer, doctor and IT specialist, they need high scores from their science courses for the national university exam. If it is considered that there are 2 million university candidates and just about one half million are placed, the great competition is inevitable. This leads to a test-orientated educational system. Besides the school, there are also numerous educational centers that prepare the candidates to the university exam. Nowadays, there is an issue with the exam

preparation educational centers is in agenda in Turkey. Student-oriented learning and inquiry-based learning require more time. Class activities are directed instead towards problem solving and test items instead of experimental practices and interactive techniques. The students from the surveyed schools are generally in the top 1% of the university exam results. They are accepted by prestigious universities in Turkey and abroad with scores from SAT and TOEFL. It cannot be claimed that a test-oriented educational system increases the success of the students. On the other hand, it cannot be claimed that student-centered classroom and inquiry-based learning will increase the success of the students.

Second, in Bulgaria, Poland and Turkey, every three or four years the curriculum is changed and teachers are obliged to adapt their yearly plans to it. In most cases, this adaptation brings about a decrease in the number of experiments and activities in the lessons. In many cases, students enter the university without any practical experience. These students may face difficulties in lab lessons and can struggle with the subjects. All of these factors may lead to unqualified specialists and individuals that work extremely hard in their first years in order to survive in their field.

Third, in these countries, there is a tendency to diminish the number of science lessons in the curriculum. For example, if this year a science class (physics or chemistry) has three or four hours lessons in a week, in the following year they will be two or three hours. After the Polish educational reform, there has been an improvement in education according to PISA. On the interviews with the teachers, it has been clarified that the decrease in the number of lessons will affect the preparation of science profiled students for their career.

Conclusion

The results from TOSRA show that Polish and Turkish students have close perceptions of science classroom according to the mean scores of questions 2, 4 and 7 which manifest average enjoyment, fun and interest of students. In the same questions the standard deviation is high which means that there is a heterogeneity and anonymity in their perceptions.

TPPI results of the survey show that in both sets of questions, the answers of the majority of surveyed Bulgarian teachers rank in the middle of the scale, which characterizes them as teachers of traditional – constructivist type. Their students, according to the study with CLES, also count them into this category. Despite the pursuit of practice the control in the process of learning, the attitude of teachers towards change is obvious.

With 66 % result of the question number two, most of the Polish and Turkish teachers reveal themselves as constructivist teachers. On the other hand, the results of question number three show that half of the teachers, in fact, do not apply the constructivist approach in their lessons because of the reasons mentioned above.

The discussed results show that some of the teachers apply constructivist teaching approach in classroom while some do not. Based on the interviews with the teachers it can be concluded that there is a tendency of the European teachers to apply a constructivist teaching approach and the students are ready to initiate and collaborate a constructivist science classroom environment.

The analysis of the survey will continue with the other instruments CLES and WIHIC which are not discussed in this article to get a more precise picture of

science classroom environment with the previous contribution of Telli (2010) on typologies in classroom environments and other studies.

It is expected that the study will make some contributions to create a basis for the development of worldwide partnership in the field of science education, practitioners, and policy makers and to the officially declared “European year (2013) of citizens” by EU.

The necessity to continue the research on the development of understanding and interest in chemistry by implementation of modern teaching methods and strategies is crucial.

In this context this study will be useful for universities, schools, and other educational and cultural organizations in the realization and development of partnerships and international cooperation in theory and practice.

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Promoting Girls' Voices: Using Cogenerative Dialogues (Cogens) in Science

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Teachers and researchers have introduced cogenerative dialogues as a pedagogical research strategy to examine science teaching and learning by the generation of local knowledge and theory. This paper discusses how cogens are examples of an interstitial space that provides participants the opportunity to act agentially to challenge and change societal structures. When focusing on issues that impact girls' science learning, cogens may be viewed as feminist pedagogy|research that supports girls' agentic actions to engage in science and to incorporate science into their identities. Silence is also considered as an agentic act by girls either within cogens and in choosing not to participate in cogens. This material is based upon work supported by the National Science Foundation under Grant No. (HRD 1036637).

Keywords: girls; cogenerative dialogues; science; interstitial spaces, feminist pedagogy, feminist research

Introduction

What are cogens?

Urban science education researchers and teachers conceived of cogenerative dialogues (cogens) as a process/mechanism to provide students and teachers the opportunity to address issues of teaching and learning science in a non-threatening space. The goal of cogens is to generate local knowledge of students' science learning and teachers instruction to support that learning (Bayne & Scantlebury, 2013). The initial engagement of cogens occurred in urban high school science classrooms, where teachers, students and researchers engaged

in discussions about how to improve science teaching and learning. Since their initial inception, instructors have used cogens in a range of education settings.

Cogens usually have between 3-5 participants. Participants may self-select to become involved or a cogen member (often the teacher) will purposefully select students who bring a range of cultures, attitudes and practices to the discussion. In arranging cogen participation the facilitator may begin with the question, 'Who is the most different person from me?' as a guide in identifying the next participant. Then, one could operate

serially and contiguously on subsequent selections with the goal of bringing a diverse range of perspectives into the discussion. Cogens may be formally planned, that is, meeting each week at a set time and place, or evolve from the circumstances from daily social interactions between students and teachers, or both approaches can be implemented (Bayne & Scantlebury, 2013).

Theoretical Framework

Science classrooms are fields where culture is produced, reproduced and enacted through participants' actions and the ability of those participants to access the resources that exist within the culture. Cogens are situated within the social and cultural context of the classroom. They can be examined using the concepts of social, cultural and symbolic capital (Bourdieu, 1986) and how these different forms of capital impact participant's agency and structures. Agency and structure exist in a dialectical relationship which contribute to how participants 'do' culture (Sewell, 1999).

Agency is viewed as in a dialectical relationship with structure, and as such actors with agency have the power to influence structures. Structures are composed of schema and resources. The resources are material and human. One's agency is determined by the different types of capital that are generated by the social field, namely, social, cultural and symbolic capital which provides an actor the capability of interacting and modifying structures. For example, in a class, there are students who have high social capital that provides them the agency to dominate situations such as the classroom discourse. In some circumstances, students with cultural capital, that is those with good science knowledge, may use that capital to improve their social setting. For example, they might be asked to join a group or

selected as a lab partner, by a student with high social capital in order to improve the possibility of gaining good grades.

Cogens as interstitial spaces

Martin and Scantlebury (2009) note that cogens differ from conversations because of the explicit intent by participants to examine the socio-cultural context through purposeful discussions that generate local knowledge and theory about teaching and learning which in turn can produce new cultural knowledge. Cogens are a particular space where participants from different cultures interact and examine practice. These spaces are an example of interstitial spaces. Interstitial spaces exist between cultures and provide participants the location and flexibility to generate new knowledge, practices and theories (Hussénius, Scantlebury, Andersson, & Gullberg in press). In particular, interstitial spaces provide a location for one to develop a transgressive identity. Hussénius, Scantlebury, Andersson, & Gullberg (in press) discuss how that transgressive identity can act as a carrier, taking new practices and ideas into cultures. Others have noted that cogens can act as a third space, providing the context for participants to develop new practices (Bayne & Scantlebury, 2013), new culture and the opportunity to engage in discourse across cultural boundaries and barriers, e.g. student and teacher. In an interstitial space, participants share their cultural understandings and practices, and also acquire new practices that they can 'carry' into other cultural fields.

For example, within cogens, students can help teachers understand the issues both from within the classroom and outside, which impact their learning. Teachers can assist students to develop practices to improve their engagement and learning with

science. However, cogens are a unique cultural space, and as such have knowledge and practices. Cogens provide a space for teachers and selected to students to reflect upon and examine the space labeled 'science classroom'. In these discussions, the cogens' participants can generate topics for discussion, and local experience generated a few important 'rules' for the cogens. The rules stipulate that no one person's voice is privileged; cogens deconstruct the power differences between teachers and students in 'typical' urban high school. (LaVan, 2005; Scantlebury & LaVan, 2006). However, various social categories influence a participant's social, cultural and symbolic capital within a field. What cogens provide is a different cultural field, within science learning, from the 'traditional' classroom. Yet, further research is needed to illuminate how participants could change cogen structures to enhance learning and support their transgressive identities.

Gender and Cogens

Gender is a social category and impacts one's agency and other forms of capital, but one does not have 'gender capital'. However gender can influence the capital one attains in a field (Moi, 1999). Within fields, gender codes are subject to power relations and are field dependent, which can mean that they are uneven, or possibly discontinuous (McNay, 2000). In cultural settings, female gender reduces one's symbolic capital. Gender interacts with the micro, meso and macro structures of society (Risman, 2009) (Risman & Davis, 2013) and is category that is constantly shifting and changing (Segal, 2010) In academic discussions of gender, the discourse notes the influence of queer theory in establishing that there are a plethora of genders. Within pre-university, formalized schooling gendered practices remain overwhelmingly heteronormative.

For the purposes of this paper, gender is examined as existing on a feminine to masculine continuum and the girls, who have engaged in cogens, re-presented themselves, as heteronormative.

Reay (2010) argues that the identities students develop at school are constructed through what others make of us, and are also ascribed through what 'we are not'. School norms and practices strongly define societal norms and expectations, and, research has shown how these norms influence students' learner identities (Reay, 2010). Within cultural fields, participants' gendered identities impact the different forms of capital, and a gendered identity is mutable (McNay, 2000). As a social category, gender continues to influence who is viewed as a scientist and who is constructed as capable in science (Hussénius & Scantlebury, 2011). Given that science retains its strong, masculine, white image, many students do not identify with the subject (Scantlebury, in press). Cogens provide the interstitial space for a student to engage in a discourse about science and thus begin to develop an understanding of how s/he may engage with scientific practices and ways of being.

Cogens as Feminist Pedagogy/Research

The structure of and practices within cogens are intended to reduce power hierarchies between teachers and students, as well as provide a forum where students can give voice to their needs and concerns (Bayne & Scantlebury, 2013). Often feminists take a reflexive approach to research when identifying and reconciling power differentials between research 'subjects' or informants. Cogens can expand to a research strategy when the participants use the cogenerated knowledge to examine local learning contexts from theoretical

perspectives. Depending upon the parameters, their research could be feminist pedagogy or feminist research (Scantlebury & LaVan, 2006). The terms 'feminist pedagogy' and 'feminist research' have a range of meanings and interpretations dependent upon the feminist theory used to frame the research or inform the pedagogical practice. For feminist pedagogy, when the emphasis is on the feminist part of the phrase the pedagogical practice includes political, critical and praxis-oriented components. While if pedagogy is the focus, discussions focus on the practices that instructors use to teach and assess students, as well as examine the curriculum (Scantlebury & LaVan, 2006).

Feminist research examines how power structures impact female's lives, it gives voice and privilege to female perspectives, knowledge and lives, and, strives to transform the settings it has examined (Scantlebury & LaVan, 2006). Knight (2000) discussed the specific ethics associated with feminist research. She suggested that feminist research expects the researcher(s) to situate her/himself in the work to provide a deeper understanding, use the research outcomes to improve the participants daily lives, address inequalities, consider the roles and circumstances of all stakeholders when representing the research, and, reflect upon the new possibilities raised by the research.

Cogens can support feminist pedagogy or research under particular conditions, such as including only female participants, focusing the cogen on the circumstances impacting girls' science learning, and/or setting up a structure for girls to (re) voice) their position and perspectives on learning science (Scantlebury & LaVan, 2006). One version of cogens as feminist pedagogy|research could be to have only female participants.

Several urban teachers have used this approach, and girls have reported how the cogens provided the space to develop friendships. Often girls, especially in urban settings, do not have the opportunity to interact with each other outside of school, because families restrict their mobility out of concern for their physical safety (Scantlebury, 2005). Further, cogens can act as a forum to promote participants' consciousness raising about the unique circumstances and contexts that influence girls' learning experiences and teachers can begin to use the social resources generated among students to improve science learning in their classes.

Other cogens may involve girls and boys, however, to retain a focus on feminist pedagogy or research, the discussion would need to consider how gender influences students' learning and the teaching practices. A critical perspective using a gender as one of the social categories is a key for feminist research. However, including female and male students in cogens could also provide the space for students to generate new practices regarding gender and science.

Feminist researchers have also noted how participants may choose silence as an agentic act in response to a masculinist and risky world (Parpart, 2010; Ryan-Flood & Gill, 2010). Parpart (2010) suggests that in certain contexts, choosing silence and/or not to participate, is a survival strategy because using one's voice can place a girl or a woman at risk. Or, silence is used strategically to challenge patriarchal structures and as a subtle act to renegotiate gender hierarchies and practices (Parpart, 2010, p. 24).

Research could also focus on when and why students may chose to remain silent during cogens. To speak out, to use one's voice is

to engage in risk taking practices, especially when you are a member of an oppressed group. Arguably, while science remains the purview of white males, girls speaking out are challenging strong societal norms both in offering their perspectives on science and using their voices. In western cultures, in the gender norms around femininity, girls remain quiet. Researchers have warned that we should not privilege voice over silence, but examine the agentic potential of silence, gender, and power (Parpart, 2010).

While cogens can empower girls to articulate their learning needs, a critical challenge is understanding and respecting the students' cultural backgrounds. For example, because of their cultural backgrounds, some students' may be reluctant to critique those in authority or power positions, such as teachers. For English Language Learner (ELL) students, engaging in cogens offers different challenges. Silence from these students could be a reluctance to engage with language in a highly focused setting.

Currently, cogen research has not examined which students chose to nominate or are asked to participate in a group. Being asked to engage in a cogen could be viewed as a privilege and/or a subversive act. Nor, has the research focused on the non-verbal interactions and gestures that occur among participants.

Foregrounding of girls' voices and perspectives

Cogens are an interstitial space where girls can focus, talk and share their perspectives on science and learning with each other and their teachers. Within cogens, new understandings between and among participants can generate new practices and culture. The structure of cogens is intended

to reduce power hierarchies between teachers and students, as well as provide a forum where students can give voice to their needs and concerns. For example, Jen, a high school biology teacher arranged an all female cogen to address issues related to the girls' learning and engagement with science. As a teacher, Jen voiced her frustrations that the girls in her biology class did not engage with scientific practices, but rather the girls were usually in the back of the classroom talking, doing their nails, brushing their hair and doing whatever. In an interview, Jen said, And that's when I got upset because I didn't think they were doing science, let alone paying attention and contributing to class. (Jen, Interview 2005). From the girls' perspective, their science class was scheduled before lunch and as teenagers, they used part of class to groom themselves for the social interaction that occurred over lunch. As I have discussed elsewhere, (Scantlebury, 2007) a strong aspect of these girls' lifeworld was the importance of looking "flyy." Flyy girls have style, established through their clothing, earrings and coiffures, and, that style can garner them symbolic and social capital within their peer group. Aptitude in science and doing well in the lessons, were less important to Jen's female students. However, during the time they participated in the cogens, through the discussions, they realized they had unintentionally disrespected their teacher through the grooming practices. Conversely, Jen understood that she had a constrained view of what scientific practices were, and how students should act in science class. Jen observed that before the cogens, her view was that there were appropriate ways of participating in science, and that meant that it looked and sounded a certain way. Ultimately, that meant that the girls had to behave and act a certain way in the classroom when doing science. Said Jen,

“And more often than not, the girls that were in my class did not illustrate *these* practices of science.” Through the cogens, Jen and her female students generated new knowledge about science, each other’s lifeworlds and what are scientific practices. The girls began to engage in the science class by participating during the lab sessions, taking notes, and answering questions during the teacher’s explanations. The girls identified, for Jen, teaching practices that would help them understand science. Through the cogens, they also developed an understanding about what they could and should, do to learn science. Part of those practices was to become actively engaged in the class through asking questions, and doing the experiments. In her explanation about how to engage in class, Charnae illustrates another aspect of a female culture, that is, the role of assuming responsibility for others. Charnae noted that the more questions that you ask the more that it shows you are paying attention, “I mean, and then it helps you in the long run, don’t sit there and not know, that ain’t going to work, if you are too scared to ask questions and then, if you feel like you can’t ask questions, then hopefully you will have a friend like me who will ask for you.” (Charnae, Cogenative Dialogue, October 2004)

Confident and articulate, as Charnae engaged with thinking about science and constructing science into her identity, she also recognized that several of her friends in the class did not share her confidence. ‘Too scared’ to speak up and ask questions, what unfolded for this group of girls was the ‘othermothering’ practices that they often showed towards the boys in their class. Through the cogens, they developed a sense of community and developed friendships with each other that extended to ‘looking out for others’. As Patricia Hill Collins (1991)

described because of slavery, historically, African American children were often raised and cared for by females who were not their biological mothers. Known as ‘othermothers’ these females were typically too old or too young for manual labor in the fields or homes. They cared for the children, Collins (1991) has noted that mothering, caring and nurturing are shared duties within the African American culture, among female community members, which is different from a Eurocentric approach where mothering and child rearing are responsibilities that remain within a biological family. The assumption of responsibility to care for others who are not able to fend for themselves is a core precept in Black feminist culture.

Re-structuring teachers’ gendered practices using cogens

For over thirty years feminist research has focused on the socio-cultural climate within science classrooms and the gender norms and codes that teachers and students practice. Much of that research was located within white middle class settings (Scantlebury & Baker, 2007) and common themes were boys dominating the classroom resources, such as the teachers’ time, lab resources and the physical space. Girls revert to, and are expected to assume, caring, nurturing and domestic roles such as recording the data from lab work but not conducting the work or using the equipment, being expected by teachers and peers to complete domestic chores such as cleaning up laboratory benches, and nurture. More recently, classroom studies within urban settings and in diverse racial settings have found that these practices persist (Scantlebury, in press).

Many teachers have an unconscious practice of expecting girls to modify boys’ behavior, assist others in learning material and assume

a range of caring roles in the classroom (Scantlebury, 2007). Without active intervention from teachers, girls often do assume caring roles in science – they record results but do not manipulate equipment and clean up after a laboratory.

Cogens offer teachers and students space for examining their practices and to considering how gender shapes teacher expectations and girls' science learning opportunities. Cogens can also inform ways to restructure the class so that boys are expected to become responsible for their own learning. For example, four Chinese 7th grade girls commented during one of their cogens that the teachers always ask them to help boys who have missed school to catch up. The girls noted that they would like to concentrate on their own science learning. However “needing to explain something over and over again, [they] learn more science too” (Cogen, 3/10/11). After this cogen, the teachers agreed to change the group composite so that the girls were not always given responsibility for the boys' learning (Wassell, Martin & Scantlebury, in press).

Jen's cogens, with a group of girls from her biology class, led to her changing how she presented information and 'lectured' the class. The girls noted how quickly Jen wrote and talked and Jen shared how she was trying to cover the curriculum but found it difficult to engage students in question and answer sessions while presenting material and writing notes. The girls suggested that she could provide the notes, which they would copy, and then she could ask questions to help them understand the concepts. Jen agreed to this approach, but also told the girls that they needed to assume the responsibility for being focused while taking the notes and asking her questions

when they did not understand. Over the ensuing weeks, the girls became more engaged in science, asking questions and using their notes to answer questions (Scantlebury, 2007).

Conclusion

Cogens enable students and teachers to examine the local culture within the science classroom/school/neighborhood through discussions of how to improve teaching practice and student learning. These discussions can produce new culture that enable participants to engage across social boundaries such as age, gender, socio-economic background and/or ethnicities (Bayne & Scantlebury, 2013). Within the interstitial space that cogens occupy, students and teachers generate local knowledge and develop theories about that knowledge. More importantly, cogens provide the space for students to find their voice, to engage with science and to develop and take, as a 'carrier,' new practices and culture back to the classroom. For example, during cogens, Charnae spoke up for her friends who did not have the confidence to speak; she then took that critical approach to the classroom, and also worked out ways with her teacher, Jen, as to how to engage others in science.

Although cogens are one way to destabilize and reduce the power differential that exists between teachers and students, it is naïve to assume that the differential disappears (Ali, 2006). Moreover, we have yet to explore the issues and challenges of examining race within cogens: The teaching profession in the United States is becoming increasingly white, middle class and feminized, while the number of English Language Learner (ELL) students in US K-12 education continues to grow. Cogens can identify the pedagogical practices and strategies that improve

teachers' and students' understanding of each other's needs and circumstances can contribute to improving the cultural climate within science classrooms. Cogens can offer students, particularly girls, an interstitial space to talk and share their perspectives on science and learning with each other and their teachers.

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Dimensions of Health in Polish Students' Opinions

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This paper presents a broad perspective of health understanding as well as its interpretation in relation to five dimensions of health: the state, aims, processes, characteristics and results. Based on the results of data from a survey of 170 Polish students based on the Questionnaire of Health Criteria by Zbigniew Juczyński, biological and psychological aspects of health are the most popular among respondents. Understanding the social dimension of health is rather minor. Health was most often described in the context of a state. An adequate understanding of health is essential to develop health skills and health awareness, it is a significant part of formal and non-formal education throughout a lifetime.

Artykuł porusza problematykę rozumienia pojęcia „zdrowia” przez młodzież studencką, jak i jego interpretacji w kontekście stanu, celu, procesu, właściwości i wyniku. Analiza badań, przeprowadzonych na 170 polskich studentach w oparciu o Listę Kryteriów Zdrowia autorstwa Zbigniewa Juczyńskiego pokazała, że zdrowie najczęściej rozpatrywane jest w kategoriach biologicznych i psychicznych. Niejednokrotnie pomija się jego aspekt społeczny. Co więcej, respondenci definiowali zdrowie głównie w kategorii stanu. Podsumowując, właściwe rozumienie konstruktów zdrowia jest niezbędnym elementem podnoszenia poziomu świadomości społecznej i kompetencji zdrowotnych. Ich nabywanie odbywa się w procesie edukacji formalnej i nieformalnej, co ma duże znaczenie w kształceniu przez całe życie.

Keywords: health, models of health, dimensions of health, value of health, Questionnaire of Health Criteria

Introduction

“A wise man should consider that health is the greatest of human blessings, and learn how by his own thought to derive benefit from his illnesses,” - Hippocrates. Since that time nothing has changed much. It must be stated that good health is an essential condition of well-being, not only physical, but also psychological and social. That is

why health is one of the most important values for the Polish society. The Public Opinion Research Centre (CBOS) provides data on this matter. It shows that during the last few years the significance of health has risen. In 2005, 69% of respondents considered health as one of the most important values, while in 2010 it was 74% (CBOS 2010). This tendency may have been

caused not only by the fact that people are better-educated in the matter of health, but it also may be a significant sign of a change in thinking about health. Although considerable research devoted to health as a value shows its importance, people's health behaviours present a rather sad image (CBOS, 2012; TNS-OBOP for Medical Centre of ENEL-MED, 2011; NAT-POL, 2012). There is the rift between theory and practice. People value their health, but they do not do much to maintain their health in good condition. Why? The answer to this question needs a separate analysis. However, it should be stated that it is strongly connected with the proper understanding of health, which is the subject of this article.

Every person has his own point of view on health. An individual understanding of this term may differ in accordance to age, background, possessed knowledge, experience, belief or simply philosophy of life. For this reason, the definitions of health may vary. The topic of health has been extensively studied in recent years. In the literature, it is possible to find more than a hundred explanations of this term and the list is still not closed. Not only have many studies focused on health, but also on health behaviours, attitudes towards health as well as health education. It should be underlined that health behaviour reflects a person's health beliefs. It is connected with the subject of lay concepts of health (Schmidt & Frohling, 2000; Faltermaier, Kuhnlein, & Burda-Viering, 1998; Flick, 1998; Petrie & Weinman, 1997; Williams & Calnan, 1996; Skelton & Croyle, 1991). Some previous research in this field focused on the aspect of individual health understanding as a central issue to preserve health. These conceptual models used by individuals, communities or cultures are trying to explain in a folk way how to maintain health and

explain illness. The analysis of those components shows that health and illness may be treated in two ways. The first one presents health and illness with a theoretical background including wider theories, like biomedical or socio-economical. On the other hand, they may not be related to any major theories, but, for locally developed and contextual (Encyclopedia of Public Health, 2002).

The purpose of this study focuses on individual understandings of health, in relation to three dimensions. Accordingly, the primary objective in this paper is to provide information on the matter of students' health understandings, which tackles the physical, psychological and social dimensions of health. A further reason for the investigation is to analyse the meaning of health in the context of health as a state, aim, process, characteristic and result. Chosen options may influence people's health behaviours that are in relation to *Body Mass Index* (BMI) treated as an indicator of health behavior and the understanding of health. It would thus be of interest to learn how the situation presents in this matter.

Theory and Review of Literature

It is impossible to describe the results of research and image of the problem without referring to the theory and literature on the matter of health. That is why, it should be stated that health is an interesting area not only for medical sciences, but also for psychology, sociology or pedagogy. It means that in accordance to the particular area of knowledge, it may be interpreted in a different way. As a result, Bulicz and Murawow (1997) presented about one hundred definitions of health, while Miller (2001, p. 15) mentioned 120 explanations of this term. For the purpose of this study, health is defined as a "*state of complete*

physical, mental and social well-being and not merely the absence of disease or infirmity” (Official Records of the World Health Organization, no. 2, p. 100). The explanation mentioned above has changed the whole attitude towards health. Except for physiology, it pays attention to the human psychological and social aspects of life. Adding these two dimensions led to the creation of a holistic concept of health which displaced the biomedical paradigm popular until the late 1940s. The latter explains health in terms of lack of disease (Trowler, 1996, p. 2). As Ann Bowling claims, this model “*is based on the assumption that disease is generated by specific etiological agents which lead to change in the body’s structure and function*” (Bowling 2009, p.20). It means that there are some physical causes for disorders (Curtis 2000, p.3). As a result, health is presumed to be a biological fact that is isolated from social and environmental factors. What is more, the medical model of health compares the organism to a machine. As a consequence, it attempts to change the part which malfunctions. Such a concept derives from the XVIIth century Cartesian dualism that made a distinction between mind and body (Bowling 2009, Curtis 2000, Allen 1998).

Although widely accepted, the biomedical model is not fully satisfying nowadays as some of its limitations were observed. The question of why a group of people exposed to the same hazards do not all succumb has always posed difficulty for this model (Allen 1998, p. 4). First of all, the author outlines that the biomedical concept explains the illness at the low level of cellular processes. Next, it provides only a single factor analysis of illness avoiding other aspects of an individual’s life. Finally, it focuses on curing the disease instead of promoting

health that crushes the main idea of health education. What is more, it does not take into consideration the multidimensional reality, in which people function.

Thus, in modern times a new paradigm has appeared which shows the individual as a whole (Malinowski, 2000, p. 317). As Allen claims, “*The view that mind, body and socially determined opportunities interact to affect many aspects of both health and disease is referred to as the biopsychosocial model and is currently a dominant paradigm*” (Allen, 1998, p.6). In contrast to the biomedical concept, the biopsychosocial model takes into account other dimensions of an individual. It treats a person as a biological, psychological and social unity (Engel, 1977). Except for being in the state of disease, there are other factors like motivation to recover, meaning attached to the illness or support given by others that may influence on the ability to maintain health (DiMatteo & Martin, 2002). As Brannon and Feist confirm, “*the biopsychosocial model has at least two advantages over the older biomedical model: first, it incorporates not only biological conditions but also psychological and social factors, and second, it views health as a positive condition*” (Brannon & Feist, 2010, p. 10). As stated, the development of this concept has led to the observation that people can influence their health. As a consequence, there has been a shift from negative definitions of health toward positive ones, which have been interpreted in the term of dynamism and action taken by an individual to maintain health.

Although the definition of health proposed by WHO incorporates different dimensions of people’s life, it has its limitations. First of all, it refers to the concept of well being

which is not only difficult to define, but also to operationalize. Secondly, it interprets health in the category of a state, which indicates stability and lack of taking responsibility for the activity necessary to keep the individual's health. Moreover, it suggests that it is impossible to influence on one's health. In addition, some theorists claim that noetic aspect should be included in the definitions of health in order to provide humanistic look on the matter of health (Seredyńska, 2009; Kropińska, 2000). As a result, physical, psychological, social and spiritual dimensions form a self-contained whole of the individual. Despite its limitations, the WHO's definition of health seems to be suitable for the purposes of this paper as the questionnaire used in the research is based on three dimensions. The theory and models of health have changed, but it is a matter of analysis to explore if the same change has been made in lay concepts of health among ordinary people.

Method

Participants

170 students of technology (N=170) consented to participate in the research done in Warsaw. They shared their point of view on health as well as their understandings of its dimensions. The choice of the city was made in accordance to the fact that Warsaw is a scientifically interesting city that attracted many students from the whole of Poland. As a consequence, it allowed indirectly to evaluate the process of health education conducted during previous levels of education. A further reason for choosing technology students was the limited scope of

health issues in their study program. Not only did it indicate the lack of current influences on their interpretations of health, it referred to the mental structure of health that already exists in their minds. Both genders were represented; there were 71.8% men and 28.2% women. Almost two thirds of the respondents (61.2%) were in their second year of studies, and 38.8% were in their third year of the BA program. As many as 92% of the respondents were between 20 and 23 years old. 8% of students were older. What is more, 90% of respondents finished secondary school, while the rest were former pupils of technical secondary school. The analysis of average marks received by questioned students in the last academic year was presented in Table 1.

As can be seen from the table, as little as 1.8% of the students received the average marks higher than 4.5. More than one fifth (22.9%) of the respondents had average marks between 4.0 and 4.5. The students with the average marks between 3.5 and 3.9 accounted for 58.8% of all the examined respondents, while 16.5% - below 3.5.

When it comes to the birthplace, a greater variation is observed. It can be seen from Table 2 that almost half of the respondents came from a town below 100,000 inhabitants. Almost every third person came from a village, while 15.9% lived in a town where there were more than one million inhabitants. As little as 8.8% of the questioned students came from a town between 100,000 and a million inhabitants.

Table 1. Average marks received in the academic year 2011/2012 by respondents. Source: Own research.

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid below 3.5	28	16.5	16.5	16.5
3.5 – 3.9	100	58.8	58.8	75.3
4.0 - 4.5	39	22.9	22.9	98.2
above 4.5	3	1.8	1.8	100.0
Total	170	100.0	100.0	

Table 2. Birthplace of respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
Vaild Town: more than one million inhabitants	27	15.9	15.9	15.9
Town: between 100,000 and one million inhabitants	15	8.8	8.8	24.7
Town: below 100,000 inhabitants	82	48.2	48.2	72.9
Village	46	27.1	27.1	100.0
Total	170	100.0	100.0	

Source: Own research.

However, it should be noted that in the moment of conducting the research, one out of three (31.8%) persons was living in a residence hall. The percentage of students renting a room or a flat accounted for 28.7% of the whole sample. This result is comparable to the percentage of respondents living with parents (27.1%). As few as 12.4% of the students were living in their own house or flat. However, the latter is quite surprising because nowadays buying one's own flat in Poland is very expensive.

Another significant characteristic of the sample concerns the *Body Mass Index* (BMI). According to the indicators presented by WHO, 2.9% of the respondents suffered from underweight, 71.2% had normal weight, and 22.4% were overweight. Of the latter, as much as 3.5% were moderately obese. Consequently, one fourth of the respondents had problems with proper weight, which may affect the right functioning of organism.

Students' knowledge of health behaviours is mostly derived from their homes. It means that parents have a great impact on shaping the proper lifestyle of their children. Though, it may be presumed that with more highly educated parents the better health awareness of their children. That is why Table 3 provides data on the education of respondents' parents. As presented in the table, according to the general trend, mothers were better educated than fathers. More than one third of mothers (35.3%) finished higher education, while only 23.5% of fathers did so. Moreover, more women finished secondary schools than men, 45.9% and 36.5% respectively. On the other hand, fewer mothers finished primary and vocational schools in comparison to fathers. The latter accounted for 40% of the whole population of fathers, while there were only 18.8% of mothers finishing this level of education.

Table 3. Education of respondents' parents

EDUCATION	MOTHER		FATHER	
	Frequency	Percent	Frequency	Percent
Higher education school	60	35.3	40	23.5
Secondary school	78	45.9	62	36.5
Vocational school	27	15.9	62	36.5
Primary school	5	2.9	6	3.5
Total	170	100.0	170	100.0

Source: Own research.

Recruitment and Data Collection

After receiving permission from the principals of the university, interested students agreed to participate in the research. Based on feedback from the pilot study, necessary changes were made to the questionnaires. In the interest of generating maximally useful data, additional steps were taken. Not only did the informed consent need to be provided by the researcher during the data collection, but it also helped those individuals, who did not fully understand the task. Nevertheless, it is important to report that 38 questionnaires out of 170 were incomplete, thus they were not taken into further analysis.

Instruments

All students completed the psychological Questionnaire of Health Criteria (*Lista Kryteriów Zdrowia, LKZ*) created by Zbigniew Juczyński. It consists of 24 statements, which describe three dimensions of health: physical, psychological and social in accordance with biopsychosocial model

of health. The respondents' tasks were to choose five of the most important statements and arrange them from 1 (the least important) up to 5 (the most important). In order to present the participants' point of view, one additional question has been added. Moreover, the questionnaire queries understandings of health in accordance to health as a state, aim, process, characteristic and result. The author underlines the fact that it is impossible to establish norms in relation to Questionnaire of Health Criteria. However, according to the questionnaire, all validation measures were fully satisfied. Results provide data on the respondents' preferences in health understanding. In addition, participants were obliged to fill in the form including personal information such as sex, age, weight and height, as well as place of living and their parents' education.

Data Analyses

The data was analysed in both quantitative and qualitative ways.

Results

Dimensions of health

Table 4 presents the share of different criteria of health among students in their general understanding of health. The Table includes 24 statements which describe biological, psychological and social aspects of health. Except for the criteria given, the Table contains columns representing different levels of importance of the above mentioned criteria. Number 5 is considered to be the most important item, 4 (a very important item), 3 (an important item), 2 (a fairly important item), and 1 (the least important item). Answers which are not chosen by participants are described as zero. The part of the Table called “Frequency” represents the sum of answers which had

occurred (in percentage), while “Ranking” depicts answers in order of magnitude with #1 being the most significant. The first column describes the definitions of health in reference to it being a state, aim, process, result or characteristics.

As can be seen from Table 4, almost half of the respondents associated health with the feeling of happiness (overall 42.3%). Being happy is considered to be a psychological factor which may also include biological determinants of health. On the other hand, 32.2% of students treated health as a state of being able to rest and sleep appropriate to their needs. This biological way of thinking about health is reinforced by the proper diet as well as lack of ailments (both 31.8%).

Table 4. Meaning of health

DEFINITION	Be healthy means to me:	5	4	3	2	1	0	Frequency	Ranking
A	To live until sunset years	11.4	1.5	2.3	3.0	1.5	80.3	19.7%	11
S	To feel happy for most of the time	12.1	8.3	4.5	8.3	9.1	57.7	42.3%	1
P	To get on well with other people	2.3	2.3	4.5	2.3	3.8	84.8	15.2%	15
P	To be able to solve problems	3.8	5.3	3.8	6.1	3.8	77.2	22.8%	10
R	To have a balanced diet	6.1	6.1	7.5	7.6	4.5	68.2	31.8%	3
R	To rest and sleep a lot	6.8	10.6	6.1	2.3	6.8	67.4	32.6%	2
R	To drink little alcohol or not to drink at all	0	6.2	4.5	4.5	3.0	81.8	18.2%	13
R	Not to smoke	3.8	6.1	8.2	6.1	2.3	73.5	26.5%	7
R	To have a proper weight	2.3	0.7	3.0	5.3	7.6	81.1	18.9%	12
C	To take medicines just in exceptional occasions	0	2.2	0.8	0.8	3.0	93.2	6.8%	20
C	To have a good mood	2.3	7.5	8.3	5.4	4.5	72.0	28.0%	5
C	Not to feel any physical ailments	12.1	4.5	6.9	4.5	3.8	68.2	31.8%	3
P	To be able to work without stress	0.8	7.6	3.7	7.6	3.8	76.5	23.5%	9
C	Not to be ill or have a flu occasionally, indigestion	3.1	1.5	2.3	4.5	3.0	85.6	14.4%	16
C	To have healthy eyes, hair, complexion	2.3	3.0	3.0	3.8	2.3	85.6	14.4%	16
P	To be able to adapt to changes in life	0	1.5	3.8	3.8	3.0	87.9	12.1%	17
S	To be able to enjoy life	7.7	4.5	6.1	4.5	4.5	72.7	27.3%	6
A	To be responsible	0	2.2	1.5	2.3	2.3	91.7	8.3%	19

P	To be able to contain your emotions and impulses	0.6	3.0	0.8	2.3	2.4	90.9	9.1%	18
C	To keep all parts of the body fit	9.8	5.3	5.4	4.5	6.1	68.9	31.1%	4
A	To accept yourself, to know your advantages and disadvantages	3.1	1.5	2.3	5.3	4.5	83.3	16.7%	14
R	To have a job, vary interests	5.3	0.8	0.8	2.2	6.1	84.8	15.2%	15
S	To feel well	3.8	4.5	6.8	2.3	7.6	75.0	25.0%	8
C	Rarely go to the doctor	1.5	2.3	3.0	1.5	0.8	90.9	9.1%	18
LEGEND									
5 – the most important item (%)		A – aim							
4 – a very important item (%)		C – characteristics							
3 – an important item (%)		P – process							
2 – a fairly important item (%)		R – result							
1 – the least important item (%)		S – state							
0 – answers not chosen by respondents (%)									

Source: Own research based on Juczyński's Questionnaire.

One out of three respondents (31.1%) understood health as a capability of keeping all the parts of the body fit. However, it must be stated that despite the fact that happiness is identified with health, the next psychological criteria appear as the fifth, sixth and eighth position in the overall ranking. Factors like having a good mood, being able to enjoy the life, or feeling well, represent 28%, 27.3% and 25% respectively. What is more, almost one out of four participants have focused on the lack of stress (23.5%), while approximately every fifth person considered health as a state of being able to solve all their problems (22.8%). Furthermore, almost one-fifth of respondents (19.7%) underlined that longevity was a significant criteria of health. Quite the opposite was true of the social dimension of health as little importance has been paid to this matter. Only 15.2% of students noticed that getting on well with other people may influence the proper and healthy functioning in society. What is more, a bit more than every tenth respondent (12.1%) considered health as the ability to adapt to changes in life. Although general results show that both biological and

psychological understandings of health are popular among the students, there are significant differences in the importance of particular criteria. Graph 1 provides data on this matter.

The graph presents the share of students choosing a particular criteria. The horizontal axis contains 24 criteria included in the Questionnaire, while the vertical axis shows the percentage of students choosing specific answers. The color bars represent the percentage of students choosing the particular criteria in accordance to the significance of the statements. As shown in Graph 1, being happy for most of the time as well as lacking physical ailments is an essential aspect of health. These two categories are the most important items connected with health for 12.1% and 12.1% of respondents respectively.

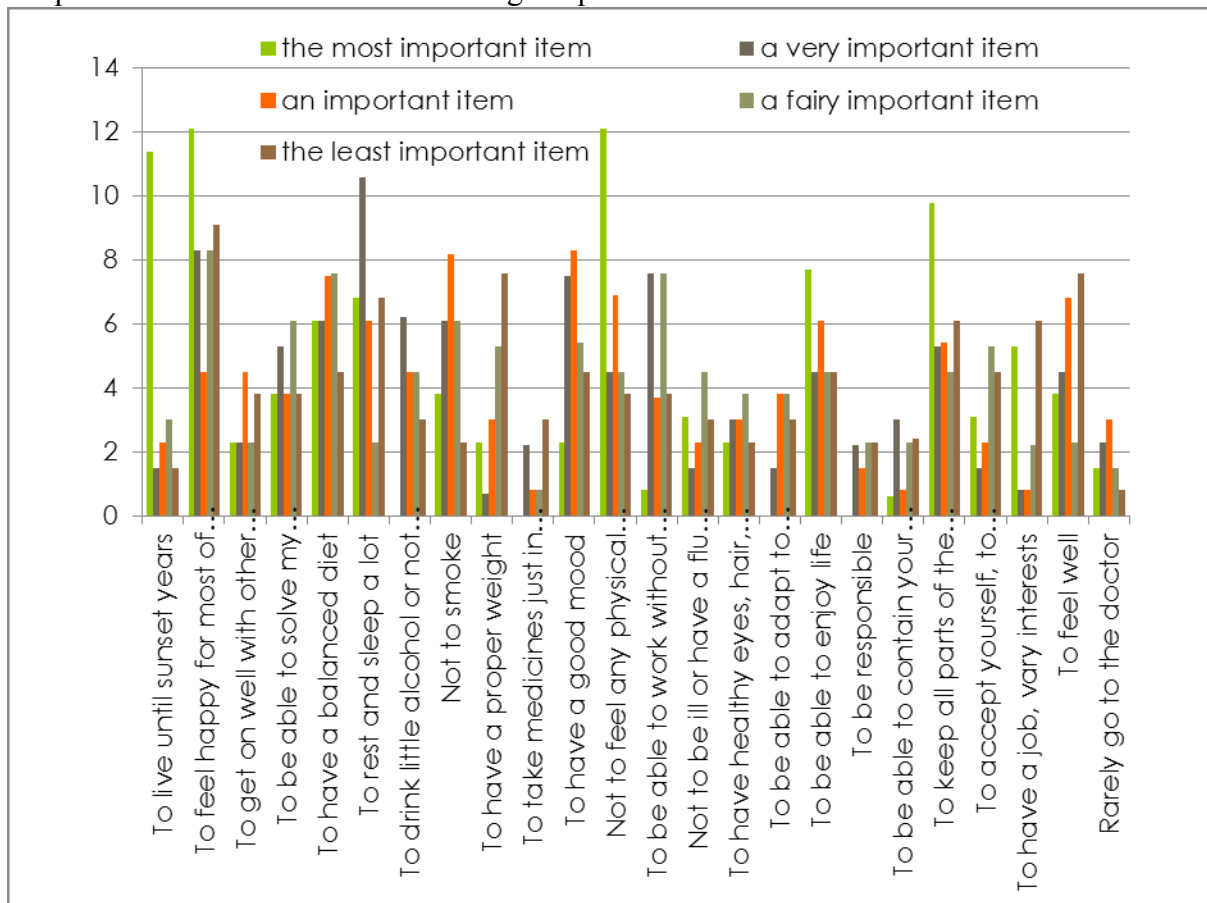
Biological health encompasses other criteria important for the participants such as keeping all the parts of the body fit (9.8%), and being able to rest, relax and to sleep well. The latter is generally considered to be a vital aspect of health, because most of the

students point it out in their questionnaires. 6.8 percent of students considered it to be the most significant in comparison with 10.6% who treated it as very important. What is more, resting and relaxation is the least important for 6.1% and 6.8% respectively. As presented in the graph, there are other indicators of biological health. When it comes to popularity, they include a proper diet which is the most significant for 6.1% of respondents, as well as important and quite important for 7.5% and 7.6% respectively. What is more, 11.4% of participants treat being old as a significant visible sign of health. They presume that if a person is able to live for a

long time then the whole organism must be functioning well.

As far as the psychological dimension of health is considered, the most significant meaning is provided by health as happiness. This point of view gained many believers among examined students on different levels of importance. However, having a good mood was described as a criteria with a lower intensity of importance. Very low values were obtained in personal acceptance as well as in containing emotions. However, it was important not to be stressed and to be able to solve problems. The further details are presented in Graph 1.

Graph 1. The share of students choosing the particular criteria



Source: Own research based on Juczyński's Questionnaire.

Different categories of health definitions

The Questionnaire of Health Criteria provides the possibility to examine issues related to definitions of health in accordance to health as a state, aim, process, result or characteristics. The author reports that most of the people define health in the context of it being a state or aim, while health as a result did not occur very often (Juczyński, 2001). However, our research just partly supports this statement. According to the data, defining health as a state was the most popular among technical students. Our results were similar to the ones observed by the author of the Questionnaire. However, the differences appeared when it came to health as an aim. Our investigation showed that this way of understanding health was unpopular. The problems of acceptance, longevity and responsibility, which were interpreted in the context of aim, were not really important to the participants.

Similarly, understanding health as a process was not very popular. It is particularly essential to be aware of the fact that health is an ever-lasting process, which gives people the right to influence it. Lacking this point of view creates an impression that human being's health is static and unchangeable. As a consequence, people do not do anything to maintain it because understanding health as a process is not sufficiently developed.

As far as understanding health in terms of result or characteristics is considered, the findings are not fully clear. Some statements of both criteria play a vital role in defining health, but the other ones – do not have such significance. The relationship between these two sorts of health understandings remains unclear. It would seem, therefore, that

further investigations are needed in order to provide confirmed results.

Discussion and conclusion

The objective of this survey was to analyse the understanding of health in the context of biological, psychological and social dimensions. What is more, definitions of health were analysed in accordance to their interpretation of health as a state, aim, process, result or characteristics. Thus, the survey reported on in this study has produced a wealth of data.

As the results show, biological and psychological aspects of health are the most popular among students. The data provides information that physiology plays a dominant role in this matter as many biological criteria were significant for the examined students. This attitude may be explained in accordance to Maslow's Hierarchy of Needs. The author claims that in order to develop, the individual needs to fulfill his physiological needs first. According to this statement, being healthy is an essential prerequisite to further development as it is related to the basic need. If it is not fulfilled, than it dominates over other needs which becomes less important. Moreover, the author suggests that the need of safety also includes health. As far as the psychological health is concerned, the author shows that all psychological aspects appear when the basic level of physiological needs is completed. It means that health is not only connected with the biological sphere, but it also consists of psychological dimensions. Although the research showed that being happy is the best definition of health, the other criteria of psychic were less dominant than the

biological ones. When it comes to the social dimension of health, this understanding is rather minor. The social context was not considered to be an important factor of health. It may be caused by the fact that health is perceived as an individual aspect of life, thus, not social. To sum up, it may be stated that school health education did not educate enough young people in the matter of health. As a consequence, it failed to fulfill its basic prerequisites.

The important part of this research focused on understanding health as a state, aim, process, result and characteristics. Similar to the literature, health was most often described as a state. This point of view may be caused by the fact that people treat it as a general condition and wellness. On the other hand, it shows that they are not able to maintain it because they do not take responsibility for actively influencing their health. Such interpretation relates to another result of the study which shows that health understood as a process is insufficient. This fact should be explored in further research in accordance to health behaviours.

However, this research has some limitations. First of all, it focuses only on three dimensions of health presented in the Juczyński's Questionnaire: biological, psychological and social. It omits spiritual health, which is treated as an important part of human existence by some researchers. Secondly, the low number of respondents makes it impossible to generalize the results on the whole population of students. What is more, some findings are not very clear. Health in the context of these results and characteristics can be interpreted in various ways, therefore the results in this matter cannot be taken as evidence for its validity. Nevertheless, the attempts to establish a link between various definitions of health and

their influence on health behaviours might be significant for future analysis. However exploratory, this study may offer some insight into the problem of understanding of health.

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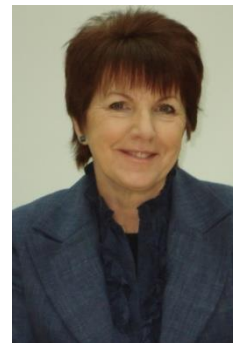
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The Level of Skills of Middle School Students in Field of Modeling Biological Experiments in View of the General Education Core Curriculum for Biology

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The modern didactics of biology require that teachers have the skills of translating their academic level of scientific knowledge into the knowledge possible to learn the previous stages of education. This is reflected in the ways of teaching. Academic teachers require of students a practical application of the skills of observation and performing experiments in the study of the fact, reasoning, data analysis, creation of generalizations and deduction. However, in practice these expectations often differ considerably from the facts of a case. The answer to the requirements of students of life sciences seems to be in the General education core curriculum in biology, which recommends the students at all stages of education, be active self-learners by performing observations, experiments, and participation in field practices. This article presents competencies needed by high school students in the field of modeling biological experiments and the range of interests of life sciences.

Nowoczesna dydaktyka biologii wymaga od nauczycieli opanowania umiejętności transponowania wiedzy naukowej na poziom szkolny, co odzwierciedla się w sposobie prowadzenia zajęć. Nauczyciele akademicy wymagają od studentów kierunków przyrodniczych umiejętności praktycznego zastosowania obserwacji i doświadczeń w badaniu rzeczywistości, logicznego myślenia, analizy danych, tworzenia uogólnień i wnioskowania. Jednak w praktyce, oczekiwania te często odbiegają znacznie od rzeczywistości. Odpowiedzią na wymagania stawiane studentom kierunków przyrodniczych wydaje się być podstawa programowa kształcenia ogólnego z biologii, która zaleca wdrażanie uczniów na wszystkich etapach kształcenia do aktywnego zdobywania wiedzy poprzez samodzielne wykonywanie obserwacji, doświadczeń i udziału w zajęciach terenowych. Artykuł przedstawia poziom kompetencji uczniów gimnazjum w zakresie modelowania doświadczeń biologicznych i zakres zainteresowania naukami przyrodniczymi.

Key words: The General education core curriculum, experiments, observations, level of skills, middle school education, scientific research methodology

Introduction

The increase of information in the world of knowledge and progress in all fields of science and technology make necessary lots of changes in education. The modern school has to teach boldness and courage in

thinking, independent interpretation of phenomena and facts, as well as activity. The teacher is required to have the skills of transcending levels of teaching processes, as reflected in the methods of teaching process. Modern biology teaching now emphasizes

the practical application of observation and experiments in the study of reality. These irrefutably teach logical thinking, clearing facts, data analysis, creating generalizations, and formulating results. Therefore, the problem which has to be solved is to examine the actual impact of the use of laboratory tests for biology on the effectiveness of teaching this subject in the middle school. Is the commonly adopted thesis, about the role of experience in the classroom, well founded?

According to the general education core curriculum of 2009, teaching biology in the middle school is thought to help in understanding the environment and surrounding world and oneself. It also should focus on the biodiversity of organisms, levels of their complexity, presenting the diversity of biology as a science and its practical applications. A new aspect of core curriculum in biology is to make obligatory experimentation and observation. It is not necessary to have complex laboratory equipment and significant resources to put into practice the new core curriculum, just teacher readiness to implement the program. Does poor equipment in biological laboratories still pose obstacles for the teachers in conducting experiments in the classroom? Or, maybe numerous classes are the real problem of our system of education? What is the impact of realizing the core curriculum in biology on the level of competencies of middle school students in the eye of the law, as is the duty of performing the experiments in the third stage of education in the Polish system? Are traditional lessons based on a textbook and exercise book still dominating other types of lessons in the school?

Study of the problem

The Polish school as an institution changed after the transformation in the system of education. The reform in 1999, which introduced middle school as a stage of education, followed by three-year secondary schools as a revolution in education. The core curriculum, which was one of the most important elements of the reform of the education system, although it was created in the context of chaos and urgency, had a very important function: it introduced the reform of the education system. The project launched to create a new core curriculum. It did not break up existing solutions. It indicated the fields of responsibility of teachers for the education, removed items unrealized in practice at school, standardized the structure, and simplified and organized the language used in the teaching process. Teachers and authors of curricula and school textbooks were given very wide discretion in choosing the specific content and teaching methods. As a result, curricula and textbooks have become increasingly different, as well as consistent between the levels of education. The new general education core curriculum introduced in 2009 significantly ordered the content of education in formulating detailed requirements in the form of student achievement at each stage of education. It leaves no space for different interpretations. According to the new core curriculum, the process of teaching biology in the middle school has two aims:

- to help in understanding the world and oneself (the student should acquire information about functioning of the body so taking care of one's health and others is possible)
- to help students in making decisions about a future educational path.

A new item of the current core curriculum makes it obligatory to conduct experiments and observation. The authors correctly pointed out that developing the ability for critical thinking and the ability to explore the world through properly planned and documented observations and experiments is a real important part of teaching the life sciences. However, teachers typically performed biology demonstrations that usually were useful for only a small group of interested students. It is worth highlighting that single experiments, performed by the students, may interest students who do not think of biology as a field in which they would like to develop themselves. The new core curriculum focuses on practical experiments and observations conducted at school, which as a minimum, and should not cause the problems for teachers to execute. They are selected for their lack of complex laboratory equipment and financial resources so not to be a barrier. Just a teacher readiness to implement the program is important, so too are meeting the requirements of the curriculum. Students should learn the basic idea of how to research a problem and develop hypotheses, and samples and controls, so they understand not only theoretically but also practically. These are the basics for further training in biology, followed by the fourth stage (secondary school), and then studies the life sciences and scientific work. It should also be noted that the most effective way to encourage young people to study the life sciences is through interesting observations and experiments. The international PISA research shows that the revolution in Polish education (the introduction of middle schools), contributed to a significant increase in the average educational level of fifteen-year-old students. Research points to a noticeable improvement of Polish students education

results in the life sciences (biology). In 2009, the educational results of middle school students were significantly higher than the OECD average value (500 points) and totaled 508 points (in the previous edition of the PISA research in 2006, the Polish result was 498 points). Poland has not only advanced to the group of countries significantly better than the OECD average, but also stands out among these countries because of significant increase in students' skills in reasoning in the life sciences. It turns out that earlier versions of the curriculum were too general in wording of the core curriculum and did not give the equal chances to all of students to developing creativity and independence. The role of laboratory method is appreciated and it is reflected by the research which shows how such an important part of learning the life sciences, not only in biology, is developing the ability for critical thinking and the ability to explore the world by the properly planned and documented observations and experiments. It is also important to note that individually performed observations and experiments (by the student) realized better results than those presented by the teacher. Terms such as the research problem and hypothesis, the research sample and control sample, the student should get to know not only theoretically but also practically. It should also be noted that interesting observations and experiments effectively encourage young people to study life sciences. Even the best lesson using a textbook is not a substitute for a contact with it in reality. The new core curriculum recommends experiments and observations, as well as field trips. In the Polish schools, lessons are still conducted poorly using active teaching methods and work in teams (groups of students). Asking questions and giving answers based on observations and

experiments is still rare. Teachers often make excuses that they have little time to carry out observations and experiments, because the curriculum consists of too much content. In addition, they point to the lack of laboratories in schools and the numerous classes as reasons. Lack of observations and hands-on experiences is still a problem in Polish middle schools and other types of school.

The core curriculum introduced in 2009 focuses on conducting experiments during the biology lessons, especially the knowledge of biological research methodology and reasoning ability. Using operational verbs, the general requirements and recommended specific experiences and observations were defined (e.g., "A student plans, conducts and documents observations and simple biological experiments, determines the conditions of experience, distinguishes between a control and research sample, draw conclusions [...]" and "The student interprets the information and explains the cause-and-effect relationships between facts, draw conclusions, formulates and presents an opinion on the issues in biology [...]) Biology is a science based on experience and observation. Analysis and interpretation of the results of even the simplest, but single-handedly performed experiments, give students a better understanding of biological phenomena and facilitating the assimilation of the associated learning content. Experience and experiments have become an important element in today's educational process, and therefore at all stages of education, students should perform simple observations and biological experiments. A combination of experiments and observations included in the core curriculum is the recommended minimum to be performed under the conditions met at school. For example,

students are to plan and carry out experiments:

- a) showing that during the fermentation of yeast a carbon dioxide is released,
- b) leading to check the impact of selected factors on seed germination,
- c) demonstrating the role of chemical components of bones,
- d) which is aimed to assess what is the concentration of receptors in the skin of various body parts),
- e) verifying the presence of starch in food products;

The advantages of experiments and biological cultures in developing students' biological knowledge are huge. PISA research shows a substantial improvement of reasoning, including interpretation and the utilization of research results. There are advantages of lessons using the laboratory method, but it is hard to find out in the literature of pedagogy and didactics, how lessons performed by this method compare with traditional lessons. The experiment is therefore the source and means of verifying students' knowledge, used to develop educational and research laboratory skills, and may also be a tool in controlling their achievements. Students learn what is the functionality of a laboratory experiment, execute dexterity, and acquire practical skills. The experiment enhances complete understanding of natural phenomena, it also stimulates and teaches self-reliance in obtaining answers to questions posed by the experimenter. Research shows that students believe that even demonstrations of experiments conducted by the teacher are helpful in better understanding the theory (87%), maintaining a concentration during lessons (95%) and are much better than professional video presentations (60%).

Research methodology

The site of this study was the secondary schools located in Warsaw. The target group of the study was the students of first degree classes in secondary school stage, who were already graduates of the middle schools, making sure, that they completed the general education core curriculum in biology at the third stage of education. The group consisted of 120 students. Among the participants there were 58 girls and 62 boys from 21 different secondary schools in Warsaw.

The research was conducted using a diagnostic survey. The main instrument was a questionnaire designed to check the basic concepts and student skills in modeling simple biological experiments. The survey was designed to compare students' feelings about basic skills of modeling experiments to their actual competencies used in practice, as well as to assess their understanding of the methodology of biological experiments. The research issues raised in the study focused on the following areas: biological experiment as a form of teaching biology; the theory and the reality in the range of bases of research methodology knowledge among students; and, the level of competencies in modeling simple biological experiments by students in the face of plans related to implementation of the general education core curriculum in biology in the middle school.

Analysis of the results

The general education core curriculum in biology at middle school stage (third stage of education), implemented in 2009, indicated teachers trends of teaching, making students' skills the most important. It means, that the main value is no longer possession of knowledge, and gaining the skill of use it in practice became the most

important. The general requirements of core curriculum were clarified by operating verbs describing students' skills that they should get after graduation the middle school. Methods and forms of work with the student should be used to design and develop these skills in close correlation with the expanding of information defined in course content as specific objectives. The laboratory method, based on experiments and observations, enables to forming all types of the skills mentioned by the core curriculum. Under the new program of the core curriculum teachers are obligated to develop lessons using experiments, because teaching is ineffective without these. However, as research indicates, teachers use this method rarely - only 1 to 3 times per a school year (60%), and 7% of respondents claim that lessons performed by them did not include the experiments. Opposition to the intentions of the authors of the core curriculum, that promotes using experimental methods, realizing the contents takes place during lessons using traditional methods, based on textbooks and workbooks. Elements of the experiments, so the implementation of scientific researches methodology is held during lessons conducting as the presentation form very often (66,7%), and this form is not demanding with time and organization, so it is comfortable alternative option for the experimental lessons. Nearly 69% of students said that during their three years in middle school, experiments were performed rarely, and 12% of the students have never done one. It seems to be a paradox that the skill of properly designing biological experiments was accomplished in 70% of the surveyed students, only 25% of them could correctly order the stages of the experiment mentioned in the questionnaire. Only 38 from 120 respondents were able to write the subject of the experiment practiced by them. They indicated e.g. "detecting a

starch in potato”, “bean seed culturing”, “examining of the sensitivity of human skin”, “cellular respiration by yeast”. However, the responses were imprecise and they indicated a low level of skills related to biological terminology, typical for this scientific discipline.

The core curriculum indicates, that middle school graduates, independent of the topic of experiments or observations conducting during lessons, are supposed to know and use in practice the basic scientific research methodology, starting from the research problem and hypothesis, through planning the process of experiments or observations to note results, to conclusions, and finally verify the hypothesis. Unfortunately, based on the results of the survey, the students’ knowledge in the field of scientific research methodology is poor. Also, according to the questionnaire, their ability to use in practice the information they get in middle school is unsatisfactory.

In the students’ subjective opinions, the range of skills related to biological experimental planning is high. Research shows that 37% of surveyed students assess their own skills at designing and planning experiments as “satisfactory” or “well,” but the competencies of forming research problems, hypothesizing and drawing conclusions they assess as “very well” (up to a quarter of respondents). The middle school graduates are sure they mastered skills linked to issues of research, and only 10% of surveyed group recognizes these skills as not enough. Exercises practically checking their skills of modeling simple experiments indicate that approximately 40% of respondents distinguished between the research sample and the control sample used in the experiment, in the correct form. Some of them were close to correctly planning and

conducting a schematic experiment illustration. However, the illustrations prepared by the students do not correlate to the most basic elements of construction, important in the biological schematic, biological figures. The rest of the group did not try to execute the task, or, they did not know how to do it.

Another task referred to the skills of forming a research problem and hypothesis. According to the task the student was to check, “is the yeast producing carbon dioxide in the process of fermentation,” and to conduct proper experiment. Only 37% of the students performed this exercise correctly by forming both the research problem and the hypothesis. The rest of respondents were not sure, despite the answer being included in the order of the task.

The skills related to making conclusions were checked by the common experiment referred to as starch detection in a potato. However, the difficulty of this task was to make a conclusion, that the reagent was supposed to be questioned, and 53% of students realized that the order of this task seems to be misleading and they indicated correct answer that has focused on the content of the bottle named as “iodine”. A group of 36% of respondents indicated a variant of answer: “The iodine is reacting with a starch and it is resulting in dark blue color.” This indicates a correct answer for the experiment named “Detecting starch in variety food products,” but, it does not correspond with the given experiment.

Summary and conclusion

Biology is a science presented to students as tedious, requiring memorization of many details, useless in everyday life practice. The task is to convince biology teachers that

biology is a dynamic science of the functioning and structure of organisms. All of these require logical thinking, clear facts, data analysis, creation of generalizations and regularity, and they all interact together. Modern biology teachers should focus on understanding nature and not focusing on remembering lots of impractical information. Teaching needs to include experiments and special emotional involvement of teachers (educators), as well as a high level of technical knowledge, manual skills, organization, and sometimes technical support. This is the best way to shape and develop the skills of observation and the practical application of experiments in the study of reality, reasoning, data analysis and inference. The current core curriculum conveys to teachers what is current in education, with students' skills the most important competence. It means that the main value is no longer possession of knowledge, but the gaining of skills to use in science. Practice becomes the most important aspect. It is the reason that the core curriculum mentions student achievement, which shows that the student can apply theoretical knowledge gained at school, on the biology lessons, in practice. However, according to the study, the level of competence of middle school students in modeling simple experiments, which are indicated in the core curriculum, is low. Although the biology teacher is reputed mostly as fully competent in teaching the subject, it seems that it would be useful to examine not only their knowledge, but the frequency and effectiveness of conducting lessons in the school laboratory, and thus find out why they are missing. Teachers, as a group, most often have to extend their knowledge (lifelong learning), and, does not stagnate. They constantly look for new methods of biological sciences, which can make young people interested in biology,

but the "shortness" of knowledge is not a positive influence on both the knowledge and skills of students in Polish schools.

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Raport PISA 2010



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The Level of Competencies of Middle School Graduates in the Field of Health Education Implemented at Biology Lessons

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Issues related to human health are closely linked to the life sciences, and it is reflected in both at the impact of environmental factors on health and the topic of health, which together with other fields of science makes an integral teaching programme of biology at various stages of education. Health education is considered as a long-term investment in the health of a population. Special attention is paid to the health risks among young people who will form the mental and health habits of the next generations by their own life styles. The most frequently discussed threat is a proneness to many risk factors and it is a direct consequence of the low level of health education of children and youth in Poland. The difficulties encountered by teachers, who implement health education are various. The necessity of assessing students' skills in the field of health knowledge should raise the debate about preparation of teachers to be health educators. The research shows the level of competencies related to health education of middle school graduates, whose health education was implemented in a biology classroom. These competencies do not seem to be enough.

Zagadnienia związane ze zdrowiem człowieka są ściśle powiązane z naukami biologicznymi, czego wyrazem jest nie tylko wpływ czynników środowiskowych na stan zdrowia, ale również sama tematyka zdrowia, która wraz z innymi obszarami nauki stanowi integralną całość programu nauczania biologii w szkołach na różnych etapach edukacyjnych. Edukacja zdrowotna uznawana jest za długofalową inwestycję w zdrowie społeczeństwa. Szczególną uwagę poświęca się zagrożeniom zdrowia wśród młodzieży, która poprzez własne zachowania kształtować będzie mentalność i nawyki zdrowotne kolejnych pokoleń. Wśród zagrożeń wyróżnia się przede wszystkim podatność na wiele czynników ryzyka, co stanowi bezpośrednią konsekwencję niskiego poziomu edukacji zdrowotnej dzieci i młodzieży w Polsce. Trudności napotymane przez nauczycieli przedmiotów wdrażających edukację zdrowotną mają zróżnicowane podłoże. W obliczu konieczności oceniania umiejętności uczniów w zakresie wiedzy o zdrowiu, dyskutowany powinien być problem przygotowania nauczycieli do pełnienia roli edukatorów zdrowia. Praca przedstawia poziom kompetencji absolwentów szkół gimnazjalnych realizujących program edukacji zdrowotnej na lekcjach biologii i wychowania fizycznego, albowiem kompetencje te wydają się być niewystarczające.

Keywords: health education, determinants of health, life sciences, health competencies, health educators

Introduction

The last century, as a period in the history of modern science, has shown many evidences that health and education are the inseparable elements (Woynarowska, 2000). Health education as a field of science includes various types of teaching methods and education in general. The interpretation of health education as holistic teaching often equates with health education as a pro-health upbringing connected with education, culture, health, or teaching about one's own and others' health. However, regardless of the understanding of this term, it relates to didactics and medical knowledge. Each way of understanding health education is inseparably linked to such determinants of health, habit or convictions (Kostrzanowska & Juszczuk, 2010). The attitudes that result from health education refer to the individual's health, such as personal hygiene, self-monitoring and observation, first aid and care for the safety of themselves and people around. In addition, health education forms psychosocial skills related to making decisions and coping with problematic and doubtful situations. These skills are necessary to forming a pro-health lifestyle, in the context of sociology, and, maintaining harmony in personal development (Woynarowska, 2008). It is believed that health education is very important in the education of the children and students because of their fascination with the medical sciences (Wejner, 2010) and that is why the expectations to the young generation's knowledge and skills are significant. Currently, most countries do not single health education out as a school subject (Woynarowska, 2008), as contents of it are taught in subjects such as biology, life sciences, and physical education. Regardless of the level of implementation of content associated with this area of science, health education in Poland is one major part

of teaching biology and physical education. Topics considering health education are also particularly addressed at geography, chemistry and physics (Rozporządzenie, 2008). The aim of this study was to compare the level of competencies of the middle school graduates student with the student's achievements associated with health education formulated by the core curriculum at middle school biology course.

Materials and methods

The target group in the study was middle school graduates. This group consisted of 113 students who were first-year students in secondary schools when the survey was conducted. Among the participants, there were 71 girls and 42 boys. Their ages ranged from 15 - 17 years.

It is assumed that the level of competencies of middle school graduates, in the field of health education, is not sufficient, as pointed out by research that considered the impact of health education on lifestyle secondary school students (Tuszyńska, 2012). The assessment of the surveyed students' health skills was done using a questionnaire that included questions about the subjective assessment of their skills and about the level of their competencies in relation to some aspects of health. The aim was also to make an assessment of the students' conviction about the usefulness of the knowledge gained through their biology lessons in everyday life. The research focused on the following areas: basic physiological processes in the human body, healthy nutrition, ways to cope with stress, and, the impact of some substances on human health.

Assessment of the health competencies of students: Analysis of research results

The core curriculum is focused on applying the knowledge gained in school lessons to

everyday life, so, the greatest value is no longer the possession of knowledge, but the ability to apply it in practice. The research shows that biology, as a science, was useful for the most respondents – as indicated by two thirds of the respondents. Despite the dominance of this among all of surveyed students, the percentage of students who think the biological knowledge is useful should be higher. According to 33% of students, knowledge gained during the biology lessons is useless in everyday life.

More than half of the respondents assessed their knowledge of how to protect their health as “well.” This was indicated by 55% of the study group (Table 1). The rest of the responses totalled 45% of the students. Of the 45% of respondents, 32% assessed their knowledge as “sufficient,” 8% as “very well” and 5% as “insufficient.” The latter is similar to the research hypothesis (Tuszyńska, 2012).

Table 1. The level of the knowledge related to the health protection – subjective assessment of the respondents

Assessment of the level of knowledge in the field of health – declarations	Percentage
Very well	8%
Well	55%
Sufficient	32%
Insufficient	5%

Health topics implemented in the curriculum of the biology course in the middle school mainly include learning about the physique and functioning of the systems. The level of a general knowledge related to physique and physiology was checked by the questions about the organs of an excretory system and about serological conflict.

The responses of surveyed students indicated that 76% of them do not know which organs are the structures of an

excretory system. For example, they answered the colon and rectum. The construction of the excretory system was correctly identified by 10% (the renal response option). The rest of the respondents indicated another incorrect options: the large intestine (11%) and prostate (2%).

Understanding the term “serological conflict,” was tested by a short-response question: "If a woman has an Rh-negative blood type and her partner has an Rh – positive, then the pregnancy may be at risk. This effect is called ... ". The correct answer was given by 42% of the students, less than half of the surveyed group. Other respondents (58%) indicated either "do not know," or named this effect incorrectly.

In the study, the authors made an assessment of the students’ competencies in the field of exercise physiology (anaerobic cellular respiration, muscle microinjuries), and, the digestion, absorption of nutrients and intestinal passage. The knowledge of the processes, typical for strong physical exercises, up 77 people, represents 68% of the respondents. Correct answers were given by the group of males (74% of surveyed boys).

Middle school is the last stage of education, when students get knowledge about the physiological processes typical of the human body (such as digestion). At the next stage of education (secondary school) such content should be provided only by teachers with advanced training. The process of digestion was correctly defined by 81% of the 113 respondents. Twenty percent of the respondents could not define the essence of this process.

In terms of students’ achievements as formulated by the authors of the general education core curriculum (Tuszyńska,

2012), the 81% of students who correctly defined the process of digestion seems to be low, because such terms and processes are the minimum knowledge given during the biology lessons in the middle school.

Biology is taught in middle school, to not only familiarize students with the knowledge of the physique and function of the gastrointestinal system, but also to form the skills which are necessary to keep a system healthy, such as planning a daily diet. The necessity of teaching such content is the reason for teaching the “health triangle,” and promoting health products beneficial and harmful to health. In this research, 78% of respondents declared the ability to plan a daily diet. The level of such competency is actually similar to what respondents declared: a diet composed correctly was indicated by 86% of students, listing the same meals included in the diet (breakfast, snack, lunch, second snack, dinner). According to the 7 percent of incorrect answers, respondents correctly made a thesis that a diet should consist of five meals a day, but that one of them can be salty or sweet snack. Also, wrong answers were indicated by another 6% of respondents who believe that a correctly planned menu consisted of a number of meals according to one’s preference. One person thinks that a correctly formed diet consists of three meals, which is a result of the reluctance of many people to eat a first meal during the day (breakfast).

A varied diet is the basic component of a healthy nutrition. In the study, the researchers checked the level of knowledge of students about why a diet should include many various products. The largest percentage of respondents (81.5%) stated that a varied diet is important because it allows people to fulfill the requirements for

each element like vitamins and minerals. Unfortunately, 14% stated that the reason for a varied diet is that a body each day has a different requirement for vitamins and minerals. 3.5% of respondents explained that a reason of a varied diet is the fact that water is a major element, which the body consists of. 1% said this would protect against sexually transmitted diseases.

An important element related to the nutrition, which the research focused on, was to investigate the ability to calculate body mass index (BMI). In order to verify the students’ competence, they were asked for write a simple formula for how to calculate the BMI; they were told not to calculate a final result. In this task, the students were given some parameters that had to be used in the construction of the formula. In order to analyze students’ responses with no doubts in relation to the interpretation, the question underlined that the final result is not subject to this task. Analysis of the responses showed that approximately every fifth person (21% of respondents) can calculate BMI. Other people wrote this formula incorrectly (41%), or missed this task (38%).

Practiced ways of coping with stress - declarations of students

Students’ achievements in the field of managing stress situations is an important result of education. It is included in the health education curriculum of teaching, according to core curriculum. However, the reference to the effect of stress is so general that it leaves wide open the interpretation of how to implement those issues in education. The aforementioned document points to students’ knowledge of the causes of stress and examples of positive and negative stress. In addition, it assumes that the student is able to cope with a stressful

situation. But it does not pay attention for the issues of the destructiveness of some behaviours, leaving it up to the free will of the teachers and authors of textbooks.

It was found among respondents that only 34% of students use effective and healthy ways of coping with stress encountered in everyday life. The answer to the question asked to students required knowledge or at least some assumptions about the effectiveness and healthiness of chosen stress coping methods. Therefore, it is justified to say that 76% of surveyed students, in the first year of secondary school, choose unhealthy and ineffective methods of stress control. According to the analysis of responses, it was also observed that the group with more effective and healthier ways of coping with stress is the boys (43%). Among girls, only 28% reported practicing such methods. Detailed results are gathered in the figure 1.

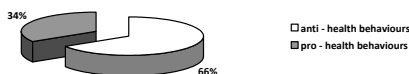


Figure 1. Declared choice of methods of coping with stress

The ways of coping with stress are often described as constructive or destructive. The evaluation of the group of respondents showed that young people tend to chose unhealthy stress management methods, so destructive behaviors predominate. In order to specify the behaviours of the students, they were asked to name their four most practiced stress relieving activities. Survey results indicated that a large group of named

activities were either healthy or neutral for health. Listening to music was the most frequently given answer - 64% of the students are coping with stress in that way. The second most practiced way to cope with stress was sleeping - a variant chosen by 42% of respondents. Talking to friends (27%), sports (27%) and going for a walk (25%) were chosen equally often, which could mean there is a much less alarming situation than would appear from the declaration of the students.

Other frequently used methods of coping with stress proved to be relaxation through computer games (12%) and watching TV (7%). These behaviours allow students to eliminate the effects of stress, but in the absence of self-control can lead to all kinds of problems (including addiction). Nearly a quarter of the respondents choose negative method of coping with stress - eating, which may indicate the increasing problems of eating disorders and maintaining a healthy weight. Given that the study group consisted of first year high schools students, whose age did not exceed 17 years, smoking is a particular concern. As a way of dealing with stress it is practiced by 16% of respondents. A similar situation was observed in the case of alcohol: all students at the time of the study were minors, and they should not have come into contact with alcohol. 6% of students consumed alcohol to dissipate negative emotions. A small percentage of people pointed drugs as a way to control stress (2%) - Figure 2.

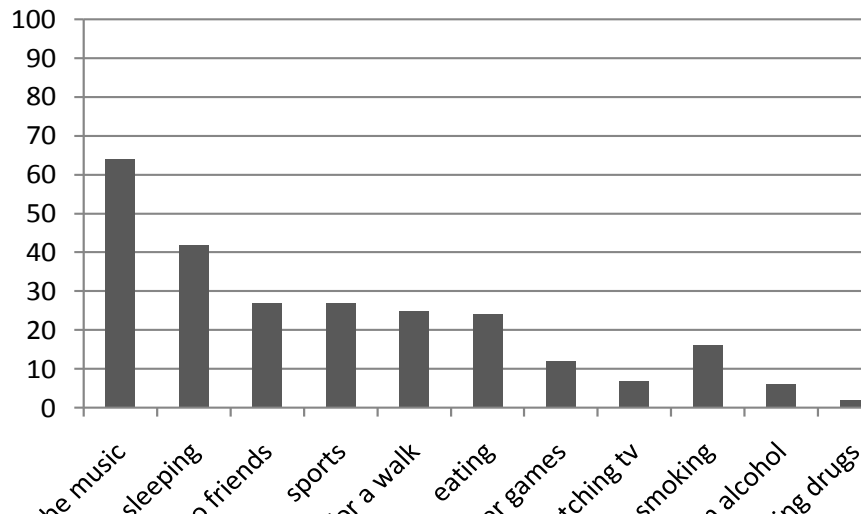


Figure 2. Ways to cope with stress - declarations of surveyed students

The level of awareness of students on the effects of certain substances on health

One of the expected competence the student should have, in accordance with the guidelines provided by core curriculum, is to be aware of the negative impact of substances such as alcohol and tobacco on human health. In this study, 96% of the students declared that they possess knowledge of the risks of using them. Alcohol, tobacco and drugs are a serious threat to health. These substances increase the risk of many diseases, an example of which may be larynx cancer, which is not a disease often associated with excessive consumption of alcohol but it may develop when the specific factors occur. People who pointed in a study that there is relationship between cancer of the larynx and alcohol consumption (12%) have shown a detailed knowledge of the issue, or it may also be the result of the lack of knowledge and giving an adventitious answer.

Relatively few students pointed out that there is association between the occurrence of lung cancer and the consumption of alcohol (5%). This disease is usually associated with smoking - as much as 93%

of surveyed students indicated that such relationship exists. The emphasis on destructiveness of smoking in the society and the omnipresence of health-related information on smoking suggest that this percentage (93%) should have been closer to 100%. The relationship between tobacco and addiction was pointed by 90% of respondents. The study group had a good knowledge of the health consequences of smoking: 70% of respondents mentioned that this activity may be the reason for larynx cancer (70%). The fact that an equal percentage of students attributed the effects of smoking to the development of cervical cancer (17%) and hypertension (18%) is quite disturbing. It is known that of those two, only the hypertension is associated with cigarette smoking. It is worrisome that 34% of respondents associated smoking with an increased probability of the occurrence of melanoma. This may be due to incorrect interpretation of the melanoma causes (smoking and sunbathing, temperature). Smoking was also associated, by the respondents, with diabetes and liver diseases (4% vs. 7%), but the occurrence of these diseases is not typical for smokers (Figure 3).

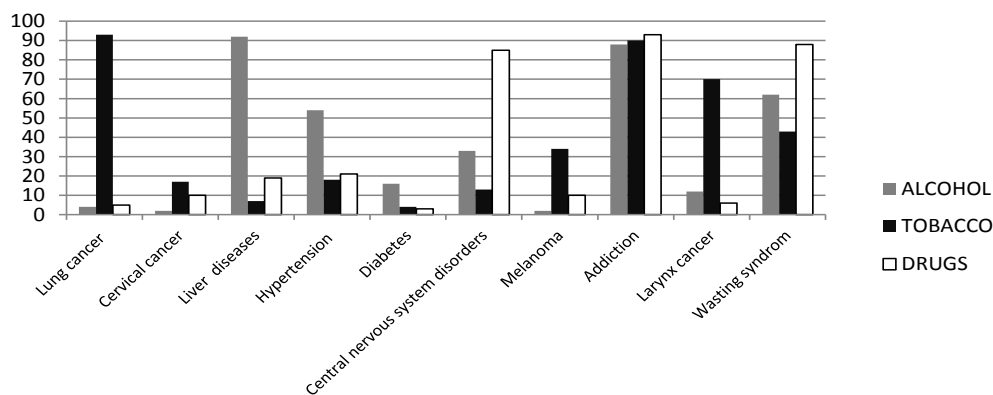


Figure 3. Health consequences of the use of the stimulants - the competence of the respondents

Drugs are the main cause of addiction (93%) and wasting syndrome (88%) in the eyes of respondents. A group of 85% correctly pointed out that drugs could damage the central nervous system. The correlation between narcotics and liver damage or high blood pressure, was not so obvious to the respondents. Only 20% of them indicated that correlation. The use of drugs is not a direct cause of diseases such as larynx cancer, lung cancer and diabetes. Respectively 7%, 5% and 3% of the students gave this answer.

Summary

Health education is a complex process of combining multiple elements, including knowledge about health and functioning of the body, the ability to cope with stressful situations, and knowledge of the environmental factors affecting health <http://www.ore.edu.pl/strona-ore/index.php?option=com_content&view=article&id=245&Itemid=1104>. Students' achievements and social competencies in the field of human health are shaped under the influence of the family, peer groups, media and the

institutions responsible for formal education, but the level of knowledge (skills) of students is not satisfactory. This is confirmed by the results of the analysis of high school students, which indicate that they do not follow proper diet, they consume alcohol, and they do not always cope well in stressful situations (Tuszyńska, 2012).

An update to the core curriculum (Rozporządzenie, 2008) was done to obtain better results in youth education in the field of a healthy lifestyle and avoid the negative impact on health of some behaviors (Tuszyńska, 2012). The aim of the health education is to provide people with necessary tools for choosing healthy lifestyle <http://www.ore.edu.pl/strona-ore/index.php?option=com_content&view=article&id=245&Itemid=1104>. All teachers are responsible for the implementation of health education into schoolteaching programmes, but the main role should be played by biology and physical education teachers. There were many concerns about the inadequate preparation of physical education teachers,

after the changes to the core curriculum were done. Intensive improvements of competence in the field of health education of this group of teachers were undertaken. Although the biology teachers are perceived as being competent in this area, it seems that it would be useful to carry out studies examining not only their knowledge but how often and efficient do they implement elements of health education into the secondary school biology classes.

Analysis of the results confirms the relatively low level of competencies of middle school graduates in selected achievements formulated by the biology curriculum. Students subjected to these studies have shown lack of knowledge in the field of health education and a low awareness of health risks.

Conclusion

Education of middle school students in the area of health and risk behaviours is part of several teaching subjects, but particular importance is attributed to biology teaching. Learning outcomes in areas related directly and indirectly to health, are not satisfactory; the competence of middle school graduates are low and do not meet the program requirements at this stage of education. A particularly noticeable result of the study was the lack of knowledge of basic terms and physiological processes typical for the human organism. Despite new trends in education that focus on measurable achievements of students, the studied group of young people consciously choose unhealthy ways to cope with stress. Smoking, alcohol, or drug use is not large, nevertheless, more and more young people treat eating as a way of coping with stress. The consequences of such behavior are long term and dangerous, which is reflected in the

growing percentage of those overweight and obese among the young generation.

Health behaviors are shaped by both the domestic environment (family) and the school, while the acquisition of expertise in the field of caring about health is typically left for formal education (school). Habits formed in the school have a significant impact on the development and health during childhood, adolescence and adulthood. Therefore, responsibility for health education should lie in a competent teaching staff in school. It seems especially important to pay attention to teacher training in the field of health education and the need for curriculum development taking into account the most efficient ways of transferring knowledge of health-oriented lifestyles. In order to raise the level of competence of the students at every stage of education, it is required to carry out activities of a non-formal education in the form of media or public benefit organizations – a multi-sectoral actions for health could increase the potential healthiness of society, including the students.

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The Role of Dynamic Computer Models in Teaching about Microworlds at the Primary Level

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One of the main aims for teachers in science teaching is to create a proper way in which students think about the surrounding world and the changes in it. This point of view concerns both the macroworld which means everything that influences students' senses as well as the microworld of atoms and molecules which are hidden from our senses. Students can easily understand the phenomena of microworlds through dynamic computer models.

Jednym z głównych celów nauczycieli w nauczaniu przedmiotów przyrodniczych jest nauczenie uczniów poprawnego sposobu myślenia o otaczającym ich świecie i zmianach jakie w nim zachodzą. Dotyczy to zarówno myślenia o świecie makro (czyli świecie w jakim uczniowie żyją i który jest dostępny ich zmysłom) jak również myślenia o mikroświecie - świecie atomów, jonów i cząsteczek, które są ukryte przed naszymi zmysłami. Ułatwieniem w zrozumieniu jak przebiegają procesy w mikroświecie są dla uczniów dynamiczne komputerowe animacje.

Keywords: didactic chemistry, microworld, computer models

Introduction

On January 1st, 1999, Poland started a major reform of its educational system. One of the changes of the reform was a new subject, "natural sciences" which was introduced to the curriculum of classes 4, 5 and 6 in the primary school. The subject consists of basic biology, chemistry, physics and geography. It is a kind of introduction into these subjects, which are taught after graduating the primary school, in gymnasium. One of the main goals of teaching the "natural sciences" in the primary school is making the students aware of the phenomena of the surrounding world and its changes. (Rozporządzenie Ministra Edukacji Narodowej, 2007). It is true not only for the

macroworld notions (world which can be discovered by senses) but also for microworld notions (the world of chemical individual atoms, ions, and particles which cannot be experienced directly through senses).

One of the most important issues included in the curriculum of teaching the natural sciences in the primary school is the changes and transformations, which are taking place around us. Also, the changes of the state of aggregation (Dmochowski *et al.*; 2000). It is a problem, which is observed by students in their everyday life. However, the phenomenon observed in the macroworld is not complete. At the level of macroworld it

is not possible to answer the question: "Why does ice melt when the temperature rises?" To be able to understand that problem a student has to know the structure of the microworld (Nodzyńska, 2011). That is why, while teaching the natural sciences subjects to students in the primary school, the teacher should introduce and explain the micro scale. Then, the knowledge of the students would be compatible with the present state of knowledge in science and it would enable them to understand the observed natural processes. In accordance with the Kupisiewicz conception, abstract thinking can be developed early in the basic level of education, because every level of sensoric-motoric thinking has capability, and at a certain level, of abstract thinking (the information concerning the structure of the material at the micro scale is considered abstract) (Kupisiewicz, 2005). To make it easier for students of the primary school to understand the notion of the microworld in the natural sciences teaching certain models are implemented (Paško, 2004; Cieśla & Nodzyńska, 2012).

Research

To explain the processes of changes in the state of aggregation (as an example - on water) a dynamic computer model was developed using the program Flash, which showed the processes widely known by students - ice melting, evaporation of water.

The main goals and characteristics of the computer dynamic models are:

- to show the three dimensional space at the level of the micro world
- to display the movements of particles, ions, atoms in the solid bodies, liquids and gases
- proportions are real in that models - the size of particular atoms in particles and in ions
- particles and polyatomic ions have their real shape

-that atoms, ions and particles are not presented as sharp structures with an end, but the form of electron cloud is being emulated with blurred image, without clear boundaries of the particle

-they meet the theory Brownian motion.

-they state the fact that the atoms, ions and particles do not have any colors

-they enable repetitions with emphasizing successive steps of the reaction

-they allow certain simplifications corresponding with the level of knowledge of the user (Bilek & Nodzyńska, 2007; Nodzyńska, 2012a; 2012b; Nodzyńska & Paško 2012).

An animation was created where through these models, the changes, which occur during the melting of the ice and evaporation of the water in the micro scale were shown.

The research was conducted in two primary schools in the fifth classes. In both schools the obligatory textbook for this subject is the same. The research was conducted using the method of pedagogical experiment, parallel groups technique. Two groups were created: -first group was an experimental group (students of the 5th class in the Public Primary "Paula Montal, Pijar Sisters" School in Rzeszów) where an independent variable was introduced - computer animation, -second group was a control group (students of the 5th class in the Public Primary "Paula Montal, Pijar Sisters" School in Kraków)

The lessons in both classes were carried out using a similar lesson plan. The goal of the lesson plan in the control group was explanation of what is happening in the micro scale by a teacher (without any additional aids) and the change of the state of aggregation was observed during the lesson on an example with an ice cube melting. In the lesson plan of the

experimental class the change of the state of aggregation was shown on the computer animation using the dynamic models and a teacher only described the process of the melting ice.

In the end of the lesson in both classes a questionnaire was carried out. The questionnaire consisted of 13 questions - both open and closed ended concerning the content of the lesson and its evaluation.

The results

The first question in the questionnaire was: "Name the pictures correctly: ice, water, steam."

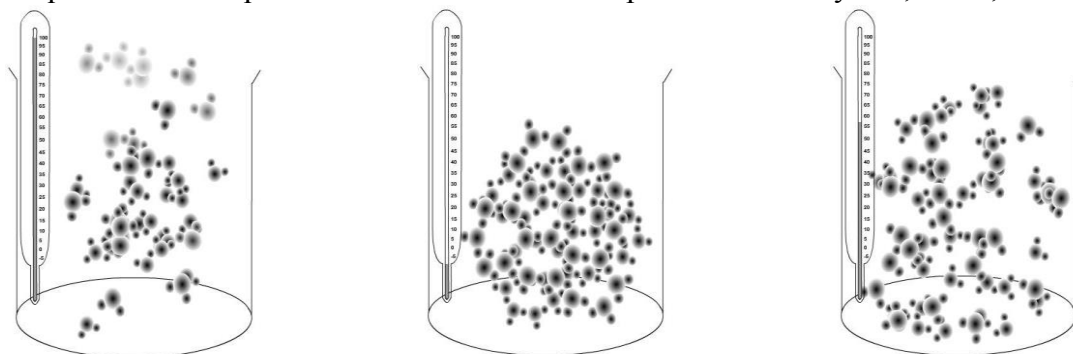


Figure 1. Picture to question 1 in the questionnaire

All the students answered this question. In the experimental school, 100% of students answered correctly, in the control school 96% of correct answers was obtained. The difference is not statistically significant, so the conclusion can be that the students who watched the animation and the ones who only heard from the teacher about the processes in micro scale can recognize the right states of aggregation.

The second question was: "describe what the ice cube is built from?"

All the students also answered that question. Because of the variety of answers, they were divided into 9 categories. The quantity of answers in each category is shown in the Table 1. The number of the correct answers (the ice cube is built from the particles of water) given by the students of the experimental classes was 70%, and, the students of control classes was 30%.

Another issue observed is that a part of students from the experimental class (18%) remembered correctly the notion "hydrogen bond" and used it in the right context, contrary to the students from the control class who did not.

A conclusion can be made that using the dynamic computer models caused not only better understanding of the inner structure of the ice crystal, but also that some part of what students learn in the next level of education are being learned first at primary school.

Table 1. Categories and the percentage of the particular answers on the questions 2:

Students' answers	control class	experimental class
from the particles of water	30%	70%
from the water molecules	22%	
from small particles which oscillate	22%	
from frozen water	13%	
from particles combined by hydrogen bonds		18%
from atoms		4%
from water		4%
from elements H and O combined with hydrogens	13%	
solid body		4%

The answers to Question 2 were also classified regarding their correctness. In the experimental classes the number of the correct answers was 96% and in the control classes it was only 87%. Next issue being compared was the number of terms from the microworld, which was used by students in their answers. In the experimental classes the students used these notions more frequently (92%) than the students from the control classes (87%).

To sum, it can be said that better results were obtained in the experimental classes. The students of these classes more frequently answered the questions correctly and used notions from the microworld.

The answers to the third question of the questionnaire:

"Describe how the particles of water behave in the temperature of 0°C." are presented in Table 2:

Table 2. Categories and the percentage of the particular answers on the questions 3:

Students' answers	Correct answer	Terms from the micro scale world	Control classes	Experimental classes
the particles oscillate	+	+	17%	
the particles oscillate and come off	+	+	9%	
the particles come off	+	+	13%	
they melt			9%	
they freeze and form an ice cube			26%	
they are joined together	+	+	4%	
less place to move			4%	
bubbles are formed			4%	
are oscillating very quickly	+		4%	
nothing is happening			4%	
they are dispersing	+	+		35%
oscillating around their axis	+	+		52%
spinning around their axis and then are separated	+	+		9%
they unfreeze				4%
lack of answer			6%	0%

In analyzing the answers, first thing seen is that the students of the experimental classes gave less varied answers. 96% of the answers were correct and concerned the world at the micro scale. The answers of the students of the control classes were varied, but only 47% can be recognized as correct and relating to the micro world. So it can be assumed that the visualization of the process of ice melting in the micro scale helped the students from the experimental classes to understand the process more fully.

The next question was: "Describe the process of ice melting."

This question concerned in fact the same process as in Question 3. But, in that case there were no notions from the microworld. The Question checked if the students used the terms by themselves, even if they are not used in the question.

Table 3. Categories and the percentage of the particular answers on the questions 4:

Students' answers	Correct answer	Terms from the micro scale world	Control classes	Experimental classes
the ice cube is melting			22	
the change of the state of aggregation from solid to liquid	+		30	30
the particles coming off the solid body	+	+	18	
disruption of the hydrogen bonds	+	+	13	
the particles tear off and glide in the form of water vapor		+	9	
slow evaporation			4	
it's detaching of the particles	+	+		17
quicker movement of the particles	+	+		40
it's transfer of the thermal energy	+			9
lack of answer			4	4

The most popular answer from students from the experimental classes was that the process of ice melting consists in quicker movements of the particles (40% of answers). No one from the control classes answered that question that way. It can be seen that the students paid attention to the correlation between the temperature of the system and the speed of moving particles.

The students from the control classes answered most frequently (30%) that ice melting consists in changing of the state of aggregation.

Comparing the percent of right answers of the students from both classes, we can note that the students from the experimental classes obtained clearly better results (94% of correct answers) than the students from the control classes (61% of correct answers). Students from the experimental classes used the terms from the micro world in 57% and in the control classes in 40%. In comparison to the former question (96% and 47% of answers consisting of the terms from microworld) it can be observed that a percent of answers including these terms decreased when the terms weren't used in the question. Therefore, it can be assumed that while asking the students to explain some phenomena, terms from the microworld should be used.

In the 5th Question, the students had to choose from 6 statements the correct ones (more than one could be correct).

- a) The particles of solid water don't move
- b) The particles of solid water oscillate slightly
- c) The particles of liquid water move
- d) The particles of liquid water only oscillate slightly
- e) The particles of water vapor move slower than in the liquid water
- f) The particles of water vapor move quicker than in the liquid water

The results show that the students from the experimental classes answered the questions definitely better - 70% of them checked all the correct answers, while the control classes did so only 35%. It can be assumed that the students watching the animation observed the movements of the particles in each state of aggregation and remembered that information.

In next Question, the students were asked about the definition of the evaporation process: "How is the process named where the liquid changes into water vapor?" students gave mostly correct answers: evaporation (56% in control classes, 52% in experimental classes), vaporization (9%, 8%), boiling (9%, 4%). Generally in that question can be observed that the control classes were doing better - 74% of correct answers in comparison to 64% of correct answers in experimental classes. In the case where the Question is not related to the computer animation, which students were watching, but to the memorized knowledge, better results were observed in control classes.

Questions 7 and 8 were analogous to questions 3 and 4, but, they concerned the boiling process. Like in the former Questions (3 & 4) the first (Question 7) had in its content the notions from the microworld and the second (Question 8) did not. In Question 7, the students had to describe what is happening with the water particles at a temperature of 100 degrees. In the next Question they were asked to describe the process of boiling.

It turned out that observation of the boiling process in presented animation wasn't easy and the majority of students (85%) from the experimental classes answered Question 7 incorrectly. The answers were: "the particles are vaporizing" or "they are changing into water vapor". In the control classes only 38% of students gave similar answers. In the control classes the majority answered correctly (45%) that "the particles move very quickly and have such big energy that come off the surface of water liquid", however, only 17% of the experimental class answered in that way.

It can be assumed that the fragment of the animation showing the process of boiling at the micro scale should be analyzed because it is probably erroneous.

In the control classes, a relatively big percent (19%) gave totally incorrect answers as "the particles are disappearing", "they are bubbling". These kinds of answers didn't appear in experimental classes.

Even more problems occurred with Question 8. Mostly, the students used as a synonym of boiling evaporation (61% in the control classes and 62% in experimental classes). 22% of students from the control class and 17% from the experimental class paid attention to the quicker movements of the particles during the process of boiling. It seems that the second part of the

animation (concerning the process of boiling) was definitely worse than the first one (concerning the process of ice melting) or maybe a break is necessary between these two animations.

Question 9 checked if the students could draw a particle of water. That question was answered correctly by 22% of students in the control classes and 96% of students in the experimental classes. So, it can be assumed that the visualization presented during the lesson improved remarkably students' ideas of the micro-structure (in that case the structure of the water particle). What is interesting is that in the questionnaire, in questions one and ten, the particles of water were drawn.

In the next question, the students had to choose the correct caption under the picture (Figure.2). In the answers to this question there is no statistically significant difference observed - 100% of correct answers given by students from the control classes, 96% of correct answers given by the ones from experimental classes.

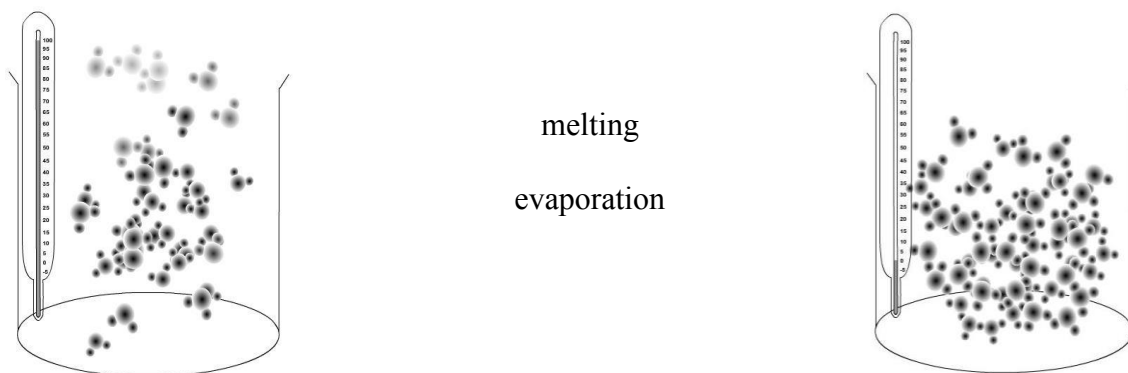


Figure 2. Picture to Question 10 in the Questionnaire

Question 11 was: "Describe what happened to the temperature which was measured by a thermometer during the whole experiment." The obtained answers are shown in Table 4. Despite that the students from both classes observed the increase of temperature during the whole process, the difference in percent of correct answers is distinct. In the experimental classes 83% correct answers were given and in the control ones 43%. The big difference can be probably explained because the students from the experimental class watched the animation on a big screen of a multimedia projector and the students from the control classes watched the experiments as shown them by a teacher. That is why the students from the experimental class could precisely observe the rise of the temperature at the thermometer.

Table 4. Categories and the percentage of the particular answers on the questions 11

Students' answers	Correct answer	Control classes	Experimental classes
was rising	+	39	70
was rising from 0 to 100	+		13
the temperature described by each state of aggregation	+	4	
it was rising and after coming to 0 it stopped	+/-		4
it was changing	+/-	17	
was increasing and then decreasing		17	
was decreasing and then increasing		13	
lack of answer		10	4
off topic answers			9

In Question 12, the students had to fill 5 boxes on a chart with words: ice, liquid water, water vapor, evaporation, melting.

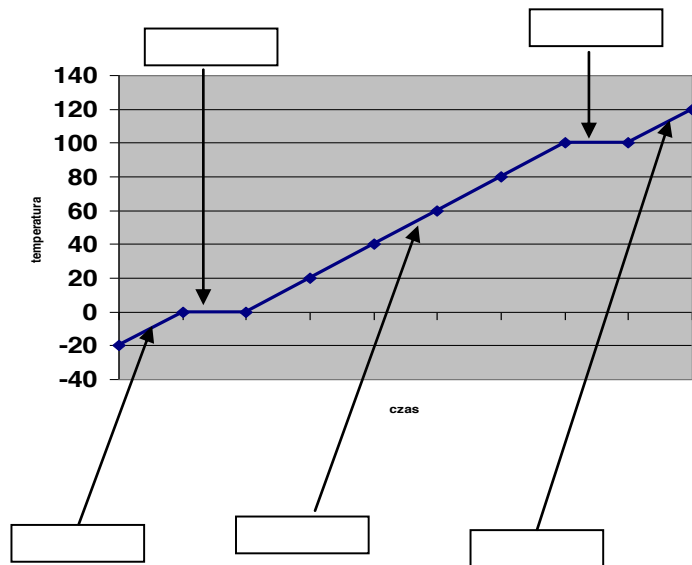


Figure 3. Picture to Question 12 in the Questionnaire

This Question is not related directly to the watched animation, analogous to Question 6. Identically like in Question 6, also Question 12 was better answered by students from the control class - 83% of the students put all the words in the right boxes. In experimental class, only 53% answered the question fully correct. In the experimental class 35% of students made one mistake (ex. confusing the notions evaporation - water vapor and melting - liquid water.)

The last Question, number 13, was the evaluation and was different for both classes:

Control class

Choose the answer:

The experiment carried out in the lesson:

- a) *I liked it very much*
- b) *It was ok*
- c) *I didn't like it*

Experimental class

Choose the answer:

The animation presented on the lesson:

- a) *I liked it very much*
- b) *It was ok*
- c) *I didn't like it*

Obtained results show that the students liked the lesson with animated computer models much better. 87% of the students from the experimental class answered they liked the lesson very much compared to 56% of students who answered that from the control classes.

Conclusions:

From this research, it follows that the questions, which were not related directly to the presented animation (Questions 6 and 12), definitely better results achieved the control classes. However, in the other 10 questions, which were related to the contents that appeared in the animation, the experimental classes did better. The control classes answered better only two questions concerning the process of boiling (probably erroneously pictured in the visualization). In two questions (number 1 and 10), where the students had to identify the state of aggregation and the process of melting and evaporation, both classes obtained similar results.

Taking everything into account, it can be summarized that the animation presented to the students of the experimental classes contributed to better comprehension by the students of the process of ice melting. These students learned to describe the phenomenon using the terms of microworld. The results show clearly that even students in primary school can learn about the micro-structure of the world if the proper teaching aids are being used. In favor of the computer dynamic models, is the fact that the students from the control classes, for Questions 1 and 10 of the Questionnaire could choose the right caption under each picture even though they were seeing these kind of pictures for the first time and without any explanations from the teacher.

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Rozporządzenie Ministra Edukacji Narodowej z dnia 23 sierpnia 2007 r. zmieniające rozporządzenie w sprawie podstawy programowej wychowania przedszkolnego oraz kształcenia ogólnego w poszczególnych typach szkół - Podstawa programowa kształcenia ogólnego dla szkół podstawowych i gimnazjów



Margaret Christine Nodzyńska, doctor of pedagogical sciences of teaching chemistry.

In 1983. she graduated from the Faculty of Chemistry of the Jagiellonian University in Cracow, graduating in 1989

with master's degree in chemistry. After graduation, she was employed at the Department of Chemistry, Pedagogical University of Cracow. While working at the university, Dr. M. Nodzyńska also worked at the school as a teacher of chemistry. Her experience as a teacher is backed up by 18 years of teaching students in various types of schools. In 2003, Dr. M. Nodzyńska received a degree of doctor of pedagogical sciences of teaching chemistry at the Faculty of History of Education at the University of Opole, where she defended her doctoral

thesis entitled "Development of chemical concepts in students in the educational process." The supervisor was Prof. Richard Gmoch. On May 16, 2013, she defended her Habilitation at the Charles University in Prague called "visualization in chemistry and chemistry teaching."

Dr. Margaret Nodzyńska organized numerous scientific conferences and seminars - including conference that is held regularly every two years called: Research in didactics science. Major achievements is the participation of Dr. M. Nodzyńskiej in eight international grants. The scientific achievements of Dr. M. Nodzyńskiej includes seven monographs, editors 12 monographs, 32 chapters in books Polish and foreign, seven school textbooks, which is authored 150 journal articles in Polish and foreign.



Mgr Joanna Tajduś studied biology with elements of chemistry and natural science at Pedagogical University in Kraków. Her magistrature was on a subject of didactics of chemistry entitled: "Usage of dynamic computer models in

science classes with regards to teaching about changes in physical states". She has been working as a teacher of science at Public Primary *Paula Montal, Pijar Sisters* School in Rzeszów since 2009. Since 2011 she has been employed in Public Secondary *Paula Montal, Pijar Sisters* School in Rzeszów as a teacher of chemistry and biology and at the same time she has been acting as a assistant headmaster in the same institution.

Cooperation in Science Education between Austria and Taiwan using the Science Garage, an Approach for Self-Motivated Science Learning

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The education in various science disciplines like chemistry and physics has been for a long time disregarded as not feasible in primary schools or early middle school grades. The same situation was valid for related technology fields. In reverse, it is commonly accepted that hands-on experiences in those age groups often last a lifetime such as sports or music. At the University of Teacher Education Vienna (pädagogische Hochschule PH Wien) since 2010, a concept was created to initiate pupil's motivation to develop interests in science and technology, bearing the name "Science Garage." The aim is not only to start this particular interest but to design it so enriching that it lasts for several years, most desirably for the following individual school careers, including any tertiary education. Several hands-on experiments were developed based on the experiences of some primary schools in Vienna's 20th district. Additional experiments were reviewed in numerous EU & US institutions. Emphasis was laid on selected science chapters and new topics being added each term. At present some included fields are thermodynamics, fluids and gas properties, chemical compounds and reactions, electrical circuits, and magnetism. All those activities are translated for primary school pupils in terms and illustrations appropriate for their age. A Fact Book is being developed for the use of accompanying teachers at various levels (students, instructors, supervisors) to achieve more insight in scientific explanations intensely using discussion forums. The increasing heterogeneity issue developed in urban Vienna schools over the past more than two decades has to be taken into account resulting in different approaches by pupils to science topics in terms of language and literacy. The newest topic being incorporated into the Science Garage is the field of Robotics in collaboration with the Austrian Society for Computing. Based on serious interest in Asia science education such as the concept of the Science Garage was presented to the National University of Education (NPUE) in Pingtung, Taiwan, Science Department. The aim was to create mutual cooperation and it was commonly agreed to develop together further Science Garage topics, and to present them at the 5th NICE (Network for Inter-Asian Chemistry Educators) conference in Taiwan in July 2013 (NICE Conference, 2013). It generated on both sides some intention to deepen relations in the field of primary science education not limited to core science & technology topics, but also considering heterogeneity, language and literacy issues as well.

Keywords: science education, development of science and technology, Science Garage, Austria, Taiwan

Der Unterricht in verschiedenen Fachdisziplinen wie Chemie und Physik wurde für lange Zeit als nicht durchführbar in Grundschulen oder den ersten Klassen der Mittelschule erachtet. Dieselbe Situation galt für verwandte Gebiete der Technik. Umgekehrt ist es weitläufig anerkannt, dass praktische Aktivitäten in diesen Altersgruppen oft ein Leben lang nachwirken wie etwa in Sport oder Musik. An der pädagogische Hochschule PH Wien wird seit 2010 ein Konzept verwirklicht um beim Schüler eine Motivation auszulösen sich mit Interesse den Naturwissenschaften und der Technik zu widmen, dies erhielt die Namensbezeichnung „Forscherwerkstatt“. Das Ziel ist nicht nur ein spezifisches Interesse zu wecken, sondern es auch so bereichernd zu designen dass es für mehrere Jahre anhält, am wünschenswertesten für die gesamte folgende Schulkarriere, inklusive der tertiären Bildungswege. Unterschiedliche aktivitätsbezogene Experimente wurden aufgrund von anfänglichen Erfahrungen an einigen Wiener Schulen im 20. Gemeindebezirk entwickelt, zusätzliche Experimente wurden in mehreren EU & US-Institutionen begutachtet (tryscience.com, 1999-2011; Andersen & Brown, 2012; Sobey, 2012), dies wegen der Erfahrung des Autors in einem Austauschprogramm für naturwissens. Lehrkräfte in Übersee (Vienna Exchange Program, 2008). Der Schwerpunkt wurde dabei auf ausgewählte Kapitel der Naturwissenschaften gelegt, neue Themen werden jedes Semester hinzugefügt und gegenwärtig sind einige der eingesetzten Gebiete die Thermodynamik, Eigenschaften von Flüssigkeiten und Gasen, chemische Verbindungen und Reaktionen, elektrische Kreisläufe und der Magnetismus. All diese Aktivitäten werden für Grundschüler übersetzt, sowohl hinsichtlich der Ausdrucksweise als auch der entsprechenden Illustrationen, um geeignet für ihre Alterstufe zu sein, z. B. „Nemo muss überleben“, „Starte deine eigene Rakete“ oder „Bau dein U-Boot“. Ein sogen. „Fact Book“ wird derzeit entwickelt für den Gebrauch der begleitenden Lehrer auf diversen Ebenen (Studenten, Ausbildungs-, Begleitlehrer) um mehr Einblick in naturwiss. Phänomene zu erhalten, mit Gebrauch von Diskussionsforen des Webs. Das an Wiener städtischen Schulen im Zunehmen begriffene Problem der Heterogenität hat sich über die vergangenen 2 Jahrzehnte erheblich entwickelt und muss daher berücksichtigt werden, eine der Auswirkungen sind die unterschiedlichen Sichtweisen der Schüler auf naturwissenschaftliche Inhalte in Hinblick auf Sprache und Wortschatz (Wellington & Osborne, 2001; Cobern, 1998; Holub, 2010). Das neueste Gebiet in der Forscherwerkstatt ist die Robotik in Zusammenarbeit mit der österreich. Gesellschaft für Computerwesen (ÖCG). Basierend auf ernsthaftem Interesse an natwiss. Unterricht in Asien wie in (Seo, 2008; Rosenthal, 1996; Kerschbaumer, 2010, 2012), beschrieben, erfolgte im späten Okt. 2012 ein Besuch an der nationalen pädagogischen Hochschule in Pingtung, Taiwan, Abtg. Natwiss. Didaktik, um dieses Konzept vorzustellen und eine gegenseitige Kooperation aufzubauen, dabei half für den Erstkontakt die ACEN (Asian Chemical Education Network). Aufgrund der enthusiastischen Reaktion auf dieses Konzept wurde übereinstimmend vereinbart gemeinsam weitere Forscherwerkstattsinhalte zu erarbeiten, und deren Umsetzung und Resultate beim 5. NICE (Network for Interasian Chemistry Educators) Konferenz in Taiwan im Juli 2013 zu präsentieren (NICE Conference, 2013). Es bewirkte auf beiden Seiten Absichten die Beziehungen zu vertiefen im Gebiet des Natwiss. Unterrichts für junge Schulkinder, aber nicht beschränkend auf reale Wissenschaften und Technik, sondern unter Berücksichtigung der Aspekten der Heterogenität, Sprache und dem Wortschatz.

Introduction

Education in various natural science disciplines like physics, chemistry, biology, integrated mathematics, as well as technology and engineering, has been for a long time disregarded as not practical, not feasible in primary or early middle school grades. The same situation existed for the related fields of electronics and construction.

This under-representation of science and technology has generated, over decades, various gaps in the education area. First is the lack of useable *supplies* in schools, a problem that the author experienced by himself in his own school career. Second, a certain lack of *will* by school authorities and governments. And third, there is, or in some countries after serious changes over the past years, there was, a simple but overall lack of *understanding* of science and technology by the teaching staff, both beginning and experienced teachers. This was definitely the case in my home-country Austria one and up to two generations ago. South & East Asian nations show comparable lacks in some ways (Tippins & Handa, 2010; Tapan, 2009).

A fourth lack is located in the fact that this issue more easily originates in non-English-speaking countries with *languages* such as German, French or Spanish, because English is *the* modern language of science. Therefore, scientific achievements may not be as represented in the wider public, as fast as it definitely happens in the Anglo-American regions of this world (“WMS = Western Modern Science,” Kawasaki, 2010).

Professional translations take considerable time, and English as a Second Language (ESL) in science teaching is a rather new, not a ubiquitous standard in German-

speaking nations and others (Edmunds, P.2012). This was definitely the case in my home-country Austria one and up to two generations ago. Other nations experienced or still experience a similar situation (Agarkar, 2010; Upadhyha, 2009).

On the other hand, the historical development of science and technology in the past four decades, especially their inclusion in so many fields of modern, everyday life, affected a whole new generation of teachers working with kids, who wanted to improve their skills and smartness on various scientific or technical challenges. This, in reverse, had considerable effect on society and culture as a whole (*Journal of Cultural Studies in Science Education*, CSSE, Springer, 2006-2013).

The role of mass media must not be underestimated at this point. The influence of science and technology on public awareness came (not only) with the rise of independent TV stations, which decided to show “science shows” in their weekly programs. At this time, it was not a guaranteed success at all, it was a great risk to do so, but it quickly turned into a constant positive performance. The high interest rates of young children in science and technology in Austria came particularly from one single TV show which aired in the mid-nineties called the “*The Researcher’s Express*” (Brezina, 2005). In this format, an animated flying 19th-century steam-locomotive crosses time and space, with real young boys and girls travelling inside, and perform various awe-inspiring experiments under the guidance of 2-3 researchers, who are actually actors trained by real scientists. The format became subsequently a worldwide success with synchronisations in over 20 languages.

This show did contain many interesting experiments, including a great deal of suspense, sparking curiosity not only for youngsters and children down to 3-4 yrs., but also for teenagers over 16 and their parents alike. A word which became fashionable only some few years after could describe it at its very sense: “Hands-on Science.” This was a new concept back then when science was taught in school grades 1-4 mainly just theoretically, therefore titled by children as “just boring”, or even ignored completely by the teachers.

This show influenced the behaviour towards science education on a large, truly national scale. The effects can be observed until today in our schools where many episodes have been distributed if interest exists, which was and still is the case in many schools.

In our neighbouring Germany, in order to appeal more viewers, a much more developed aka “styled-up” private TV format has aired for over 15 years: “Galileo,” which became a brand of its own including a monthly magazine. Equipped with school-board approved, high-tech documentaries about scientific and technological up-to-date achievements, ranging from genetics to environmental chemistry and computer engineering, it keeps young children hooked on real science, contrary to school science. As a consequence, “Hands-on science” is now a standard method in our national science curriculum (S.IMST-Network 2013).

The Concept of the Science Garage

It is commonly accepted within the professional education community and the general public as well, that hands-on experiences in those age groups often last a lifetime such as sports, languages or music. In other words, no theory can fully substitute

for practices performed by students. In 2009/2010, at the University of Teacher Education Vienna (pädagogische Hochschule PH Wien), a concept was created to initiate pupil’s motivation to develop interests in science and technology, bearing the name “Science Garage,” sometimes referred to as “Researcher’s Garage” (the literal translation from German is “Forscherwerkstatt”). Science Education for young children can be separated into 4 larger fields, which may be divided as proposed by the Taiwan Inst. of Compilation & Translation (after Chen, 2010). See Table 1.

Table 1.

Science Education for Young Children
-Physical Sciences (Human Body, Hygiene)
-Life Sciences (Animals & plants Cultivations)
-Technology (Tools, Mechanics, Appliances)
-Earth Sciences (Natural Environment)

The aim is not only to stimulate a particular interest in science, but to design it to be so enriching that it lasts for several years or even decades, most desirably lasting for individual’s school careers, including any tertiary education.

The Science Garage Curriculum unfortunately coexists alongside a continuing decrease in the numbers of STEM (Science, Technology, Engineering & Math) students in Austria (s. Univ. of Technology, TU Vienna, Annual Report 2011/12). Many university initiatives were launched to change that since the Millennium, but the numbers keep declining. A side effect of this worrying development is the sharp drop in the number of STEM teachers, leading to awkward situations both in Vienna and practically all major Austrian cities. For example, in one of our largest states Carinthia, there was in 2011 only one (1) new chemistry teacher

entering school service. In the capital Vienna, one science teacher could well serve 3-5 schools at once – if he or she were capable. The author experienced a similar, but much more dramatic situation in his exchange teaching year in the USA, where the Department of Education allows several hundred Indian STEM teachers to serve, for usually 2-3 years, in schools of all kinds, mostly public, all over the nation. It also became custom that they return to their home-country after their US school service to work in their own educational system, and some stay, of course (Hutchinson & Bailey, 2006).

To return to Europe, this situation became well known to many European states, in no ways limited to my country (ESERA Sci.Ed.Res.EU Annual Report 2012/13). In order to make lasting changes to that specific situation, we believe that the interest in science must start in very early ages, e.g. in grade 1-4, or even earlier. In 2010/11 a new approach was launched by several colleagues to start with chemistry and physics as early as in Kindergarten. So-called “*Molecoolino*” Sets were designed and are well in use now nationwide (Becker, 2010).

Our “*Science Garage*” is based upon such considerations, assisted by one of the most successful science education initiatives in Europe, the IMST-network (IMST-Program 2012/13).

Several hands-on experiments were developed based on experiences first made by some primary schools in Vienna’s 20th district forming a science-interested cluster, additional experiments were reviewed in numerous European & US-American institutions such as Anderson, E. & Brown, A. (2010), and Sobey, E. (2010), partly due

to the author’s exchange year as science teacher overseas (Corazza, R. 2008).

Emphasis was laid on selected science chapters. New topics are being added each term. (Table 2.)

Table 2. Science Garage Current Topics

<ul style="list-style-type: none"> -<i>Thermodynamics & Hydrodynamics</i> -<i>Fluids & Gas Properties & Heat + Cooling effects</i> -<i>Properties of Solids & Mechanics + Structures</i> -<i>Chemical compounds & Chemical reactions</i> -<i>Acids + Bases & Salts</i> -<i>Electrical circuits & Magnetism + Electromagnetism</i> -<i>Kinetics & Physics of Motion</i>

All activities are “translated” for primary school pupils in terms and illustrations appropriate for their age. (Table 3.)

Table 3. Illustrations of Science Activities

<ul style="list-style-type: none"> “<i>Nemo must Survive</i>” “<i>Fly your Yard Rocket!</i>” “<i>Steer your own Submarine</i>” “<i>Light for the Mouse</i>” “<i>Build like DaVinci</i>” “<i>Attract Stuff to a Screw</i>” “<i>Drop your Favorite Lego-Figure !</i>” “<i>Blow up a Balloon without your Mouth</i>” “<i>Red Cabbage shows its Colours</i>” “<i>Be a Water Music Composer</i>” “<i>Create an Underwater Volcano</i>” “<i>Make Liquid Rainbows</i>”

These include easy to recognize, youth-orientated popular toys and figures derived from movies and other media, e.g. comics.

Our newest topic incorporated into the increasingly visited Science Garage is the field of Robotics in collaboration with the Austrian Society for Computing (ÖCG).

A Series of “*Fact Books*” is currently being developed for use by teachers at various levels (for students, instructors, supervisors, team teachers) to enhance insight into scientific explanations. They include the intensely used web-based discussion forums.

There is increasing heterogeneity in urban and metro Vienna schools like in many other European cities, for more than two decades. This has to be taken into account in developing different approaches by pupils to science topics in terms of language and literacy (Wellington & Osborne, 2001; Cobern, 1998; Holub, 2010).

What is observed repeatedly is that three different languages are created in our “Science Garage”:

1. The language of instruction (German).
2. The (mother) language of the students (Turkish, Croat, Serb, Hungarian, Slovak, Czech, Greek, a.o.).
3. A “Third State” language as referred to by several scholars, or the “Hybrid”, yielding out of a mixture of 1 and 2, often understandable only by small groups of pupils, being highly diverse (Roth, 2008).

Collaboration with Taiwan

Based on serious interests by the Asian Science Education Communities (Seo, 2008; Rosenthal, 1996; Kerschbaumer, 2010, 2012), in late October 2012 the concept of the Science Garage was presented to the National University of Education (NPUE) in Pingtung, Taiwan, Science Education Department. The aim being to create mutual cooperation made initially possible by assistance of the Asian Chemical Education Network (ACEN) with its administration based at Soka University, Tokyo, Japan (Ito, 2013).

Upon positive reception of this concept, it was commonly agreed to develop together

more “Science Garage” topics, and to present and discuss their implementation and outcomes at the 5th NICE (Network for Inter-Asian Chemistry Educators) conference in Taiwan in late July 2013.

The NPUE generated a strong focus on Robotics using Lego Scratch programs, as well as an intense schedule for Marine Science. This is moving into biochemistry and pharmaceuticals as well as environmental chemistry and geology, especially targeted on young children. A similar concept may be used by our “Science Garage” for water and lake ecosystems, because we as a nation do not have any access to the open sea.

The visit and collaboration generated on both sides several plans to deepen relations in the field of primary science education, not limited to core science & technology topics, but also to consider heterogeneity, language and literacy issues as well.

Conclusion

As Abell & Lederman (2007) stated in their “Handbook for Advancement on Research in Science Education”, the ultimate purpose of all those efforts is to improve science teaching and learning on a global scale. With such collaborations, those aims are truly achievable in the near future. Science educators should broaden their research on an international scale, and bring more cross-cultural studies into realization. They also should publish their national efforts in international journals, thus sharing it with the worldwide science educators community and scholars from other countries, and even more important, other cultures. In this way, such studies will not only affect science educational efforts, but also bring some light into the wide field of cultural studies in science education (Siry *et al.*, 2013).

Taiwan and Austria may be useful examples for the evolution of such research in non-English-speaking countries.

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Montessori Method in Polish Education – a few words...

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Acquiring knowledge and gaining social skills is at the heart of every philosophy of education. However, each child has a different set of personality traits, which according to the Montessori pedagogy should determine the individual way of development. Personal plans of improvement should result in their independent and effective implementation. An educational environment should be an activating and stimulating factor, which aims to enable a child's development with respect to the reality surrounding the child. Realization of this approach involves breaking of the still prevalent model of passive roles students in the learning process. Dependence on a managerial and executive role for teachers stands in contrast to the Montessori Method. Attempts to implement Montessori pedagogy in Poland date back to the period when some educational institutions implemented some of the Montessori recommendations. Both the economic and social situation of the country, as well as the emerging legislation concerning education, stood in opposition to adapting comprehensive Montessori approach to the educational system. For more than two decades an increased interest in this method has been observed. More and more educational establishments note the need to reject the socially accepted model of teaching and education in order to create learning conditions appropriate for the individual needs of children. Institutions implementing Montessori pedagogy at each stage of child's education are growing in number in Poland. The observed trend is associated with a number of restrictions dependent on the specificity of Polish education. Formation of institutions, organizations and schools totally dedicated to the philosophy of Maria Montessori confirms the need for a detailed analysis of its implementation. A detailed example of a Montessori lesson, in the form of a trial about radioactivity, is included.

Keywords: Montessori method, education, science, Poland

Zdobywanie wiedzy oraz umiejętności społecznych leży u podstaw każdej filozofii edukacji. Jednakże każde dziecko charakteryzuje odmienny zestaw cech osobowości, który zgodnie z pedagogiką montessoriańską powinien decydować o drodze rozwoju. Indywidualne plany rozwojowe mają owocować samodzielną i efektywną ich realizacją. Czynnikiem aktywizującym i pobudzającym do działania ma być środowisko wychowawcze, którego celem jest umożliwienie rozwoju dziecka z poszanowaniem zasad otaczającej dziecko rzeczywistości. Realizacja takiego podejścia wiąże się z zerwaniem z wciąż pokutującym założeniem o pasywnej roli ucznia w procesie kształcenia. Uzależnienie się od kierowniczej i decydenckiej roli nauczyciela w rozwoju dziecka stoi w opozycji do założeń pedagogiki montessoriańskiej. Próby jej wdrożenia w Polsce sięgają okresu międzywojennego, kiedy to niektóre placówki edukacyjne stosowały się do wybranych zaleceń tej filozofii edukacji. Zarówno sytuacja ekonomiczno-społeczna kraju, jak i kształtujące się wówczas ustawodawstwo dotyczące edukacji stały w sprzeczności z chęcią zaadoptowania w polskim szkolnictwie kompleksowego podejścia montessoriańskiego. Od ponad dwóch dekad obserwuje się zwiększone zainteresowanie tą pedagogiką. Wynikać to może z prób przeciwstawienia się ciągle reformowanemu systemowi oświaty – coraz więcej środowisk zauważa potrzebę odrzucenia społecznie przyjętego pasywnego modelu nauczania i wychowania na rzecz stworzenia warunków kształcenia nacelowanych na indywidualne potrzeby dziecka. W Polsce powstaje coraz więcej placówek wdrażających zasady pedagogiki montessoriańskiej na każdym z etapów edukacyjnych dziecka. Obserwowany trend wiąże się z wieloma ograniczeniami uzależnionymi od specyfiki polskiej oświaty. Powstawanie instytucji, organizacji oraz szkół całkowicie oddanych filozofii Marii Montessori potwierdza potrzebę szczegółowej analizy stanu jej implementacji w Polsce. W pracy zostanie przedstawiona taka analiza oraz przykładowa propozycja zajęć przyrodniczych dla uczniów.

słowa kluczowe: metoda Montessori, edukacja, nauczanie przedmiotów przyrodniczych

Introduction

The Montessori method of education was developed by Italian physician and educator Maria Montessori. Rita Kramer (1976) wrote:

Maria Montessori began to develop her philosophy and methods in 1897, attending courses in pedagogy at the University of Rome and reading the educational theory of the previous two hundred years (...). She is working in the psychiatric clinic of the University of Rome, where she was educated and brought up mentally handicapped children. The study, conducted in the course of her practice, showed that the education of children with disabilities requires not only medical methods as teaching and that suitable teaching methods and educational progress can be achieved by equating the abnormal to the normal child. Montessori developed a method also based on the experience of completed study of philosophy, psychology and practice with children (p. 60).

Theoretical Background

In the professional literature (Feez, 2010; Isaacs, 2007; Fisher, 1964, 1965; Miksza, 2009; Skjöld Wennerström & Bröderman Smeds, 2007) we can read that: the essence of Montessori education is the statement that every child is different and should develop according to individual self-created development plans. These plans include the child's abilities, competences and skills, which enable him or her to learn in a more independent and efficient way. The child works according to his or her own speed and capacities, taking actions to which he or she is already prepared.

It is obvious that every child should grow up in the best possible conditions for him or herself, in a convenient time and among

friendly people. The development of a person as a result of individual processes of independent learning by practice, experience and experiments is the main goal of Montessori pedagogy.

The process of child development – in its various stages – requires specific conditions and stimuli. It is obvious then, that the system of education should take into account specific needs of children resulting from successive stages of development. The teaching process should be harmonized with the process of a student's development and teachers' actions should be integrated with the natural cycle of child activity. Therefore, stimuli inducing concentration and attention, triggering the cycle of activity and normalization should not only be characterized by growing attractiveness, but also higher levels of difficulty (Bednarczuk, 2007).

The Montessori method is best characterized by Montessori's own words:

"I learned the child. I took what the child had told me and expressed it. This is how the Montessori method was created" (Montessori, 1967)

"The child should be the builder of himself" (Montessori, 1967)

"Help me and I will do it myself" (Kramer, 1976)

"Giving the child freedom is the best help we can offer him" (Orem, 1971)

"The teacher is like a director in the theatre – he designs and determines the sequence of scenes, and then he watches ..." (Montessori, 1967)

"Using my method, the teacher teaches little, but observes a lot" (Montessori, 1967)

"The less words, the better the lesson" (Montessori, 1967)

“The tutor must provide the child who seeks with the sense of his presence but he should hide from those, who has already found” (Montessori, 1989)

“Teaching aids are stairs that allows you to climb up the hill, step by step, and their steps are essential tools for entering the culture and gaining higher levels of development” (Montessori, 1991)

In this method, particular attention was put on the main factors of child development (Bednarczuk, 2007):

- a) polarization of attention, it means deep and long-lasting child’s interest in one object or action carried out by himself
- b) activity cycle realized in three phases: 1) preparatory phase – a child is looking for the object of his interest, 2) phase of the hard work – a child is in great concentration, 3) final phase – a child makes a discovery, he realizes it and is looking for the link between the already possessed knowledge and those newly discovered

- c) normalization, that is intrapsychic balance and harmony of a child

In order to support and develop these factors to the reality, the proper surroundings (environment), teaching aids (materials) and teacher are necessary.

The book of Barbara Isaacs (2007) contains this important statement: *“The Montessori Method of Education has three key components: the child, the favourable environment and the teacher. The relationship between the child, teacher and environment continues to evolve and develop because it is based on observation of children. The dynamic links between all three components and their interaction represent what we know today as the Montessori approach”*. The environment must be designed carefully to meet the child's development in line with the objectives of Montessori pedagogy. The main aspects of this environment are shown in Figure 1.

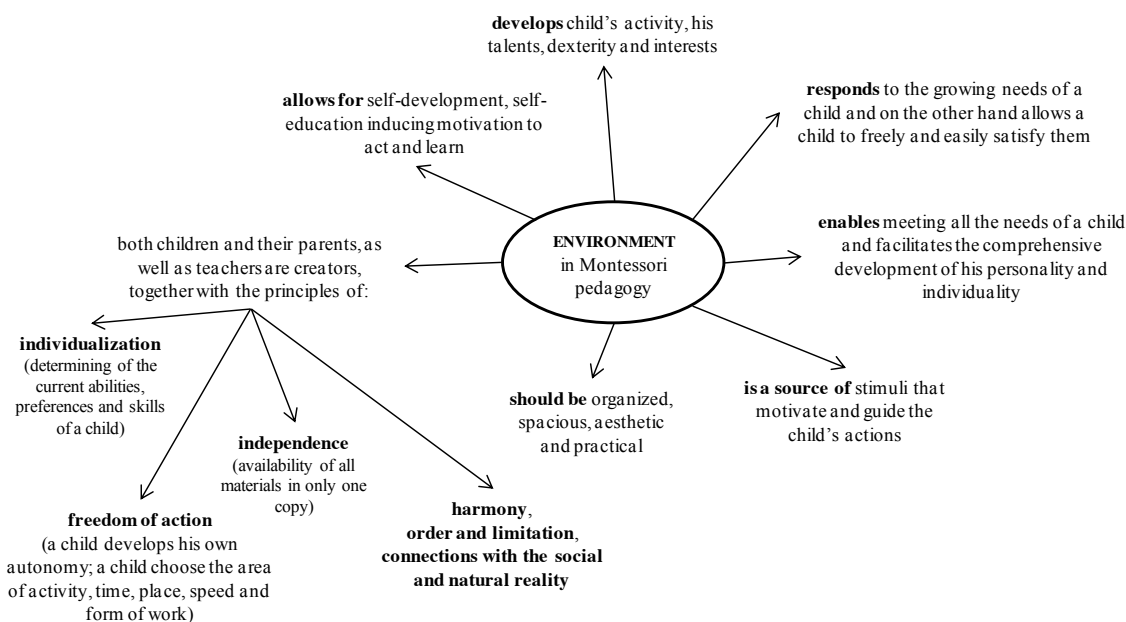


Figure 1. The role of proper environment creation in Montessori approach (Guz, 2006; Miksza, 2009)

Aids (materials), which are essential part of the environment, should be prepared according to the principle of isolation and gradation of difficulty, as well as the possibility of self-control. Materials make it able to start the process of learning from experience and sensual cognition. They are also a source of joy and satisfaction from the effect achieved (solving the problem); their presentation should be brief and it should encourage the child to do the independent work (Skjöld Wennerström & Bröderman Smeds, 2007).

What is the teacher’s role? First of all, as “full of life and cheerful guide” he or she is an integral part of the environment. It is a person who provides a sense of security and freedom; with respect and close attention, he or she observes the progress and problems of children. Special requirements for teachers are, according to Sabina Guz (2006), summarized as depicted in Figure 2.

We want to note one particular fact. The original version of the Montessori method was applied to the education of children with a variety of dysfunctions. Maria Montessori’s method has been used by the team of Professor Cameron Camp, a psychologist, a specialist in applied gerontology. He directs a research center in Hearthstone Alzheimer’s Care. For 15 years, professor Camp Cameron researched a new method of work with patients with dementia. According to Cameron, it is extremely important to create a suitable environment for patients. Appropriate patient environments poses challenges, but also enables achieving success. The task performed by the patient helps to reach the goal of the here and now, and enhances self-esteem (DeAngelis, 2009).

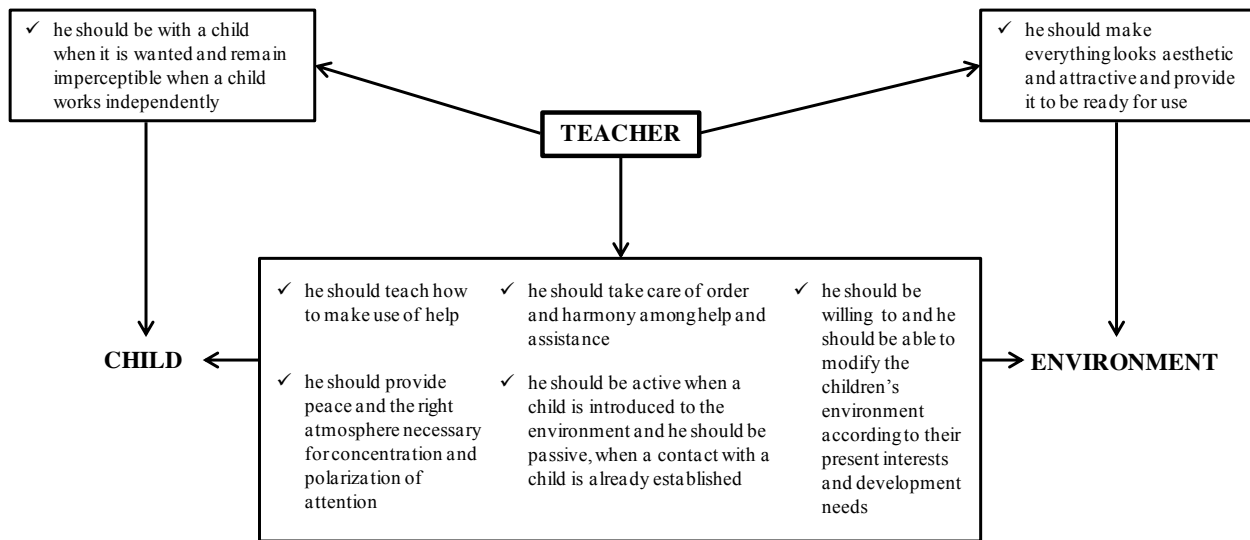


Figure 2. Teacher in Montessori approach can manage the environment in order to ensure the adequate (i.e. in accordance with Montessori pedagogy) development of the child (Guz, 2006).

Methodology

Questionnaires were prepared in several versions adjusted to particular target groups. The study involved a group of students from Kraków, Montessori teachers from schools in Warszawa, Kraków, Lublin, Gdańsk, Koszarawa Bystra, and Kielce, teachers (from different cities in Poland) with a traditional program of education, and parents. The survey was conducted in April 2013 and collected using online survey tools

(www.ankietka.pl). In addition, due to difficulties in contacting parents whose children attend Montessori schools, questionnaires were also prepared in the traditional (paper) form and they were completed by parents who visited one of the cafes in Zielona Góra – Montessori Café. The home page of this café is presented below as Fig. 3. In Table 1 we present more information about group of respondents.



Figure 3. Screenshot of home page of Zielona Góra – Montessori Café [<http://www.montessoricafe.pl/>].

Table 1. *The characteristics of the surveyed groups of students (S), teachers from schools with the traditional teaching (TTE) and teachers working with Montessori methods (TME). The numbers are in percentages.*

S	Academy			Year of study					Sex					
	JU	PU	other	I	II	III	IV	V	F	M				
	43	55	2	12	11	17	31	29	90	10				
TTE	School employment				Professional degree				Length of service in the teaching profession [year intervals]				Sex	
	K	PS	LS	US	P	C	A	C'	1–10	11–20	21–30	>30	F	M
	0	7	54	52	0	16	15	69	30	33	28	9	91	9
TME	50	58	8	0	25	42	25	8	75 (85)*	8 (13)*	17 (2)*	0	92	8

Academy: JU – Jagiellonian University, PU – Pedagogical University; School employment: K – kindergarten, PS – primary school, LS – secondary school (lower), US – secondary school (upper); Professional degree: P – probationary teacher, C – contract teacher, A – appointed teacher, C' – certified teacher.

* Senior teachers from Montessori schools is given in parentheses

Results and discussion

Montessori teachers

According to our data, the Montessori teachers started to use the method in their teaching practice mostly (50%) as a result of their own motivation, and 17% of them continued to use it after the end of their substitution Montessori school experience. The teachers started to use the Montessori method after completing specialized training courses (15 %), or, as a result of being inspired by their superiors (8%). For Montessori training courses, they mentioned the general ones organized by Polish centers (Polish Montessori Association, Association of the Friends of Montessori) and the foreign ones (Canadian Institute of Montessori Teacher Education), as well as the specific ones referring to the teaching of Mathematics or English. Most of the teachers (75%) do not belong to any institution bringing together people who use Montessori methods, 25% are members of the Polish Montessori Association (17%) or Montessori with no limits (8%).

Teachers assessed the availability of materials (teaching aids) for use in working with Montessori methods, as very good (25%), satisfactory (67%) or moderate (8%). There were no answers stating that it was unsatisfactory or that the materials were unavailable. The didactic materials that students work with should be (according to the assumptions of Montessori pedagogy) characterized by simplicity in its implementation and operation and it should support multiple forms of activity. The great majority of teachers (83%) agree with the first condition, whereas the second one is called into question by 8% of teachers. The teachers achieved perfect agreement (100%) on the cognitive properties of the material and the possibility that the students are able to control errors by themselves. Less than 20% of teachers use ready-made lesson

plans. 33% of them are scenarios of Montessori lessons taken from the literature, whereas the remaining 67% are modified by a teacher according to the principles of Montessori education.

Teachers from schools with the traditional teaching

Among the teachers who were working in schools where only traditional methods are used, 75% of them have never heard about the assumptions of Montessori pedagogy. Among the 25% of the teachers who are familiar, the following associations can be distinguished: respect for the individual working speed of the student and his individual plans of development; free and comprehensive development of a child; and promoting students' freedom and creativity. This group of teachers also emphasized that the Montessori method "is great but impossible to be realized in a number of classes in Polish schools," and its assumptions "are difficult to be implemented in normal school."

Students

The questionnaires were completed mainly by students of two universities in Cracow: the Jagiellonian University (JU) and the Pedagogical University (PU). The largest group of the surveyed students were Master's students (60%). More than half (53 %) of the respondents want to work as teachers in the future, (26% want to combine this work with another job), 29% have not decided yet, and, the remaining 18% declare that they do not want to be teachers. The types of schools, where the students would like to work, include a secondary school (44%), a primary school (30%) and an upper secondary school (26%). Only 15% of respondents did not attend courses which would have enabled them to obtain qualifications required to work as a teacher. The students who were attending such

courses declared (31% of UP students and 35% of JU students) that they are familiar with the assumptions of the Montessori pedagogy and they mention the following: focusing on the individual (student) and enabling the child to develop in accordance with his own requirements, teaching by playing, the use of original teaching aids and focusing on the students' independence ("stimulating curiosity of the children, instead of providing them with ready information").

Parents

The group of parents surveyed consisted of people who were already familiar with the assumptions of Montessori pedagogy, and 92% of them had children taught with the Montessori method. The largest number of such children were primary school students and the rest of them attended kindergarten or secondary school. There are also some children who are taught by Montessori methods at home (home schooling). The parents have learnt about Montessori education from other people whose children are taught by this method (35%) or from other sources, such as their results of searching for schools for their child (17%), or, from training and courses for parents

(9%). All the parents whose children are learning through the Montessori way would recommend this method to their friends as extracurricular activities after school (13%) and/or as regular school classes (94%). As for their reasons, they provided a variety of answers, i.e. "The method of teaching provokes a child to search, searching develops creative thinking and unconventional ways of solving problems. It is exploration. I feel that this way of thinking is a part of an exciting life, and I would like my child to have such." Or "This method does not suppress the natural child's impulse to develop and explore the world in contrast to the traditional method, which sometimes/often leads to such situation". Parents whose children had attended schools with traditional programs before were asked to point the observed changes in the child's behaviour after moving him to the school with the Montessori program (*vide*: Fig. 4.). The positive changes include, i.e. better contact with peers, growth of self-reliance, focusing on the task until it is successfully completed. The parents also emphasised that the child is keener on going to school, is more open to learn about the world, and, is able to control his or her emotions.

Question for parents: If your children attended school (classes) with traditional teaching program before, please think about changes that you have noticed after moving the child to the class with the Montessori program. [0 – no change; 5 – significant change in a given direction].

Involvement in additional activities at home/in school	5	4	3	2	1	0	1	2	3	4	5	The child is not involved in additional activities
The child focuses on one thing until the task is successfully completed	5	4	3	2	1	0	1	2	3	4	5	In case of not obtaining rapid results, the child moves his/her attention to other issues
Higher rate of interests	5	4	3	2	1	0	1	2	3	4	5	Lower rate of interests
Self-reliance	5	4	3	2	1	0	1	2	3	4	5	Lack of self-reliance
The child is mature for his/her age	5	4	3	2	1	0	1	2	3	4	5	The child is immature for his/her age
The child is able to organize time and find activities by himself/herself	5	4	3	2	1	0	1	2	3	4	5	The child needs help in organizing time and finding activities
The child establishes contact with peers easier	5	4	3	2	1	0	1	2	3	4	5	The child has problems with establishing contact with peers

Figure 4. Intensity of changes noted by parents in their children by moving them to the class with the Montessori program from class with traditional program. Blue color indicates average answer.

Principals

The principals of several Montessori schools were asked about the possibilities of transferring the philosophy of Maria Montessori to everyday practice in traditional schools. Below, there are fragments of some of the answers presenting the differences in the functioning of these two types of schools:

Individualization of the teaching process not only in the theory but also in practice.

Larger set of possibilities of choice in the later stages of education (choice of the type of school, subjects in the school, level at which the student wishes to study the particular subject)

The same form-master in classes 1-6.

The core curriculum enabling the teacher to realize the program slower or faster (prepared for the whole educational stage not for the particular year of learning)

Such schools exist all over the world for over 100 years and they are doing well.

Understanding... and falling in love with the assumptions of Montessori pedagogy by people managing education

Question for students: Below are listed principles (A – J), which should be followed by Montessori school. Put them in order form 1 to 10 with 1 referring to the principle which is according to you the most important for the child development and 11 referring to the least important in this matter.

- A Forming attitudes of mutual assistance without competition
- B Achievement of long-term concentration on the task being performed
- C Achievement of spontaneous self-discipline resulting from the children's obedience
- D Transfer of love for reality and environment
- E Development of individual talents and cooperation skills
- F Development of self-reliance and self-confidence
- G Respect for the work of other people
- H Independence from prize
- I Development of obedient attitudes based on self-control rather than external compulsion
- J Development of respect for harmony and work

Allocation of adequate resources – to equip classes and train the staff

The introduction of small facilitations connected with formal documentation – typical for the traditional schools – class registers that are not necessary in this form in the Montessori schools.

Comparison of the respondents

The ideas of students and parents about the educational role of the school as well as the parents' expectations about their children's education are similar (as shown in Fig. 5.). Both groups believe that the most important issue is development of independence and self-reliance of students together with their respect to work. It is reflected in the answers given by these groups of respondents – the students were pointing out these elements by giving examples of associations with Montessori method, whereas the parents were indicating them when justifying a decision about recommending the method to their friends.

Question for parents: In your opinion, which of principles listed below (A – J) are the most important in your child development? Put them in order form 1 to 10 with 1 referring to the principle which is according to you the most important and 11 referring to the least important in this matter.

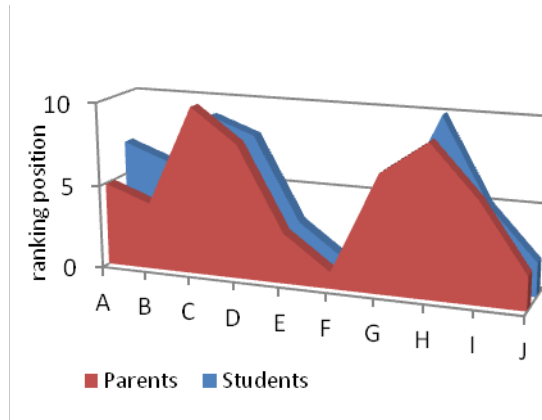


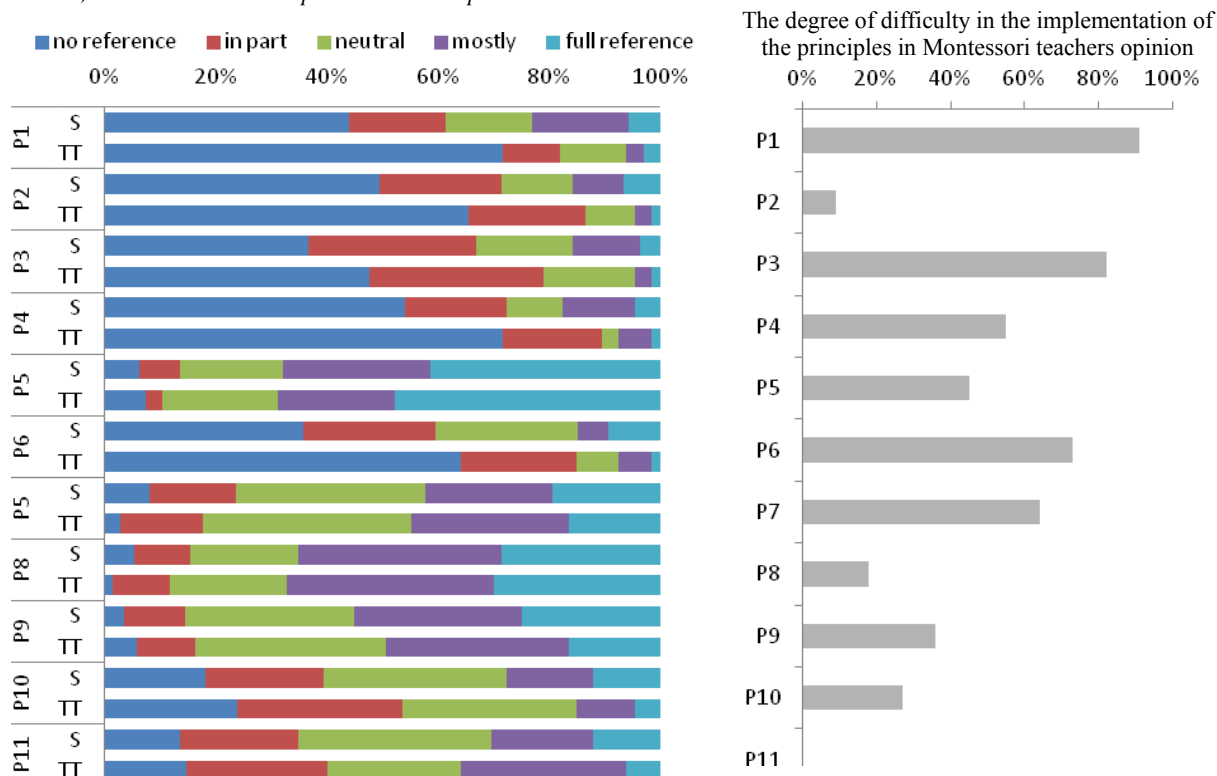
Figure 5. The school as a place for raising children through the eyes of students and parents.

In Figure 6, we present the opinion of selected groups of respondents on Montessori teaching principles. Both students and teachers that have had no experience in working with Montessori method consider the principles of free choice (P1-P4) and the principle of limitation (P6) as having no reflection in traditional school. Montessori teachers regard the principle of limitation and the principle of free choice of the material, form of work and working time as the most difficult to implement. On the other hand, the principle of free choice of the workplace is considered as the easiest to introduce in the school practice (probably thanks to the special preparation of the working environment)

together with the principle of self-control (P11) which fulfillment is determined by special construction of the didactic material (in traditional schools, despite the self-control procedures, there is also a number of evaluation and differentiation measurements, which is probably responsible for the distribution of the answers of students and teachers from traditional schools). Traditional school is (according to students and teachers working in such institutions) a place where the principle of harmony and order (P5) is the most widely applied. On the other hand, the Montessori teachers regard this principle as difficult to implement.

Question for students and teachers from schools with the traditional teaching: Below are listed pedagogical principles, which should be followed by Montessori teacher. Basing on your own experience or notion rate on a scale of 1 to 5 functioning of these principles in traditional Polish school practice. [1 – no reference, ..., 5 – full reference in Polish school practice.] [For both groups of respondents pedagogical principles were supplemented with their description]

Question for Montessori teachers: Below are listed pedagogical principles, which should be followed by Montessori teacher. Please put them in order from 1-11, with 1 referring to the most difficult principle (according to you) to be obeyed and 11 to this one, which does not cause problems with implementation in the class.



S – students; TT – teachers from schools with the traditional teaching; P1 – P11 pedagogical principles of Montessori method: The principle of free choice of the material (P1), of the workplace (P2), of the working time (P3) and of the form of work (P4), The principle of harmony (P5), The principle of limitation (P6), The principle of isolation of difficulties (P7), The principle of gradation of difficulty (P8), The principle of transfer (P9), The principle of individual actions and repetition (P10), The principle of self-control (P11).

Figure 6. Implementation of Montessori pedagogical principles according to Montessori teachers and the opinion of students and teachers in schools with the traditional teaching on functioning of these principles in the Polish school.

An example of natural science meeting

What therefore does help the child to concentrate and learn? As an example, the Montessori method draws attention to giving a child clear and explicit tasks, physical and motor involvement and freedom of actions. These concepts formed the basis of preparing the script of the consecutive natural science meeting at the school in Koszarawa Bystra.

Conducting a lesson, in the form of a trial, is well-known and frequently used form of working with students in schools with traditional forms of teaching (e.g. Ciesielska, 2003; Holeksa *et al.*, 2011). This form is also ideal for lesson preparation in accordance with the principles of Montessori pedagogy.

The meeting entitled “Trial over radioactivity” took place on the 28th of February 2013 and it was carried out in two different age groups a secondary school: a) the group consisted of the students of the first year of secondary school, and 2) the group consisted of students of the second and third year of secondary school. At the beginning, the students were informed that they are expected to stage the trial about radioactivity.

The classroom was prepared according to the principles of the Montessori pedagogy by placing a variety of teaching aids and requisites necessary for carrying out the lesson. There were such things as costumes and props, i.e. gowns, microphones, hammers, coats, and helmets.

Plan of the meeting:

1. Assigning roles to participants by drawing: each participant draws an envelope with assigned role when entering the classroom:
 - a) *A panel of judges [1-3 people]*

- b) *Defense (Advocate) [1-2 people]*
- c) *Prosecution (Prosecutor) [1 person or 2 people in case of an auxiliary prosecutor]*
- d) *Usher*
- e) *Witnesses*
- f) *Lay judges (Jury)*
- g) *Journalists*

In one of the groups, the students decided that they would make the assignment of roles by themselves; in the second group the roles were assigned by drawing.

Applying the free choice rule allowed for the choice of the area of action for role playing during the meeting.

2. Explanation of rules of conducting a trial, reminder of the main parts of a trial and distribution of the case files. The lawyer and the prosecutor (together with their teams if necessary) receive the case file. It contains an envelope entitled:
 - a) For the defense: In the course of establishing a line of defense, the following facts were established...
 - b) For the prosecutor: In the course of the process of collecting evidence, the following facts were established...

Each of the envelopes contains cardboards with the statements that are presented below. They were to serve as evidence hints – facts that were revealed during the investigation. During the trial, carried out by the students, the information was extended on the basis of additional sources of information.

File of lawyers:

Reduced costs of energy production.	Use of radioactive isotopes to study internal structures of materials, leak-tightness of pipes and tubes, detection of hidden defects in construction materials used in the building industry and aviation (the so-called defectoscopy). For example, with the use of radioisotope, the tire abrasion test could be carried out.	Archaeological clock – determining the age of archaeological findings, in which are remains with carbon-containing compounds.
Building nuclear power plants that do not produce ashes, etc. we do not pollute the environment	With the use of radioactive hydrogen ¹ H, called tritium, the underground water could be tracked, which is very important in mines.	The destructive effects of nuclear radiation are used in the treatment of cancer and other diseases.
Nuclear reactors are used as the basis of propulsion in ships and vessel	Radioactivity is also used in smoke detectors.	Food that is preserved using radiation can be irradiated in a persistent package, which prevents it effectively from recontamination.
X-ray radiation allows us to see, for example, a broken collarbone.	Sterilization of medical equipment.	Radiation is used in microwave ovens.

File of prosecution:

There are high costs of building nuclear power plants.	Ionizing radiation is very harmful and dangerous to the human body.	Changes in ecosystems caused by draining warm water into rivers.
Radioactive emissions caused by nuclear tests.	Ships are nuclear powered. In case of sinking, their fuel may be a potential source of serious contamination of the environment with radioactive elements.	The risk of contamination of the environment by storing nuclear waste.
The risk of a nuclear disaster (Czarnobyl 1986 and Fukushima 2011).	During cell phone calls, harmful radiation is emitted and our brain is exposed to it.	High-voltage wires produce harmful radiation.
Nuclear weapon uses energy, which produces a huge wave of heat of great strength of destruction and demolition, inducing thermal radiation and causing burns and fires, leaving the area with a huge rate of devastation and intoxication.		

The file also contained a list of witnesses (empty, bullet-pointed), which was filled with witnesses by advocates or prosecutors on the basis on the data from the files.

3. Characteristics of actions of participants depending on the role:

Teams of lawyers are informed that:

- The list of witnesses must be provided before the trial to anyone who is interested in it and to the decision makers.
- Fictional or historical people, as well as things from the inanimate world (e.g. an isotope of a given element that would

prove its work or a nuclear power plant) that can be called to witness

- The teams of defence/prosecution can pick up witnesses from the group of lay judges who are not relieved of their duties of lay judges
- Pieces of information from the envelopes are only hints about the collected evidence. The task of each team is to decide what type of witnesses is needed and to question them properly. Additional materials included in files – press-cuttings, fragments of books, videos – are available.

Sources of the proposed materials included in the files are presented in the following Table 2.

Table 2. The list of sources used during meeting [all the materials were accessed on 24-Feb-2013].

The use of carbon-14 to determine the age of archaeological objects of organic origin

http://fizyka.zamkor.pl/images/materialy/2004_m12_d31_Wykorzystanie_wegla_14.pdf

Exotic radioactive decays

http://fizyka.zamkor.pl/images/materialy/2004_m12_d31_Egzotyczne_rozpady.pdf

Radiation safety

http://fizyka.zamkor.pl/images/materialy/2004_m10_d28_bezpieczenstwo_radiacyjne.pdf

Is ionizing radiation always harmful?

http://fizyka.zamkor.pl/images/materialy/2004_m12_d23_Czy_promieniowanie.pdf

Chernobyl – the biggest bluff of the 20th century

http://fizyka.zamkor.pl/images/materialy/2004_m10_d25_czarnobyl.pdf

Radioactivity discovered gradually

<http://archiwum.wiz.pl/1998/98042400.asp>

Chernobyl 25 Years Later: Food for Thought [video – length: 6 minutes]

<http://www.youtube.com/watch?v=Wyu3DsfxHwQ>

Nuclear energy in everyday life [pages 12-22]

http://dsid.ipj.gov.pl/files/LudwikD/Studium2/05_zastosowania.pdf

Nuclear reactors in Poland – application in medicine [video – length: 1 minute]

<http://www.youtube.com/watch?v=vTiDMabH1BY>

Radioactivity in modern medicine

http://poznajatom.pl/poznaj_atom/promieniotworczosc_we_wspolcze,333/

Radioactive cigarettes

<http://archiwum.wiz.pl/2001/01011000.asp>

Uranium is not so scary...

<http://archiwum.wiz.pl/2001/01030100.asp>

Glowing fires (swiecec ogniska)

<http://archiwum.wiz.pl/1997/97082600.asp>

Albert Einstein biogram

http://biografia24.pl/naukowcy-albert-einstein-c-40_41

Maria Skłodowska-Curie biogram

http://biografia24.pl/naukowcy-maria-sk-odowska-curie-c-40_214

Henri Becquerel biogram

http://portalwiedzy.onet.pl/718,,,Becquerel_Antoine_Henri,haslo.html

Team of journalists is supposed to interview selected historical figures – Maria Skłodowska-Curie, Albert Einstein and H. Becquerel. The journalists are provided with the biographical notes of the scientists (their sources are included in the above table) and with the guidelines of the TV/radio station as for the information that should be included in the interview, such as:

- ✓ who is the defendant and why cannot he/she be present in court proceedings?
- ✓ In what way does the defendant affect people's lives – explanation of the purpose of the trial
- ✓ Presentation of circumstances, in which radioactivity (the defendant) influenced people's lives – for example by presenting the assumptions of the Manhattan Project

(Hiroshima, Nagasaki), cosmic radiation, the use of isotopes in various areas of life.

The task of journalists is also to examine public opinion on the feelings towards the defendant. The biographical notes were also given to people who were playing the roles of historical famous scientist and to the teams of advocates and prosecutors, who motivated by their creativity were able to call various people to witness.

The task of *lay judges* is to carefully observe the trial and fill in the lay judges forms according to the example:

Lay judge form

The acquittal is supported by the following facts:

The conviction is supported by the following facts:

My view and its justification:

4. The trial. After the final speeches, the usher collects forms from the lay judges and passes them to the judges who retire to deliberate verdict, which results in the final judgement and the end of the trial.

Judgement of the jury can be realized in three different ways: 1) an acquittal 2) a conviction 3) a stay of the proceeding and leaving the judgement to the community participating in the trial due to lights and shadows of the defendant. Although, only the judge announces the verdict, thanks to the lay judges forms, each participant of the trial had a chance of pronounce his own

judgment. An exemplary statements referring to the three possible judgments are presented in the following photographs:

In lay judges forms, there are dominants of advantages and disadvantages of radioactivity, which students were trying to gather in order to pronounce the judgment. The most dominant positive aspect was the possibility of the application of radioactivity in medicine and the production of energy that is cheaper and safer for the environment. The most frequently mentioned disadvantages of radioactivity were the effects of nuclear explosions and their impact on people and their environment. Many lay judges forms were referring to the human responsibility indicating that the radioactivity in the hands of a man can be both a serious risk as well as a tool providing the civilisation progress.

5. Examining the opinion of the trial participants by journalists – a comparative survey. The journalists basing on the interviews with the participants fill the large sheet of grey paper divided into two parts: lights and shadows of radioactivity. In the final stage of the meeting, the journalist read all the advantages and disadvantages of radioactivity listed during the trial in order to familiarize the participants with all its possible manifestations.

Conclusions

The workshop enabled the participants to develop key aspects of Montessori pedagogy, such as:

- development of self-reliance and self-confidence,
- development of respect for harmony and work,
- independence from prize,
- forming attitudes of mutual assistance without competition,
- development of cooperation skills.

It is worth noting that pedagogical principles regarding the environment were taken into account by preparing the script of the meeting. For example, the principle of harmony (each participant is aware of his role, and therefore he knows his place and he knows what belongs to his responsibilities) and the principle of

limitation (by choosing a role, a participant is doing what he is interested in at the moment and what does not bother others). The source materials prepared for the students, helping in preparation of arguments for the trial, followed the principle of isolation of difficulties by their popular science character and treatment only of the selected aspects of radioactivity. These elements of the meeting which required from the participants expressing their own opinion or listening to both sides in the courtroom, helped to follow the principle of transfer, as the young man will be able to participate actively in the discussions about radioactivity being aware of its lights and shadows. In Figure 7, we illustrate a selection of highlights from the performed staging.

Figure 7. Students participating in the class: Judge and his entourage enter the courtroom (on the left), hearing of Marie Skłodowska-Curie (in the middle) and radioactivity defense team (on the right).



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Study of Explicit Instruction and Structured Inquiry Methods on Knowledge Acquisition and Conceptual Change in Science Learning

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This study compares two pedagogical methods (Bell, *et al.* 2005; Bissonnette, *et al.* 2010; Gauthier & Dembélé, 2005; Vygotski, 1994; Minner, *et al.* 2009): explicit instruction and structured inquiry methods. We question the effectiveness of the two learning methods to acquire scientific knowledge and to modify learner conceptions. Do explicit instruction and structured inquiry methods have the same impact on the learning of science? If not, why? The results of this work show that explicit instruction and structured inquiry methods strongly increase the acquisition of knowledge, however, conceptual improvement is weak. So these two methods have the same positive effects on the acquisition of scientific knowledge and the same minimal results on the evolution of conceptions. The “allosteric model”, proposed by Giordan (1999), is an alternative didactical model (Pellaud & Eastes, 2003) which could constitute a different approach to learning science, within a systemic and antagonist learning environment, to transform the learner’s conceptions.

Keywords: explicit instruction, inquiry methods, conceptual change, knowledge acquisition, science education

Mot-clefs : enseignement explicite, démarche d’investigation, conceptions, connaissances, apprentissage

Introduction

Gauthier & Dambélé want distinguish explicit instruction and traditional instruction: “*Difference between explicit and traditional instruction is very important. Direct instruction transfers knowledge, although the aim of explicit instruction is the understanding of subject and its sustainable in mind of pupils. Direct instruction assesses the understanding at the end of course, although explicit instruction assesses pupils during instructed phase*”. It seems for some

authors that explicit instruction is an active pedagogy different from constructivist pedagogy established on discovery. Explicit instruction, (Bissonnette *et al.*, 2010) according to Gauthier & Dembélé, (2005) is a structured pedagogy: “*Explicit teaching is derived from research on efficient education practice. Explicit and systematic instruction is also beneficial to all students when dealing with ordered material, a new and complex subject, even with more efficient students (p.24). There is no large-scale*

empirical research which shows that children-centred activity based learning is superior to explicit instruction in the teaching of basic skills. All the large-scale studies show explicit instruction is superior". UNESCO studies, based on more than 10,000 students (Gauthier & Dembélé, 2005), show that "explicit instruction" is far more effective on performance, than constructivist learning in the long term, and on very different age groups, for both primary and secondary school pupils, including those with difficulties (Bissonnette *et al.*, 2010).

The inquiry method is based on the model of "constructivism" (Astolfi, 1996; Bell *et al.*, 2005; Vygotski, 1994; Minner *et al.*, 2009) and must begin by situation with problem to enter in phases of hypothesis, construction of protocols and research to answer to the initial question. Constructivism has played a significant role since the 1970s, at least in the literature. This learning theory is based on the spontaneous needs and the natural interests of each individual. It promotes freedom of expression and creativity. It gives rise to self-discovery and emphasizes the importance of trial and error in the learning process. The acquisition of knowledge occurs primarily through action on objects and individuals' self-expression through their bodies (Meirieu, 1996; Meirieu, 1990; Perrenoud, 1996; Perrenoud, 1997). Minner *et al.* (2009) show that participation of pupils to process of inquiry increases their conceptual learning in science (Minner *et al.*, 2009). Nevertheless, no research shows that inquiry process used frequently improves acquisition of science education. More, Bell *et al.* (2005) distinguish four different inquiry methods: 1) confirmation inquiry methods; 2) structured inquiry methods; 3) instructed inquiry methods; and, 4) opened inquiry

methods. In the first inquiry methods pupils know final results and in the last inquiry methods pupils choose protocols and propose solutions to the problem.

This study wants to compare effects of explicit instruction presented as an effective method on performance and structured inquiry methods often used by teacher in France. What respective impacts do they have on knowledge and conceptions in science education?

Methodology

1. Studied public:

This case study focuses on a group of 29 primary school pupils with a good level in science education (ten years old).

Data were collected following diagnostic assessments by collecting initial conceptions and knowledge before the activities and final knowledge and conceptions at the end of the 10 sessions.

These evaluations enabled us to measure the knowledge acquisition and conceptual change of the pupils on two specific topics; breathing and blood circulation, during 10 sessions in total.

The explicit instruction was presented on the topic of breathing and structured inquiry method was used during the topic of circulation.

2. Data processing:

Results are all grouped in double-entry tables indicating pupils' percentage acquisition of knowledge or pupils' percentage of right conception at the beginning and at the end of the breathing topic (explicit instruction) and the circulation topic (structured inquiry method).

Results

1. Comparison between initial and final knowledge acquisition after explicit instruction and structured inquiry methods.

Table I: Pupils' right knowledge at the beginning and at the end of the topic on breathing after explicit instruction	Initial knowledge	Final knowledge
Path of air through the nose and mouth	49 %	70 %
Passage of air through the 2 lungs at the same time	59 %	90 %
Involvement of CO₂ and O₂ in inspiration-expiration	45%	60%
Link between breathing-gas-blood	7 %	72 %

Table II: Pupils' right knowledge at the beginning and at the end of the topic on circulation after structured inquiry methods	Initial knowledge	Final knowledge
Knowing that blood vessels are connected to the heart	45 %	68 %
Différentiating arteries from veins	8 %	62 %
Distinguishing between blood which is rich or poor in CO₂ and O₂	7 %	62 %
Knowing the existence of the distinct sides of the heart	0 %	90 %
Knowing the roles of the right and left sides of the heart	0 %	62 %

First of all, by comparing the two approaches, it can be noted that with explicit instruction, approximately 40% of the pupils are a right initial acquisition of knowledge against 73% at the end of sequence, while structured inquiry methods totals about 12% of success in initial phase against 69% at the end.

It is also important to note that activities during explicit instruction involved many more memorization and organization strategies and less development strategies, while activities in

structured inquiry methods mainly involved organization or development strategies, as well as conceptualization strategies and less memorization strategies.

2. *Comparison between initial and final conceptions after explicit instruction and structured inquiry methods*

Table III: Pupils' right conceptions at the beginning and at the end of the topic on breathing after explicit instruction.

	Inspiration and expiration of air	Involvement of CO₂ and O₂	Link between breathing-gas-blood	Passage of air through lungs	Path of air through the nose or moth
Initial conception	100%	45%	7%	83%	100%
Final conception	100%	60%	30%	87%	100%

Table IV: Pupils' right conceptions at the beginning and at the end of the topic on circulation after structured inquiry methods.

	Blood through heart	Blood is contained in blood vessels	Rule of heart as a pump	Circulation of blood directed to organs	Blood presents in organs
Initial conception	64%	82%	41%	90%	17%
Final conception	90%	95%	50%	92%	20%

By analyzing effects of these two methods on conceptions, we can note that with explicit instruction, approximately 67% of the pupils have a right conception at the beginning and only 76% at the end of the sequence are better representation on these topics. In same case, structured inquiry methods totals about 58% of right initial conception against 70% at the end.

Discussion-Conclusion

This study shows that for two pedagogic approaches, knowledge acquisition increases strongly while conceptual change is more limited. We can note an increase of 33% for explicit instruction and 57% for structured inquiry methods. These data could show that structured inquiry methods increase in a significant way acquisition of knowledge. But we can also propose that pupils got less initial knowledge on circulation than breathing and finally performed at the same level of knowledge at the end of the topic. So more probably these two methods could have the same impact in this study as acquisition of knowledge.

Results from evolution of conceptions indicate an increase of 9% for explicit instruction and 12% for structured inquiry methods between the beginning and the end of sequence. These increases are very similar but very weak. We can observe in fact that pupils have high level conceptions at the beginning (67% for breathing and 58% for circulation), so pedagogic approaches don't increase significantly representations of pupils. Nevertheless, we have noted more structured conceptions from two methods presenting specific scientific language in the final conceptions (as arteries, veins, two side of heart...). We can suppose that structured of scientific language comes from acquisition of knowledge during sequence.

It is interesting to observe that the increase of right conceptions is very low (about 10 %) for both methods against a high increase in the acquisition of knowledge (about 45%) between the beginning and the end of sequence. We have recorded that these pupils have a very good general level. They

have representations structured since beginning, but conceptions on “rule of heart as a pump”, “blood presents in organs” and “link between breathing-gas-blood” have increased very little. These representations are correlated to concepts more elaborated. It seems that neither explicit instruction nor structured inquiry methods result in positive development of these representations, although, structured inquiry methods use more activities involving conceptual strategies than explicit instruction (Di Scala-Fouchereau & Fouchereau, 2013).

So, these two methods seem to have the same positive impact on acquisition of knowledge in the short term. It will be interesting to study the long-term impact in subsequent research. Furthermore, the evolution of conceptions is very similar for these two approaches: only specific scientific language is improved, but conceptual representations are not.

Finally, another educational model, based on a new theory of learning, offers an attractive alternative (Di Scala-Fouchereau, 2012). Giordan proposes an allosteric model where intervention of a didactical environment with eight factors could favour a transformation of conceptions. It could be a new viewpoint to change the teaching of science (Giordan, 1999; Pellaud & Eastes, 2003).

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