INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Zvyšování kvality vzdělávání učitelů přírodovědných předmětů

EUROPEAN DIMENSION IN SCIENCE EDUCATION

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Olomouc 2010

Tento projekt je spolufinancován Evropským sociálním fondem a státním rozpočtem České republiky.

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This material was printed with the support of European Social Fund and Ministry of Education of the Czech Republic in the framework of the ESF scheme under the project N° CZ.1.07/2.2.00/07.0074.

Tento projekt s registračním číslem CZ.1.07/2.2.00/07.0074 je spolufinancován Evropským sociálním fondem a státním rozpočtem České republiky.

First Edition

ISBN 978-80-244-2488-0

CONTENTS

Unit 1

The Problem of the European Dimension in Education

DANUŠE NEZVALOVÁ

Objectives

- To understand the concept of European dimension in education;
- To implement concept of European dimension in education in curricular materials;
- To apply the concept European dimension in science teaching.

The EU has shown increasing attention to education and the European dimension during the last three decades. The question of the European dimension in education is a controversial one and reflects debates and discussions about the meaning of Europe, European identity and citizenship (see for example, Osler et al, 1995; Davies &Sobisch, 1997). However, despite a growing body of literature on the European dimension in education, there has been relatively little research into its curricular meaning and practical implementation. As Convery et al (1997) put it, ‘in practical terms no detailed research has yet been carried out to test their (the definitions’ of the European dimension) effectiveness and appropriateness for pupils in classrooms’ (p. 3).

Education remains however a sensitive area which potentially creates a dilemma between national and/or European priorities. Education has traditionally constituted, for most modern societies, a nation-building ideological mechanism; it is thus perceived as difficult for it to abandon its ‘national’ role and become a ‘eurobuilding mechanism’(Stavroula, 2005). The main purpose of the European dimension within compulsory education until 1995, Brine (1995) concluded, was ‘to build a shared cross-national understanding of what it means to be “European”’ (p. 161). The goals of European dimension in education included democracy, social justice and respect for human rights as well as ‘strengthening a sense of ‘European identity’ as part of the preparation of pupils for making “concrete progress” towards European union’ (Lewicka-Grisdale, McLaughlin, 2002, p. 55).

Member-states were encouraged explicitly to introduce the European dimension in all ‘appropriate’ subjects of the school curriculum. The teaching of the European dimension should be an integral part of the education of the future citizens of Europe. These views suggest changes such as the development of new attitudes and new skills which will be in accordance with the new conditions of work, the new economic and social relations and the new cultural situation (Persianis, 1998, p. 7).

The European dimension has been implemented as both a subject-based and a crosscurricular innovation. There have been some subject-based initiatives, such as the ‘Science across Europe’ Programme (Adams, Tulasiewicz, 1995) and some cross-curricular initiatives. This principle means that the European dimension is a perspective permeating the whole of the curriculum and not a mere addition of information about Europe. The need for viewing the European dimension as an interdisciplinary approach is also dictated by the multiplicity and complexity of the outcomes it is expected to achieve: values, knowledge, and skills which are difficult to compartmentalise in different subjects.

The second principle is that of ‘curricularity’ and suggests that the European dimension acquires a specific form within each school subject, given the particularities of their curriculum intent and

content. Despite the value of the cross-curricularity principle, curricularity seems necessary, because, under the influence of modernist knowledge systems, the structure of curricula in Europe remains subject-centred. Such an approach would also involve helping pupils to adopt a critical point of view on issues of ecological sustainability.

Pupils can thus begin to attribute the ecological crisis not to broad and impersonal causes such as overpopulation, overconsumption or inappropriate technology, but to the tensions and gaps the current world economy causes. In the latter case, they can recognize others’ and their own responsibilities as citizens of Europe, which is to a very large extent responsible for the world’s ecological situation since the Industrial Revolution. Thus ecological issues provide sample material both for the study of frontiers within Europe, as well as for the study of Europe in relation to the rest of the world. There has been a lot of discussion and research concerning concepts’ importance, development and teaching in the classroom and progression in the curriculum (for example, by Counsell, 1997; Haenen, Schrijnemakers, 2000; Newton, 2001).

Tasks (assignments)

1. Can you explain the meaning of the concept of European dimension for science education?
2. Try to demonstrate some useful examples of application the European dimension in science education.

Case study

The group of the prospective science teachers discussed about the concept of European dimension in education. Student A thought that it means how to use common EU curriculum in schools. Student B explained that it could be a comparison of the science education in different EU countries. Student C meant that this concept is important only in civics education.

Questions to Case Study

1. Can you explain the mis-understanding of the concept of European dimension in education of the students A, B and C?
2. What is the correct explanation of the concept of European dimension in education?
3. Do you think that the concept of European dimension in education does not fit to science teaching at upper secondary school?
4. Do you think that European dimensions are suitable only for humanities?

Summary

The main purpose of the European dimension within compulsory education was ‘to build a shared cross-national understanding of what it means to be “European”. The goals of European dimension in education included democracy, social justice and respect for human rights as well as ‘strengthening a sense of ‘European identity’ as a part of the preparation of pupils for making “concrete progress” towards European Union.

Member-states were encouraged explicitly to introduce the European dimension in all ‘appropriate’ subjects of the school curriculum. The teaching of the European dimension should be an integral part of the education of the future citizens of Europe. These views suggest changes such as the development of new attitudes and new skills which will be in accordance with the new conditions of work, the new economic and social relations and the new cultural situation. The European dimension has been implemented as both a subject-based and a crosscurricular innovation.

Frequently Asked Questions

I do not believe in the concept of European Union personally. I think that it means more and more regulation to education. I guess that education is based on national traditions. How can I work with the concept of European dimension in education?

Answer the question above

It is recommended to study professional literature deeply. Try to discuss with your students about this concept. Maybe you can find their point of view on this concept. You can get some personal experience in this way and it could help you to change your approach to the implementation of European dimension in science education.

Next Reading

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Unit 2

Science Education in Europe

DANUŠE NEZVALOVÁ

Objectives

- To understand the reasons for science education in EU countries;
- To describe general goals of the science education in EU countries;
- To understand the role of science in education;
- To explain the recent weaknesses of science curriculum.

The State of Science Education in Europe

Science education in Europe has recently been the focus of considerable attention. The predominant factor behind this interest is the declining numbers of young people choosing to pursue the study of science (European Commission, 2004) and the threat this poses to the Lisbon agenda which seeks to place the EU at the forefront of the knowledge economy of the future.

Why study science? Science is an important component of our European cultural heritage. It provides the most important explanations we have of the material world. In addition, some understanding of the practices and processes of science is essential to engage with many of the issues confronting contemporary society (Osborne, Dillon, 2008). Yet in recent times fewer young people seem to be interested in science and technical subjects. Why is this? Does the problem lie in wider socio-cultural changes, and the ways in which young people in developed countries now live and wish to shape their lives? Or is it due to failings within science education itself?

There are shortcomings in curriculum, pedagogy and assessment, but the deeper problem is one of fundamental purpose. School science education has never provided a satisfactory education for the majority (Osborne, Dillon, 2008). Now the evidence is that it is failing in its original purpose, to provide a route into science for future scientists. The challenge therefore, is to re-imagine science education: to consider how it can be made fit for the modern world and how it can meet the needs of all students; those who will go on to work in scientific and technical subjects, and those who will not.

In the past two decades, a consensus has emerged that science should be a compulsory school subject. However, whilst there is agreement that an education in science is important for all school students, there has been little debate about its nature and structure. Rather, curricula have simply evolved from pre-existing forms. Predominantly these curricula have been determined by scientists who perceive school science as a basic preparation for a science degree – in short a route into science. Such curricula focus on the foundational knowledge of the three sciences – biology, chemistry and physics. However, our contention is that such an education does not meet the needs of the majority of students who require a broad overview of the major ideas that science offers, how it produces reliable knowledge and the limits to certainty. Second, both the content and pedagogy associated with such curricula are increasingly failing to engage young people with the further study of science. Much of the current concern about science education, expressed in reports such as Europe Needs More Scientists (European Commission, 2004), concentrates solely on the supply of future scientists and engineers and rarely examines the demand. Science education for all can only be justified if it offers something of universal value for all rather than the minority who will become future scientists. For these reasons, the goal of science education must be, first and foremost, to offer an education that develops students' understanding both of the canon of scientific knowledge and of how science functions. In short that school science offers an education in science and not a form of pre-professional training.

Most school science curricula do attempt to serve two goals – that of preparing a minority of students to be the next generation of scientists – and that of educating the majority in and about science, most of whom will follow non-scientific careers. For the future scientist, their education best begins with the fundamentals of the discipline. In this approach, only students who reach a relatively high level of education in science develop a sense of the explanatory coherence of science and its major ideas. Yet it is this latter understanding – good examples of which can be found in the better quality of popular science writing (Angier, 2007) – that everyone requires. Asking the school science curriculum and teachers of science to achieve both of these goals simultaneously places school science in tension where neither goal is served successfully. In addition, the standard school science education has consistently failed to develop anything other than a naive understanding of the nature of science, commonly called ‘how science works’.

Today, many of the political and moral dilemmas confronting society are posed by the advance of science and technology and require a solution which, whilst rooted in science and technology, involve a combination of the assessment of risk and uncertainty, a consideration of the economic benefits and values, and some understanding of both the strengths and limits of science. The current debate about how the challenge of global warming should be addressed is one example. Is it amenable to a technological solution or will it simply require humanity to adapt to the inevitable changes through measures such as better flood defences, improved water conservation and changes in agricultural land use? To understand the role of science in such deliberations, all students, including future scientists, need to be educated to be critical consumers of scientific knowledge. Improving the public’s ability to engage with such socio-scientific issues requires, therefore, not only a knowledge of the content of science but also a knowledge of ‘how science works’ – an element which should be an essential component of any school science curriculum (Osborne, Dillon, 2008).

The primary goal of science education across the EU should be to educate students both about the major explanations of the material world that science offers and about the way science works. Science courses whose basic aim is to provide a foundational education for future scientists and engineers should be optional.

Traditional curricula in school science suffer from a number of difficulties. Knowledge is usually presented in fragmented concepts where the overarching coherence is not even glimpsed let alone grasped – an experience which has been described as akin to being on a train with blacked-out windows – you know you are going somewhere but only the train driver knows where. In addition, there is a growing gulf between the focus of school science – commonly the achievements of the 19th and early 20th Centuries – and the science that is reported in the media, such as astrophysics, neuroscience and molecular genetics.

The issue of why school science is not as engaging for young people as other subjects is complex. Nevertheless, two factors would seem important. Students now live in a culture which is increasingly reflexive and one, in addition, in which they are confronted with a much wider range of subject choice than was the case in the past. Adolescence is a period of identity formation and there is good evidence that a critical issue for young people is how their subject choice frames their sense of self-identity – in particular, how it reflects their personal values. School science has done little to consider how it might appeal to the values and ideals of contemporary youth and their culture. Hence, our view is that what school science requires is a new vision of why an education in science matters that is widely shared by teachers, schools and society. In particular, it needs to offer a better idea of what kinds of careers science affords – both in science and from science – and why these careers are valuable, worthwhile and rewarding.

EU countries need to invest in improving the human and physical resources available to schools for informing students, both about careers in science – where the emphasis should be on why working in science is an important cultural and humanitarian activity – and careers from science where the emphasis should be on the extensive range of potential careers that the study of science affords.

A growing body of recent research has shown that most students develop their interest in and attitudes towards school science before the age of 14. Therefore, much greater effort should be invested in ensuring that the quality of science education before this age is of the highest standard and that the opportunities to engage with science, both in and out of school, are varied and stimulating. Within schools, research (Osborne, Dillon, 2008) has shown that the major determinant of student interest is the quality of the teaching. Evidence suggests that this is best achieved through opportunities for extended investigative work and 'hands-on' experimentation and not through a stress on the acquisition of canonical concepts.

An accumulating body of research shows that the pedagogy in school science is one that is dominated by a conduit metaphor, where knowledge is seen as a commodity to be transmitted. For instance, teachers will speak of trying to 'get across' ideas or that students 'didn't get it.' In this mode, writing in school science rarely transcends the copying of information from the board to the students' notebook. It is rare, for instance, to see any collaborative writing or work that involves the construction of an argument. Even experiments are written up formulaically. Little opportunity is provided for students to use the language of science even though there is good evidence that such opportunities lead to enhanced conceptual understanding. Research would suggest that this limited range of pedagogy is one reason why students disengage with science.

The recent report produced by a team for the EU Directorate General on Research, Science, Economy and Society (Rocard, 2007) argued that a 'reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods' was more likely to increase 'children's and students' interest and attainment levels while at the same time stimulating teacher motivation' – a view with which we concur.

Research would also suggest that deep, as opposed to superficial understanding, comes through knowing not only why the right answer is right but also through knowing why the wrong answer is wrong. Such learning requires space to discuss, to think critically and to consider others' views. Contemporary school science education offers little opportunity for such an approach. Developing and extending the ways in which science is taught is essential for improving student engagement.

Any learning experience is framed by three aspects – curriculum, pedagogy and assessment. For too long, assessment has received minimal attention (Nezvalova, 2009). Tests are dominated by questions that require recall – a relatively undemanding cognitive task and, in addition, often have limited validity and reliability. Yet, in many countries, the results of a range of tests, both national and international, are regarded as valid and reliable measures of the effectiveness of school science education. Teachers naturally, therefore, teach to the test, restricting and fragmenting the content and using a limited pedagogy. Transforming this situation requires the development of assessment items that are more challenging; cover a wider range of skills and competencies; and make use of a greater variety of approaches – in particular, diagnostic and formative assessment (Nezvalova, 2009).

Key issues to the nature of school science

In the teaching and learning of science there are three key issues that are central to the nature of school science. That is:

- Curriculum
- Pedagogy
- Assessment

What are the major issues confronting formal secondary science education? What evidence is there? Is the situation common throughout Europe or is there variation?

A major characteristic that emerged immediately is that there is no commonality within Europe, confirming a feature which is shown in more detail in the Eurydice report on Science Teaching in Europe (Eurydice, 2006). Rather, what Europe has is a distribution around a mean. Whilst some countries have curricula that offer more integrated science curricula, others are still strongly rooted in the separate sciences.

The one area, however, in which there is a common trend is in the decline of student attitudes to science. Data from the ROSE (Sjoberg, Schreiner, 2005) project shows that there is a 0.92 negative correlation between students' attitude towards school science and the UN index of Human Development. Thus Norway, which is top of this index, has the worst student attitudes to science. That there is such a clear trend would suggest that this is a feature that is systemic to the nature of advanced societies and not to schools or the teaching of science.

Many countries are experiencing significant problems with engaging students with the advanced study of physical sciences. Where this is the case, it is a source of significant concern. However, this pattern is not universal across Europe and appears to be strongly correlated with the level of economic advancement in any given country. Many countries have seen declining numbers of students choosing to pursue the study of physical sciences, engineering and mathematics at university. For instance, from 1993-2003 the percentage of Science and Technology graduates has fallen in Poland, Portugal and France. The same is true in Germany and the Netherlands (OECD, 2006). In addition, the percentage of graduates studying for a PhD – the most common route to becoming a professional scientist – has dropped in all European countries.

The ROSE study of students' attitudes to science in more than 20 countries has found that students' response to the statement 'I like school science better than other subjects' is increasingly negative the more developed the country (Sjoberg, Schreiner, 2005). In short, the more advanced a country is, the less its young people are interested in the study of science.

One interpretation of these data sets is that this is a phenomenon that is deeply cultural and that the problem lies beyond science education itself. Given that learning science is demanding, that it requires application, discipline and delayed gratification – all values which contemporary culture might be said to neglect – there may be some substance to this view. In addition, the immediate relevance of the subject may not be evident to students.

Rather, at the heart of many European conceptions of education is the liberal notion that it should serve the purpose of offering young people the best that is worth knowing. In many Northern European countries there is a somewhat more complex notion of 'bildung' which is that education should develop the full potential of the individual. In short, our view is that the primary goal of including science in the school curriculum is because it is an important component of our European cultural heritage which provides the most important explanations we have of the material world. In addition, some understanding of the practices and processes of science is essential to engage with many of the issues confronting contemporary society. The primary goal of science education across the EU should be to educate students both about the major explanations of the material world that science offers and about the way science works. Science courses whose basic aim is to provide a foundational education for future scientists and engineers should be optional.

Whilst science and technology are often seen as interesting to young adolescents, such interest is not reflected in students' engagement with school science that fails to appeal to too many students. A lack of perceived relevance. School science is often presented as a set of stepping-stones across the scientific landscape and lacks sufficient exemplars that illustrate the application of science to the contemporary world that surrounds the young person. An oft-quoted example is the inclusion in science lessons of the blast furnace and the Haber process, both of which do not relate easily to what has been christened the 'iPod generation'.

School science begins with foundational knowledge – what a cell consists of, the elements of the Solar System, or the laws of motion – ideas which appear to most children as a miscellany of unrelated facts. The bigger picture only unfolds for those who stay the course to the end. Lacking a vision of the goal, however, the result is akin to being on a journey on 'a train with blacked-out

windows, you know you are going somewhere but only the train driver knows where.'(Claxton, 1991).

Curriculum

Across Europe, the structure of the science curriculum varies, reflecting different and contested views of how school science should be organized. In most countries, biology, chemistry and physics are clearly distinguished – at least in secondary education. However, the degree of organization and specificity of the curriculum varies widely. For example, in Spain the curriculum is divided into 9 or 10 units for each of the science subjects, whereas in England there are only 4 units for science as a whole and the words biology, chemistry and physics do not appear in the National Curriculum. Norway follows a relatively typical 'academic' pattern in which science is obligatory throughout grades 1–11, during which time it is taught as an integrated subject called 'science'. In grades 12 and 13, students can choose to follow science lessons or not. At these grades students can decide if they want to study any of the following subjects: biology, chemistry, physics, geology and technology. In Germany, the secondary curriculum clearly distinguishes the separate sciences and, even if science is taught in an integrated manner, it is usually as a succession of the separate subjects. Current movements for science curricula (in the different types of school: Hauptschule, Realschule, Gymnasium and – in the growing replacement of the three-tiered system Gesamtschule) aim to have a more integrated focus. So, if there is a trend, it is that school science is becoming more integrated across Europe, although the pace of change is relatively slow (Eurydice, 2006).

The science curriculum can appear as a 'catalogue' of discrete ideas, lacking coherence or relevance, with an over-emphasis on content that is often taught in isolation from the kinds of contexts that might provide essential relevance and meaning.

Weaknesses of the curriculum in EU countries

- The goals and purpose of science education are neither transparent nor evident to students.
- Assessment is based on exercises and tasks that rely heavily on rote memorization and recall of knowledge;
- Knowledge is quite unlike those contexts in which learners might wish to use science knowledge or skills in later life (such as understanding media reports or understanding the basis of personal decisions about health, diet, etc.).
- The relationship between science and technology is neither well-developed nor sufficiently explored.
- There is relatively little emphasis, within the science curriculum, on discussion or analysis of any of the scientific or environmental issues that permeate contemporary life.
- There is an over-reliance on transmission as a form of pedagogy with excessive use of copying (Lindhal, 2007; Lyons, 2006; Osborne, Collins, 2001).

How to change curriculum

A complementary goal of science education, however, is to educate students about science in order to provide them with the kind of understanding required of informed citizens. Whilst the achievements of science offer us the best explanations of the material world we have, it is important to have some understanding, in addition, of how the ideas and understanding that science offers – few of which are self-evident – have been achieved. Such intellectual capital contributes to developing the educated person.

Contemporary scholarship (Osborne, Ratcliffe, Collins, 2003; Comas, Olson, 1998) would suggest that such a goal is achieved by:

- developing an understanding of the major explanatory themes of science; showing the tremendous intellectual and creative achievement such ideas represent;
- exploring the initially tentative nature of scientific knowledge claims and the ways in which these ideas are consensually agreed to generate reliable knowledge;
- exploring the implications of the application and use of scientific knowledge.

Such a curriculum – which serves the needs of developing a scientifically literate public – would be significantly different from that currently offered throughout most of Europe. It would recognize that, for the overwhelming majority, their experience of learning science in school will be an end-in-itself – a preparation for living in a society increasingly dominated by science and technology and not a preparation for future study. Its content and structure could then only be justified on this basis. It would represent an introduction to the cultural capital offered by science, its strengths and limitations, and develop an understanding, albeit rudimentary, of the nature of science itself. Our view is that all students, including future scientists, need this form of education at some stage of their school career.

However, the content of the science curriculum has largely been framed by scientists who see school science as a preparation for entry into university rather than as an education for all. No other curriculum subject serves such a strong dual mandate. The result for teachers is that they must work with the tension that exists between these twin goals – the needs of future scientists and the need of the future nonscientists. As we have argued earlier, different goals require different approaches.

The solution is twofold. First, there needs to be greater clarity about these twin aims so that it is clear which goal is being served by any curriculum at any one time. Second, all countries need to offer, at some stage, a curriculum which is an education about science, its achievements and its practices to all students. Even for scientists, let alone the nonscientist, the current system results in teachers of science and scientists who have a limited understanding of their own subject (Koulaidis, Ogborn, 1995; Lederman, 1992). In addition, courses which aim to prepare students for the further study of science should be optional – something which students choose to do rather than being compelled. There have been several attempts to engage students with school science by changing the curriculum. The outcomes of these innovations are, as yet, unclear.

Across Europe there have been a number of notable attempts to enact a form of science education that, in one form or another, might achieve the goal of educating young people for citizenship in contemporary society. In the UK, these began with the development of an optional course called Science for Public Understanding (Hunt, Miller, 2000) for 17-18 year olds. From this, the University of York and the Nuffield Curriculum Centre developed a course for 14-16 year olds – Twenty First Century Science – which consists of three components. First, a core curriculum that explores both the major explanatory themes of science and a set of 'ideas-about-science' that all students do. This is then followed by an additional course of academic science which is for those who wish to pursue the study of science at a later stage. Alternatively, students with a more vocational inclination can take a course in Applied Science. One of the primary goals of the course has been to free school science from the twin mandate of simultaneously educating both the future scientist and the non-scientist.

Pedagogy

Weaknesses of pedagogy are following:

- A pedagogy that lacks variety.
- A less engaging quality of teaching in comparison to other school subjects (Cooper, McIntye, 1996).
- An assessment system that encourages rote and performance learning rather than mastery learning for understanding (Nezvalova, 2009).
- Pedagogy where breadth and repetition are emphasized at the expense of depth and variety.

How to Change Pedagogy:

- be rich in opportunities to manipulate and explore the material world;
- use a pedagogy that is varied and not dependent on transmission;

- offer some vision, however simplified, of what science offers both personally in satisfying material needs and as a means of realizing an individual's creative potential;
- developing an understanding of science itself;
- transforming science-teaching pedagogy from mainly deductive to inquiry-based methods';
- increase 'children's and students' interest and attainment levels while at the same time stimulating teacher motivation' – a view with which we concur.

Developing and extending the ways in which science is taught is essential for improving student engagement.

Assessment

Too little effort has been invested in developing more reliable, valid and engaging methods of assessment in school science. Any teaching and learning experience is a synthesis of three components – a curriculum which defines both the goals and the experiences by which those goals will be achieved; a pedagogy which enacts the curriculum which is predominantly the responsibility of the teacher; and an assessment system. The last can usually either be formative – in that it seeks to ascertain student progress and adjust either the curriculum, the pedagogy or both to meet the learning needs of the students; or alternatively, summative where the function is to undertake a terminal evaluation of student attainment.

What is needed are science courses that engage students in higher-order thinking which includes constructing arguments, asking questions, making comparisons, establishing causal relationships, identifying hidden assumptions, evaluating and interpreting data, formulating hypotheses and identifying and controlling variables. Assessment that is dominated by low-level cognitive demands risks too much emphasis being placed on the recall of factual information which often leads teachers into a pedagogy which emphasizes rote learning. This approach undermines student interest in science. Improving the range and quality of assessment items used both to diagnose and assess student understanding of processes, practices and content of science should, therefore, be a priority for research and development.

Tasks (assignments)

1. Why do we teach science in EU schools?
2. Try to find the weaknesses of science curricula in EU countries.
3. How the curricula should be changed recently?
4. Is pedagogy and assessment adequate to science education in EU schools?

Case study

The prospective science teachers discussed with students at upper secondary school about physics teaching. She found that the majority of students dislikes to study physics. Students mostly thought that physics is boring subject and they really do not know why to study physics because they will not need the knowledge and skills to be taught in the future.

Questions to Case Study

1. Why students should learn physics?
2. Is physics important for their work and life in the future?
3. Which should be done in science curriculum to be physics more important and interesting for students?

Summary

More fundamentally we have argued that the primary goal of science education cannot be simply to produce the next generation of scientists. Rather, societies need to offer their young people an education in and about science – and that this needs to be an education that will develop an understanding of the major explanatory themes that science has to offer and contribute to their ability to engage critically with science in their future lives. In addition it should help develop some of the key competencies that the EU aspires to for its future citizens. Achieving this goal requires a long term investment in curricula that are engaging; in teachers of science by developing their skills, knowledge and pedagogy; and in assessment systems that adequately reflect the goals and outcomes we might aspire to for science education.

Frequently Asked Questions

I am a teacher of chemistry and physics at agricultural vocational school. These subjects are not too favour for my students. I guess that it would be useful to do some changes in curriculum. I am not sure if the integrated science curriculum is suitable for our students.

Answer the question above

Studies of your students are professionally oriented. These students do not need academic knowledge in physics and chemistry and integrated science (physics and chemistry) is recommended.

Next Reading

Lamanauskas, V., Vilkonienė, M. (2008). *European Dimension in Integrated Science Education*. Olomouc: Palacky University Press, 112 p. ISBN 978-80-244-2163-6. Avaiable on: www.iqst.upol.cz

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Unit 3

The Constructivist Perspective and Teaching Integrated Science

DANUŠE NEZVALOVÁ

Objectives

- To compare approaches to science curriculum in EU countries and the Czech Republic;
- To compare science pedagogies in EU countries and the Czech Republic;
- To understand future directions in science education;
- To reflect the constructivist theory in science education.

How science is taught in the Czech schools

In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone (Science for All Americans, 1990, National Science Education Standards, 1996). Everyone needs to use scientific information to make choices that arise every day. The constructivist perspective is becoming a dominant paradigm in the field of the science education. In many industrialized countries, physics has become relatively unpopular subject for study. Before 1990 good mathematical and polytechnic education was stressed within general education in the Czech Republic. After 1990 the importance of this part of education has been weakened, and humanistic studies have been emphasized.

The science education is the entire school experience including content, pedagogies, student interactions, and extra-curricular activities that transmit the community's values and beliefs. The focus of the Czech science education is the canonical knowledge of science facts, concepts, and theories. The focus on canonical knowledge is also demonstrated by the fact-driven curriculum and teacher-centred pedagogies that dominate the Czech classrooms. The lessons included a mix of basic and challenging content, a higher density of science content, more theoretical ideas, and more unrepeated technical terms. Science lessons are more likely to focus on acquiring knowledge in the form of facts, definitions, and algorithms than on making connections.

Separate science classes begin in 6th grade when students take physics and biology every year with chemistry being added at the earliest in 7th grade and required in 8th and 9th grade. Little effort is made to integrate between the science subjects. Observations of the classrooms shows very little hands-on learning or inquiry learning. The curriculum emphasizes content learning goals with only the expectation that students learn to conduct simple experiments and develop observation and use of scientific instrument skills. Students are more likely to be asked to interpret results given to them by the teacher than collect and record data.

Science Pedagogies

The pedagogy is predominately teacher-centred and lacking in variety, but there are efforts to change. On the basis of the research (Hoffer, Mechlová, Svoboda, 2004), physics teachers do presentations nearly every lesson, review material and engage in task solving a little more than 50% of the lessons, conduct teacher experiments less than 50% of lessons, and use pupils´ experiments about one third of the lessons.

In this research, investigation was realized in representative sample of 3 764 students at lower secondary school on the physics teaching. We can present some results from this study:

- The most frequent mark in physics for both boys and girls is mark 2. Marks range between 1 (best) to 5 (worst).
- 24 % of boys and 27 % of girls have the best mark in physics that is 1.
- Sciences are in the second part of the list of popularity. Physics is at third place from the end. The sequence in sciences is: biology, geography, mathematics, chemistry, and physics.
- Math is more difficult than physics.
- 45 % of boys and only 31 % of girls look forward to physics lessons.

- Order of popularity of particular parts of the lesson (0-6 points): teacher experiments (5.09), video (4.96), movies (4.87), pupils experiment (4.85), internet (4.77), explanations (3.72), problems (2.69), revision (2.08).
- What teachers and students do: presentation (5.07 nearly every lesson); revision (3.56 a little more than 50 % of lessons); task solving (3.45 a little more than 50 % of lessons); teacher experiment (2.79 less than 50 % of lessons); pupils experiments (2.15 appr. in every third lesson); video (1.36 appr. in every fifth lesson); movies (1.06 very low frequency); internet (0.86 almost never).
- Majority of students (67 % boys and 55 % girls) claim that the knowledge they acquire in physics lessons will be needed in their future.

A minority of physics teachers supported the learning activities of students using problem solving, projects, role play, projects, cooperative learning. The majority of teachers oriented the students to accept a ready knowledge and limits their understanding of physics concepts. These teachers reproduced the content of the textbook and this reproduction is then asked on the students. Most of teachers use more traditional teaching methods and teaching strategies. The lessons are very structured with a clear introduction and a summary at the end of the lesson. Teacher lectures incorporate a variety of memorization strategies and reviews.

Assessment often occurs in the form of public interviews (oral exam) in which an individual student stands at the front of the classroom and answers the teacher's questions. At the end, the teacher tells the student the grade and the student records it in their grade book. Students are expected to show their work that is then evaluated and corrected in a public manner. One question that emerged from the assessment practices is how do the types of assessment and the tone taken by the teacher contribute to the student's self-confidence? Is the frequency of summative assessment or its public nature diminish the effectiveness of the frequent feedback?

Inquiry is not an instructional practice common in our classrooms. The classrooms are so teacher-centred that it would be difficult to implement a more student-centred and student-driven curriculum. Classrooms focus on seatwork and seldom employ cooperative groups beyond working with a partner. The impact of the teacher-centred education system is that students are very passive and resistant. The lack of formal cooperative learning instructional strategies can also be observed in the classroom. Students seem to work in groups but the groups are informal and usually more social. There is little modeling, expectation, or help in learning to apply collaboration skills in the workplace. Students do not have an opportunity in the classroom setting to learn the politics of working in a group, choosing a leader, finding roles, allocating workload, learning how to cooperate, and resolving conflicts. Does the lack of cooperative learning strategies impact the students' future success in the workplace and the nation's economic success?

In the science education the content is 'coherent' because it follows the traditional structure of the respective nature sciences without any adaptation for education purposes. It does not take into account interests or possibilities of students in particular ages. The science curriculum is very formal and academic and the students do not acquire most of it.

Future directions in science education

Science pedagogy has not changed much in recent years. Currently there is a greater focus on the integration of topics from different science subjects. Independent and creative work is stressed more. The laboratories in science are more investigative in nature, moving away from a 'follow the cookbook' style. More emphasis is placed on written and oral communication. Reasoning, as opposed to mechanical memorization of facts, is stressed. There is an effort to balance deductive and inductive approaches in the curriculum. Schools are still dominated by teacher-centred pedagogies with modest progress toward student-centred approaches. Some schools and individuals have made more changes than other schools, but, with current reforms emphasizing local schools determining their own curriculum, it is difficult to see widespread change. There is a desire to replace the traditional emphasis on memorization and theoretical knowledge by problem solving and real-life applications.

Despite the success on the test, the Czech science education system is adopting curriculum and instructional practices more consistent with recent American reforms and reforms in other EU countries. While the success on the international assessments would appear positive, we do not regard our curriculum as exemplary and believe children need other skills not measured on the assessments in order for the country to be able to complete on the European and global markets. But achievement and knowledge do not result in economic success. Do the achievement scores actually measure a quantity that is a predictor of a nation's economic potential?

The constructivist theory

This paradigm of the constructivist theory starts to infiltrate into the thinking process of science education and that is documented by increased publishing activity especially in Anglo-Saxon and Germanic literature (Bransford, Brown, Cocking, 2004; Brooks, 1999; Bybee, 2002; Jensen, 1998; Lawson, 2002; Miller, Leach, Osborne, 2000; Minzes, 1998, 2000; Saunders, 1992; Sunal, 2004;). In the Czech pedagogical literature some works concerning this issue seem to appear, but only in little number in the field of scientific education. The perception of cognition as a construct activity relates both to cognitive activity of a student and to a teacher of science subjects or researches in the fields of the science education.

The most salient feature of the constructivist perspective is reflected in Watzlavick´s (1984) definition. It is the notion that learners respond to their sensory experiences by building or constructing in their minds, schemas or cognitive structures, which constitute the meaning and understanding of their world. Individuals attempt to make sense of whatever situation or phenomenon they encounter, and a consequence of this sense making process (a process which takes place within the mind of these individuals) is the establishment of structures in the mind. These structures or schemas as they are frequently called can be thought of as one's beliefs, understandings, and explanations, in short one's necessarily subjective knowledge of the world. Meaning is constructed by the cognitive apparatus of the learner (Resnick, 1983). Consequently, it is not communicated by the teacher to student.

To say it another way, meaning is created in the mind of the student as a result of student's sensory interaction with her or his world. Learning science is something that students do, not something that is done to them. Learning science is a process, in which students learn such skills as observing, interpreting, and experimenting. Hands-on activities (Cunningham, Herr, 1994; Wood, Walker, 1994), while essential, are not enough. Inquiry (Hubbard, Miller, Power, 1993) is central in science learning. When engaging in inquiry, students describe objects and events, ask questions, construct explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. Students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills (Chiappetta, Kobylka, 2002; Mariano, Pickering, Pollock, 2001).

The general theoretical and practical constructivist consensus indicates that eight factors are essential in constructivist pedagogy (Doolittle, 1998):

- Learning should take place in authentic and real-world environments: knowledge construction is enhanced when experience is authentic.
- Learning should involve social negotiation and mediation: knowledge can only be attained through social contact.

- Content and skills should be made relevant to the learner: if knowledge is to enhance one's adaptation and functioning, then the knowledge attained must be relevant to the individual's current situation, understanding, and goal.
- Content and skills should be understood within the framework of the learner's prior knowledge: all learning begins within an individual's prior knowledge.
- Students should be assessed formatively, serving to inform future learning experiences: knowledge and understanding are not directly visible, but rather must be inferred from action; teacher must continually assess the individual's knowledge.
- Students should be encouraged to become self-regulatory, self-mediated, and self-aware: constructivist perspective would be subsumed under the construct of meta-cognition which consists: (1) knowledge of cognition (knowing what one knows, knowing what one is capable of doing, and knowing what to do and when to do it), (2) regulation of cognition (the on-going tasks of planning, monitoring, and evaluating one's own learning).
- Teachers serve primarily as guides and facilitators of learning, not instructors: the role of the teacher is to create experiences in which students will participate that will lead to appropriate processing and knowledge acquisition.
- Teachers should provide for and encourage multiple perspectives and representations of content: experiencing multiple perspectives of a particular event provides the student with the raw materials necessary to develop multiple representations.

It is important to note that these mental constructions are often not in accord with those of the community of scientists or those given in textbooks and as such are described variously as misconceptions, alternative conceptions (Viennot, 1979; White and Tisher, 1986), alternative frameworks (Driver, Easley 1978), home-grown conceptions (Rowe 1983) and intuitive conceptions (Burbles, Linn 1988).

To implement the constructivist approaches to learning and inquiry, we need to create a classroom research community - one that applies an inquiry process to create progressively more adequate models through a principled process of experimentation, model building, and application. This is a complex of individual and social activity, one that is seldom practiced in middle school classes. It brings instructional dilemma to teaching. The paradox is that, to understand this complex activity, one needs to do it, but to do it, one needs to understand it. The instructional solution we develop combines aspects on prior work on preconceptions. It scaffolds carefully the inquiry process and understanding for students. The cycle –questioning, predicting, experimenting, modeling, applying, reflecting and self-assessing- seems to be very useful in the constructivist classroom. In this classroom we suggest the following steps:

1. Understanding
Understanding the science. Students show that they understand the science concepts developed in instruction and can apply it in solving problems, in predicting and explaining real-world phenomena.
Understanding the process of inquiry. Students can talk about what approach they or others have taken in exploring a topic.
Making connections. Students see the big picture and have a clear overview of their work and how it relates to their prior knowledge, ideas or situations. They relate new information, ideas and experimental results to what they already know.
2. **Doing science**
Being inventive. Students are creative and examine many possibilities in their work. They show originality and inventiveness in thinking.
Being systematic. Students are careful, organized, and logical in planning and carrying out their work.
Using the tools of science. Students use the tools of science appropriately. The tools may include such things as lab equipment, measuring instruments, diagrams, graphs, charts, calculators, and computers.
Reasoning carefully. Students can reason appropriately and carefully using scientific concepts and models.
3. Social context of work
Writing and communicating well. Students clearly express their ideas to each other or to an audience through writing, diagrams, and speaking. Their communication is clear enough to allow others to understand their work.
Teamwork. Students work together as a team to make progress. Student respect each other´s contribution and support each other´s learning. Students divide their work fairly and make sure that everyone has an important part.

This instructional solution combines aspect of prior work of Brown (Brown, 1983; Brown, Collins, Duguid 1989), Vygotsky (Vygotsky 1978), and White and Frederiksen (1998).

Preconceptions

The fundamental resource is comprehension of scientific vision and students´ conception (preconceptions) as an equal sources for reconstruction the content structure. The way of assertion relationships between student's cognition and the scientific vision is crucial factor in constructivist-oriented approach. In this approach the academic positions are understood as content cognition and are components of everyday visions of students´ as personal structure particular individuals. Pre-concepts are not viewed as mistaken (misconcepts) in respect of academic concepts, but they are viewed as equal sources for construction of education. The reconstruction of these pre-concepts arises from an effort to create meaningful instruction and research in the field of science education (Smith, J.P., Disessa, A.A., Roschelle J., 1993). The acquisition of knowledge from particular scientific subject is involved (1) by pre-concepts with which students come to education and (2) by their social and material conditions for the actual realization of the education. Pre-concepts are single characteristics of learning individual and are created by all other influences and experiences that had any connections with them. All other aspects have very important role during the creating of it. These are exogenous factors (social, economical, ethic, cultural etc.) and endogenous factors that come from psychological and psychosocial characteristics of each individual.

The current clear instrumental approach towards instruction at school is characterized by dominant status of the teacher, receptive passivity of students and memorizing learned information. The scientific findings are acquired in a form that excludes their later application and utilization. The students cannot use their knowledge in concrete situations because they cannot recognize their relation to the reality. They cannot transfer their experience to the real situation. One of the possible ways to gain active knowledge is constructive approach to the instruction of scientific subjects. In this approach the present instructive teaching practice is completed by chosen learning problems through creating adequate learning environment. First of all, a student compares new knowledge with his/her experience and view to the world. This process is individual, relative and unpredictable. The teacher's goal must form rich and communicative setting in content that will address the subjective field of experience and at the same time will include new problems that will attract to creative self-orientation. The mastery of a teacher lies in the fact that he/she can predict the chain of sequences between former situation constructions at a student and scientific knowledge which are taken by the student as a state of expected clash and sorts out and overrule by the way of tests and errors. In the learning environment the individual has the subjective extent of knowledge and experience.

During the model creation it is necessary to know that knowing is not closed, it is forming – it constructs itself individually and in terms of social relationships. Learning is an active process, it realizes in multidimensional relationships. From this perspective the learning process is primarily the matter of construction, learning individuals enter as a co-creators of learning process. The results of learning are not predictable. We always come out from the existing construction knowledge. The function of the tutor is to lead the subject to objective adoption of already existing construction and that is given by easy reach and the transfer knowledge. The goal is learning that is always constructive, the goal of instruction must be to enable the students to create the constructions. This is an individual building up of multiform relationships that in its network will create the structure of knowledge for application in further contexts and social contacts.

The fact is that during the instruction of science subjects in the schools the traditionalistic approach prevails and in where the knowledge transmission by the teacher in ready form plays the crucial role and in which the activity of the students is minimal and the emphasis is put on memorizing. The teacher is the source of transferred information. It is natural that nowadays this model is untenable.

Possibilities for change in science education in the Czech Republic

Two basic aspects of school science need to be changed if it is to respond to society´s demand for ´science for all´. These are: (i) the science to be learned (the content); and (ii) its manner of the teaching (pedagogy). However, the Theory of Science Instruction (didactics) dedicated little attention to this area in the Czech Republic. Some research works were published (Hoffer, Prokšová, 2003; Mandíková, Zieleniecová 1993; Mandíková 1993). We consider to focus on application of current pedagogical theories to the area of science education and to succeed its quality and to increase the interest in science subjects.

For the great majority of learners who will not go on science related careers, the case for the content of their science learning in school must be built on learning outcomes that will be sustained by their lives in society as citizens, in the world of work, and its personal life. Following suggestions come from these premises:

- The interdisciplinary conception of science, there is an idea of the world in the middle of it. The world is not depended on the interpretation of individuals who live in it.

- The objective reality is encounters the subjectively constructed and interpreted reality and their connection in process of communication.
- Purely biological, physical or chemical do not exist.
- The natural construction of terminology in the student's thinking.
- Gradual formation of logical structure of knowledge.
- The strategy of learning, cognition and interpretation.
- The internal understanding based in personal and social competencies of a student.

The challenge of science for all is summarized by the four goals:

- to develop citizens to participate in political and social choices in technological society;
- to train those with special interest in further studies in science and technology;
- to provide appropriate preparation for modern fields of work;
- to stimulate intellectual and moral growth in students.

Pedagogy

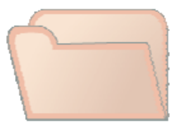
One of the possibilities is to apply constructivist approaches to science education to be influenced the Czech pedagogy. Teachers would develop an instructions and corresponding materials that make scientific inquiry accessible to a wide range of students.

This integrated model sciences for all has no deep tradition in our country. Interdisciplinary relations were described in some articles (Janás 1996, 2003; Kolářová 1998, 2000; Bílek a kol. 2001, Bílek, 2001). But in other countries there are obvious tendencies towards to integration of scientific education (Science for All Americans, 1990). In many countries this model is successfully realized especially on primary level. Integrated and at the same time coherent didactics model of science subjects abolishes the diversity of knowledge and simplify their transfer and the processes of education. It will increase the content understanding of science concepts, rules and theories and their application in modern technologies. It will create the space for the methods supporting individual and creative activity of students and increase the quality and effectiveness of instruction. Integrated science education would be implemented on some lower secondary schools. Teachers design school curriculum in the Basis of Framework of Educational Progamme that was approved by Ministry of Education. It is not so easy for teaches in schools to design integrated science education programme. Teachers have no experience whatsoever with this approach and therefore it will be difficult for teachers to realize integrated science education in schools. Integrated science education would be also implemented in some upper secondary schools (for instance vocational schools) that are not focused on general education. The first step how to integrate science subjects is implementation of interdisciplinary projects that are described in school curriculum. It will enable the transformation into integrated instructional projects. It reflects the demands of teachers in practice and it will make the curricular material development easier. We believe that projects of integrated science give a chance to students to understand science and to be science literacy.

Tasks (assignments)

1. How do we teach science in CR schools?
2. Try to find the weaknesses of science teaching in CR.
3. Compare the science pedagogy in EU countries and in the Czech Republic. Are you willing to apply constructivist theory in your science teaching and why?

Case study



The prospective science teachers discussed their reflection and understanding of constructivist theory. They compare traditional teaching methods which in they were mostly taught during their studies at secondary schools with constructivist approach. Most of them think that the role of science teacher is very important. But one student thinks the opposite.

Questions to Case Study

1. Point out the new role of the science teacher in constructivist classroom.
2. Compare the role of teacher in traditional and constructivist classroom.
3. Describe how you would organize a constructivist approach in the topic which you select (for example Floating of bodies, Reflection of Light…).

Summary

The fact is that during the instruction of science subjects in the schools the traditionalistic approach prevails and in where the knowledge transmission by the teacher in ready form plays the crucial role and in which the activity of the students is minimal and the emphasis is put on memorizing. The teacher is the source of transferred information. It is natural that nowadays this model is untenable. Two basic aspects of school science need to be changed if it is to respond to society´s demand in EU countries. These are: (i) the science to be learned (the content); and (ii) its manner of the teaching (pedagogy).

Frequently Asked Questions

I am a teacher of chemistry and physics at upper secondary school. I am going to implement constructivist theory in my science teaching. But I was taught in traditional strategies during my school days. In this case my former science teachers are not an example how to teach science for me. I am not sure if I am able to use this theory in my practice.

Answer the question above

Yes, you can. There is a true that your former science teachers have strong influence on your individual concept of teaching. But your study of constructivist theory and your tutors during teaching practice can help you to implement this theory in your teaching.

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Unit 4

A Conception of Integrated Science Education

VINCENTAS LAMANAUSKAS

Objectives

- To have a look at the evolution of the integrated teaching idea;
- To define the essential elements of integrated science education.

Depending on the adopted criteria, integration has never remained to be identical. The process itself was known in didactics long time ago and was used for training by the famous classics of pedagogy such as Komenskij, F.A.Dysterveg, J.Lock, etc. B.Kedrov maintains in his description of the evolution of natural sciences that since the outset of the 20th century, "… two converse tendencies of natural sciences evolution appeared: one was famous for its resolution, embranchment and differentiation of sciences, the other– on the contrary, was seeking to combine the isolated sciences into a single system of knowledge, i.e. integration…" (Kedrov, 1967).

The various ideas of integration spread out in Europe and North America pretty late after the World War II. The very first educational projects of integrated natural sciences were conceived in Great Britain. Later, teaching integrated natural sciences was distributed into the schools of the Netherlands and other continents including Australia, Asia, etc. New projects were developed: Biological Sciences Curriculum Project, Elementary Science Study, etc. (Charles B.Klasek, 1972).

The integration issues of natural sciences have been a field of interest for many scientists from various countries. Thomas R.Koballa, Lowell J.Bethel (1985) paid close attention towards the integration of natural sciences into the other educational subjects. H.Cohen and F.Staley (1982), R. Francis (1996) and other scientists were trying to prove the meaning of natural sciences and mathematics integration. Judah L.Schwartz and Jerrold R.Zacharis (1977) additionally supplied the integration method with the science of technology. They supposed there would not be possible without the formation of the concept of modern technologies. A.Glatthorn and A.Foshay (1981) were interested in the issues of launching integrated teaching programs. Arthur A.Carin and Robert B.Sund (1989) paid much attention to contemporary teaching of natural sciences. They tried to define contemporary natural science as a subject as well as considered the question how to integrate the subjects of natural sciences into the other subjects, how to individuate the educational process, how to apply the latest technologies (for instance, micro computers, etc.). Other researchers focused on the problems of the integrated curricula/syllabuses. The following main points can be underlined:

- the integrated curriculum must strengthen and reinforce existing student knowledge in a given area (Gunston, 1985; Jacobs, 1989);
- the integrated curriculum must extend student understanding into new areas, student need to participate in activities which allow them to grow and to learn (Underhill, 1994; Abraham, 1989; Francis, 2001; Šapokienė, 2001). Teaching on the integrative base is one of the tendencies of modern primary school (Korozhneva, Melnik, 2003);
- the curriculum must make the connection to the real world. It directly influences the child's motivation to learn. (Fogerty, 1991; Lamanauskas, 2001);
- thinking in terms of integration is generally difficult for teachers (Lang, 2001, p.132), at the same time they don't fully understand the process of integration and this limits their opportunities in realizing the integrative way of teaching in primary schools (Lamanauskas, 2001; Korozhneva, Melnik, 2003). Nevertheless, primary natural science education has to be purposefully implemented on the basis of integration (Akvileva, Klepinina, 2001).

In addition, integrated natural science education is examined in the context of the ideas of constructivism. A basic premise of constructivism is that knowledge is not passively received but developed as students construct their own meanings (Treagust, 1996). Teachers who valued their students existing ideas` and attempted to link learning to them (i.e., using a constructivist premise about learning) were more able to make relevant links and transfer of skills across curriculum areas. They were more likely to involve integration as a framework in their teaching (Waldrip, 2001). According to Bentley and Watts, learning is always an interpretative process involving individuals` constructions of meaning. New constructions are based upon previous experience and prior knowledge (Bentley, Watts, 1994, p.24).

Tasks (assignments)

1. Draw a chart showing the evolution of the idea of integrated science education (chronologically indicate the evolution of the idea of integrated science education).
2. Enumerate the essential elements of integrated science education.
3. Outline the objectives of Integrated Science.

Case study

A teacher *N* of a school *XXX* teaches physics, always searches for different forms of work and frequently makes original decisions. Sometimes, the classes given by the teacher involves more than the taught subject, for instance physics/chemistry, physics/biology or physics/physical education and physics/music. The students enjoy such lessons as they find them easier, funnier etc.

Questions to Case Study

1. What is your opinion on the possible problems that can be encountered by the above mentioned teacher who prepares for non-traditional lessons?
2. Why are the above mentioned lessons favourably evaluated by the students? What are the ways of having benefit from the situation?

Summary

The experience of teaching integrated natural sciences is enormous. The ideas of integrated education spread out over the schools of Europe and the North America in 1960 – 1970. The first projects of the similar method of teaching were set up in Great Britain: Nuffield Secondary Science, Scottish Integrated Science, etc. Later, such projects as “Improvement of the Curriculum of Natural Science Subjects” and “Natural Sciences – Society – Technologies”, etc. were established in the U.S.A. The models of integrated natural sciences teaching carried a character of the experiment the results of which were thoroughly assessed.

A primary purpose of integrated natural science education is the construction of the whole world picture, the development of the child’s world outlook and intense correlation with an environment, the fosterage of affective experience. In this case, integration helps to avoid resolving educational content into related /or loosely related fields that expand the child’s world picture.

The integration of natural science education with other educational subjects should present pupils the knowledge of natural sciences as well as the material produced in the textbooks and workbooks that are linked with the current affairs of school, with the customs and traditions of the schoolchildren and their relatives of the inhabited locality. The closest natural objects such as the park, forest, lake, mound, etc. are not out of the way. Hereby, the learners are encouraged to show interest in an environment of their inhabited locality, are stimulated to know more and more, their thoughtful evaluation of nature is developed, etc. Integral natural science education requires a different approach to the educational process itself.

Frequently Asked Questions

What is the main point of integrated science education?

Science education is an integral phenomenon that can be grasped as a whole science. It is disintegrated in the substantial parts such as ecology, environment education, etc. The parts of any of the units advance and finally settle in the complete wholeness. In order to understand the problems of science education, they have to be investigated complexly embracing different fields and levels.

What will you consider as a classical definition of Integrated Science?

There are many classical definitions of Integrated Science which you may find in many advanced books.

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Unit 5

Some Philosophic, Didactic and Social Aspects of Integrated Science Education

VINCENTAS LAMANAUSKAS

Objectives

- To find out the impact of the well-known philosophical trends on education of the 20^{th} century and to discover how those promoted the ideas of integrated science education.
- To learn how integrated science education affects the processes of students' socialization;
- To analyze and understand the main problems of natural science education in terms of pedagogy;
- To motivate the qualities of natural science education in terms of the constructive aspect of teaching/learning.

Philosophic aspects

The basic task is to raise the awareness of the harmony of the world, and therefore the role of integral processes at school is extremely important as holistic essential visuals are embodied here (Gelman, 1991). Gelman supposes that the end of the 20^{th} century – the beginning of the 21^{st} century is an epoch of integration.

W.Gräber and other scientists (2001) maintain that science teaching can be described in three dimensions:

Teacher centred – student centred

Teaching facts – teaching processes

Discipline oriented – daily-life oriented

Social aspects

The socialization of the personality is also notable in the process of natural science education. Some authors maintain that integrated natural sciences teaching is obligatory when we discuss the socialization of personality. According to J. Gedrovics and I. Wäreborn (1999), integration in science teaching may be necessary, if we want to reach some other goals, such as the socialisation of a student to promote his/her incorporation in the society.

Didactic aspects

In terms of philosophy, integration is the intensification of the correlation, the combining of separate elements into the wholeness. However integration at school level is differently understood.

Three burning issues of didactics become pronounced along the integration of natural sciences:

- integrated subjects change (structure, tasks, the logics of a subject, the complex of concepts, etc.);
- methodological means reach a higher level;
- the format of teachers and pupils' activities and that of teaching-learning alterates. How can it influence the process of teaching/learning?

Only having solved the mentioned problems, a certain level of the completeness (knowledge, information, etc.) will be achieved. For example, if the knowledge of physics is demonstrated at molecular level and that of chemistry – at atomic or ionic levels, an integral correlation between these subjects will be weak. From a didactic point of view, the most important ideas are as follows: what are the possibilities to apply the model of integrated natural sciences teaching in school practice; how it can be achieved under the circumstances of the present situation; what is the level of the integration of natural sciences, etc.; what are the main differences between integrated and linear teaching/learning of natural sciences; does integrated natural sciences' teaching help the pupil to perceive the outward things. The move to integrated teaching abundantly changes the process itself. Will integrated natural sciences teaching really develop and strengthen children's intelligence and abilities to realize and accept the changed content of teaching? Won't the process disorganize their normal development (for example, along with integration a degree of abstraction increases) and help to stay efficient? Such questions are raised bearing in mind that ***formal*** and ***informal*** integration of natural sciences is noticed. Trying to implement informal integration, primarily the affinity of all science subjects (physics, chemistry, biology) need to be distinguished, i.e. goals, teaching/learning conditions, the opportunities of practical work, concepts, etc. have to be classified. In other words, integrated natural sciences teaching is possible up to the degree and volume which leave the learner's system of natural science knowledge undisturbed.

Table 1. The key issues of integrated natural science education.

General didactic and methodic integration of teaching	The system of the categories (concepts) of the integrated educational course	The essence, forms, principles and functions of integrated teaching	The consistent patterns of integration processes
The forms, stages and trends of teaching and educational process integration	Theoretic reasoning of the significance and opportunities of integrated teaching	The consistent patterns and models of applying integrated teaching in school practice	The integral results of teaching/learning and their evaluation

Pedagogy literature stresses that the integration of natural sciences needs all possible preconditions such as:

- the general principles of the structure of subjects (for example, chemistry, physics, biology);
- general laws and consistent patterns;
- general concepts, definitions etc.;
- the general didactic conditions etc. of integration;
- similar methods and forms of teaching, etc.

Tasks (assignments)

1. Describe some philosophical trends and emphasize the impact of the philosophical trends on promoting the idea of integrated science education.
2. Explain the impact of integrated science education on the processes of students' socialization.
3. Define the main didactic problems of integrated science education.
4. Complete the scheme indicating how the content of science education changes in the process of replacing the linear educational strategy with the integrated one.

Linear science subjects teaching/learning

Teaching content:	Teaching/learning forms /methods:	Students` activity:	Teacher`s role:

↓ ↓ ↓ ↓

Integrated Science Education

Teaching content:	Teaching/learning forms/methods:	Students` activity:	Teacher`s role:

Case study

An integrated lesson of science introduces the students an everyday phenomenon – a car suddenly stops on the roadway. The learners work in groups, every group examines the situation from a different angle (physics, chemistry, environment protection) and the end of the lesson, presents its work results and arrives at conclusions. The students ask questions about the topic they deal with. Discussions between the groups are sometimes possible.

Questions to Case Study

1. Do you think this case of integrated science education corresponds to the essential elements of constructive teaching/learning? Use 3-5 propositions to motivate your position.

2. What is the role of teacher in this particular lesson?

Summary

The issues of integrated natural sciences teaching should be complexly discussed. ***The system of personal values – theoretical and practical knowledge of the personality – practical skills of the personality*** is an undivided system closely interrelated and functioning only through specific, intensive, practical activities of a personality.

Evidently, the integrated natural science course helps pupils to convey the whole (***holistic***) world picture that encourages to easier realize the issues of ecology, nature (environment) protection, the implementation of modern technologies, etc., to link outcomes with reasons, obtained knowledge with socio-cultural life. Integration should not be only formal (mechanic) combination of a few related natural science topics. A nominal coherence of knowledge does not allow to reach the level of the wholeness, i.e. the synthesis of knowledge. An important point is that integrated/integral teaching should be optimal as schoolchildren most frequently arrive at a single-sided understanding of the basic laws of nature, the structure and qualities of substances, etc. and answer the questions in different ways (agreeably to the subject).

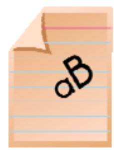
Frequently Asked Questions

Why the teaching and learning of natural sciences are so important in comprehensive school level?

It could be acknowledged that natural sciences, according to their specifics, play a very important role in broadening pupils' world outlook. Science subjects, such as biology, physics, chemistry, etc. are taught at school. These subjects theoretically and empirically examine the world of experience – reality: nature that surrounds pupils, technical and human being who is a part of nature. All these objects, things, descriptive and motivated relations of science subjects are researched and explained by natural sciences and can always be checked and practically proved. Herewith received and made conclusions are correct and have not any doubts…The science classes always discuss real, concrete things and phenomena which are a part of pupils' reality and even every day life...

…A weak position of natural sciences in the development of pupils' world outlook is the disunity of the sciences but not imagination or empiric experience (their strength is exactly here).

(*According J. Vaitkevičius, 1999*).



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Unit 6

The Main Tendencies of Integrated Science Education Development

VINCENTAS LAMANAUSKAS

Objectives

- To analyze the reasons determining the need for integrated science education;
- To identify the basic terms describing the integration of sciences;
- To perceive integrating the content of subjects as the most efficient way of integration offering possibilities, advantages and links with the principles of constructivistic teaching/learning?

Complex knowledge, its application for a certain activity becomes a crucially important object for the various fields of the man's life. Integrated education should decrease the objections between the knowledge gained from the teaching subjects and the necessity and inevitability of their synthesis. The presentation of content only (knowledge, information, etc.) is not a core of teaching.

What are the main reasons that determine the need of teaching integration? They are diversely described by pedagogy literature. J.Rimkutė and E.Motiejūnienė (1993) point out the following arguments:

- the integration of natural sciences (there are more and more fields of research combining traditional subjects (physics, chemistry, biology) and the modern branches of science such as biochemistry, biophysics, biogeochemistry, astrophysics etc.);
- the undividedness of the world and the knowledge of it (individual traditional subjects of biology, physics and chemistry reflect the

theoretic structure and evolution of science, have no close links with the learner's daily life, his/her interests outside school);

- the implementation of new technologies (a broad background is requisite for working people of a number of the areas of production and service);
- ecology issues (integrated education will help to perceive the correlation between animate and inanimate nature and to adopt the approach to the environment based on ecology culture);
- the need of the correlation between education content and a socio-cultural life (natural science knowledge related to a social and cultural life and science history of Lithuania and the world is very important to the process of fostering personal and value-based attitudes).

Raja Roy Singh (1993) has examined the education issues under the circumstances of the rapidly rotational world and distinguished the succeeding reasons:

- the enlargement of the radius of knowledge the basis of which is automatic communicative technologies;
- the growth of the world's interdependence (globalization);
- global problems and the obligation to find decisions;
- need to anticipate education to the most advanced (front) cognition (science), i.e. to get schoolchildren acquainted with various subjects, to seek to develop interdisciplinary skills and abilities in order to identify and clarify the problem and to effectively apply gained knowledge and skills to solve it, etc.);
- a direct correlation between teaching and global questions (the application and development of problematic integrated teaching, etc.).

I. Suravegina and R. Ivanova (1990) indicate the ensuing reasons of integration: 1) the necessity to concentrate attention in order to know the wholeness; 2) the opportunity for pupils to choose the subjects considering their interests; 3) a need to decrease the number of individual educational subjects at every stage of teaching. On the basis of the papers of other researchers, A. Blum (1994) identifies the following main reasons: 1) the boundaries of different subjects constantly change, and therefore new subjects appear (for example, biochemistry, bioengineering, etc.); 2) integrated natural sciences teaching increases the transformation of teaching, i.e. the learners easier notice an intrinsic correlation among notions, principles, concepts; 3) children cannot logically study the same subject that is scientifically framed. The structures of knowledge acquisition and spread are similar to those of physics and biology; 4) the integrated course of natural sciences affords an opportunity for the teachers of different subjects to plan and teach together as then they can feel more relaxed and less tired, their cooperation rises up. Some educologists of the USA notice (Collins, 1994; Frederiksen, 1994; Stodolsky, 1988) that:

- knowledge acquired at school is perceived using a pattern that is digressed from the methods applied to use information to solve the problem;
- the correlation between obtained knowledge and life is weak (efficiency, scholasticism etc., is insufficient).

Scientific literature suggests such concepts as ***integration variants*** (Paulauskaitė, 1994), ***integration types*** (Case, 1991), ***integration forms*** (Beitas, 1995), ***integration varieties*** (Bagdonas, 1994; Pečiuliauskienė, 1992), ***integration method*** (Salite, 2000); ***integration approach*** (Chepelev, 2003). The above information confirms that we use different concepts in the discussions on the same subjects, and therefore there is plenty of confusion and lack of a uniform concept. Finally, a thick accent should be put on the efficiency of integrated teaching. If it is not effective under specific circumstances or do not correspond to the requirements of training, the approaches to natural sciences teaching can be definitely diverse.

Hence:

- the experience of integrated teaching is diverse and rich;
- experience is personal in every country - history, practice and experimentation etc. S. Sjøberg notices that many countries have introduced more or less radical reforms, and there has been support for curriculum development and experiment (Sjøberg, 2002);
- there is no country, the experience of integrated teaching of which should be extremely advanced and the most efficient;
- the major task is to find out the essential factors that crucially influence the efficiency of natural science education and the circumstances preventing from successful integrated teaching. One of the most frequently named aspects – a professional competence of natural science teachers (Lamanauskas, 2003b; Pak, Solomin, 2003);
- two competing paradigms are obvious:

- the interception of the experience of other countries needs a thorough analysis;
- the teachers of natural sciences should constantly be engaged in the innovations of natural science education and conditions for that should be established. Finally, the concept of integrated teaching of every teacher is unique. Thus, the best way out is the cooperation of natural science teachers when planning and introducing integrated curricula. Research reveals that the main differences exist in the city site school and that of the rural area. According to K.Tobin, W.M. Roth and A.Zimmermann (2001) teaching in urban schools, with their problems of violence, lack of resources, and inadequate funding, is difficult /it is even more difficult to learn to teach in urban schools/.

All over the world, educators and scientists have joined forces to produce different integrated programs such as the Biological Sciences Curriculum Study (BSCS), the Chemical Bond Approach (CBA) and CHEM Study program in chemistry, Physical Science Study Committee (PSSC) and Harvard Project Physics (HPP) and the Earth Science Curriculum Project (ESCP) etc. It is clear that not all these programs made identical success. Despite of this realization in a school practice of the different integrated programs there was a bright promotion in didactics of science teaching.

It is clear that the most important and relevant goal of science education is to prepare young people for a full and satisfying life. According to A.Toldsepp (2003) we need to implement future oriented paradigm of science education (figure 1).

Goal of science education

Formation of scientific and technological literacy (STL)

↓

Realized according to

↓

Balanced curricula and syllabi

↓

Achieved by means of

↓

Higher order cognitive skills (HOCS)

- *Generating ideas*
- *Solving problems*
- *Making decisions*
- *Etc.*

↓

Formed on the strength of

↓

Science- technology-environment-society interface context (STES)

Figure 1. Future oriented paradigm of science education (Toldsepp, 2003)

There were three main waves of science education reforms (De Jong, 2007).

Table 2. Science education reform and influential psychological theories

Wave of reform	Influential theory that shapes curricula and courses	Issue of growing interest
* 1960s	* Descriptive behaviourism * Stages of cognitive development	* Programmed instruction * Sequence of science topics
* 1980s	* Guided discovery learning * Information-processing perspectives	* Lab work for school students * Learning cycle
* 2000s	* Social constructivism * Socio-cultural perspectives	* Students' ways of reasoning * Role of context and language

After 1990 special interest to integration of science subjects has arisen in the countries of Central and Eastern Europe. It has been closely connected with the begun reforms of education systems. It is obvious that science education is currently going through a process of change worldwide.

Tasks (assignments)

1. Use the presented material to identify separate areas under the indicated topics grouping the reasons determining the necessity of integrated science education:

Reasons determined by changes in teaching content	Reasons determined by the process of teaching/learning	Social/socio-cultural reasons

2. Use the offered literature to define the following terms:

Term	**Definition**
Integration types	
Integration forms	
Integration method	
Integration approach	

3. Try to express a personal opinion to define the core of integrated science education, for instance, *Why is it required? What are the ways of implementation? etc*.

4. Briefly discuss the development of integrated science teaching in Europe from the 1990 until now.

Case study

Every part has unique experience in this field: an intended different level of integration at different education stages, varying intensity of educational content, different forms and methods of integration etc. However, some common points exist. Recently, ecological education is frequently integrated in different subjects, for example, the above mentioned integration of content. Use the documents regulating the content of education in comprehensive schools (curricula, education standards etc.) as well as other major tools for science education (course books, work books etc.) to analyze the situation of integrating the content of ecological education into general education in your country.

Questions to Case Study

1. What is the stage and which are the subjects containing the major part of indications of ecological educations? What is the stage and which are the subjects having the highest intensity? Point out the reasons.
2. How does the examined integration of subject content influence the quality of the educational process and the results of self/education?
3. Find the links between the integration of the content of ecological education and the principles of constructivistic teaching/learning?

Summary

Natural sciences closely correlate; their content reflects a united reality. These points cannot be isolated from one another in the educational process. On the contrary, their interaction should be encouraged and only then the efficiency of the educational process will equally increase. Physics and chemistry as well as biology research describe the phenomena taking place in nature. From this viewpoint, their interpretation is supposed to be similar in order pupils should get a solid concept of natural phenomena.

Along with the integration of teaching content, the conveyance of the holistic view of the world, the application of training aids and methods to the level of pupils' development (without respect of age), teaching pupils to systematize and implement interdisciplinary relations, etc. are very important to education. Different patterns of integrated teaching/learning exist. A promising method (particularly in primary school) is when the content of natural science education is integrated into each educational subject in all forms. At last, the life of an exact school community may have a natural science context (various projects, community environment protection education, practical environment protection work, etc.).

Frequently Asked Questions

What is important from the historical point of view?

From the viewpoint of history it is obvious that science education should combine natural history achievements and prognostic future victories. Children need conditions to be imposed and possibilities to be perceived how the ideas of natural sciences have been changing throughout the time, how they have been realized and used and what their social, inward, cultural context has remained.

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Unit 7

The Models of Integrated Science Education

VINCENTAS LAMANAUSKAS

Objectives

- To meet up with and carefully analyse one of the possible models of integrated science education emphasizing the classification of the subjects taught:
- Define the advantages of integrated science education;
- Understand the levels of integration in science education.

A practic relevant problem which is patterning of integrated teaching becomes pronounced when proceeding to integrated teaching. The patterns of such teaching can vary. K. Pigdon and M. Woolley (1993) presents the following pattern of teaching/learning.

Information	**Nature of activity**	**Subjects involved**
Facts	**Prior knowledge** • **making prediction** • **asking questions** **Shared experience** • observation • collecting information/data	**Learning about** • social education • science • environmental education • personal development • technology studies
Concepts	**Processing information** • listing • grouping • categorising • classifying • labelling • organising ideas	**Learning through** • language • art • drama • mathematics • movement • music
Generalisations	**Synthesising** • making statements • generalising • looking for relationships	**Learning about** • social education • science • environmental education • personal development • technology studies
Further information	**Refinement and extension of knowledge** • elaborating • justifying • reflecting	

Figure 2. A model of integrated learning (Pigdon, Woolley, 1993)

The authors think that the pattern of integrated teaching is delivered to classify the knowledge of subjects, to include the overall ideas of how the world acts. Two groups of subjects are specified:

- the subjects of content (social sciences, natural sciences, environment sciences, the evolution of personality, technologies);
- the subjects of a process (language, art, drama, mathematics, music, plastics). Integration creates opportunities for learners to investigate, conclude, process information, improve knowledge and impart information on different topics without embarrassment and leaving the barriers of traditional subjects behind. One of the practical arguments for integration, particularly in the middle school years, is that it enhances pupil engagement with school. Several studies show that providing an authentic curriculum, well connected to pupils` needs and interests and to the world outside of school, can result in reduced alienation and increased participation and engagement (Venville, Wallace, Rennie, Malone, 2002).

The process of the integration (in the light of content, forms, activity, etc.) of natural sciences is acclaimed to be very important. We suppose that the model defining the key components of the integration process at every level is possible.

Three fundamental levels can be sorted out:

- mechanic selection and combining / the main components are didactic conditions and integration trends and methods /;
- synthesis of the integrated course / the main components are needs and integration methodology (completeness)/;
- application in the teaching process / the main components are activity forms and application mechanisms and the complex of didactic means (textbooks, workbooks, teacher‘s books, extra didactic material, computer programmes, etc. /.

A close correlation and interaction exists between these levels. The correlation is not equivalent (*level 1* $\leftrightarrow$ *level 3*). The integrated course of natural sciences as a teaching subject, as a matter of fact, is not changed but refreshed and complemented regarding the essential alterations of the educational system. In case of infraction of at least one of the links, integrated teaching will not be effective.

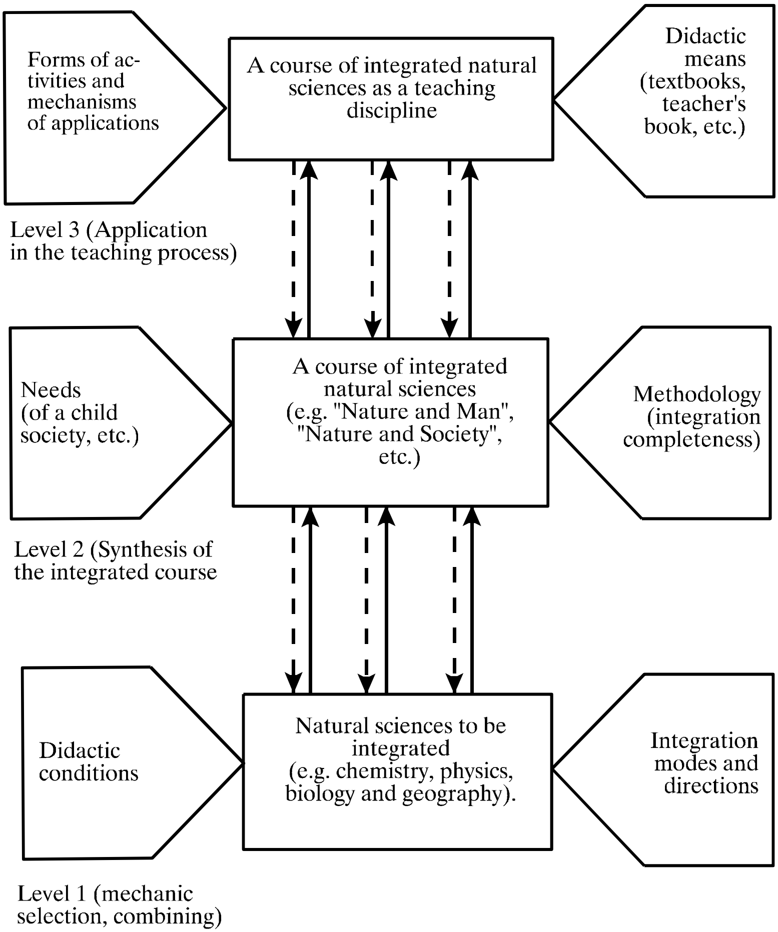

Figure 3. The model of the process of natural sciences integration (Lamanauskas, 2003)

Also is interesting the Berlin-White Integrated Science and Mathematics Model developed to address the need for a definition of the integration of science and mathematics education. There are six main aspects (Berlin, White, 1994):

- ways of learning;
- ways of knowing;

- process and thinking skills;
- content knowledge;
- attitudes and perceptions;
- teaching strategies.

It is obvious, that the choice of model of integration first of all depends on what form of integration prevails, for example:

- integration of experiences;
- integration of students activities;
- social integration;
- integration of knowledge;
- integration as a curriculum design etc.

Also, it is possible to notice varied levels of integration (Palmer, 1991, p. 59):

- developing cross-curriculum sub-objectives within a given curriculum guide;
- developing model lessons that include cross-curricular activities and assessments;
- developing enrichment or enhancement activities with a cross-curricular focus including suggestions for cross-curricular "contacts" following each objective;
- developing assessment activities that are cross-curricular in nature;
- including sample planning wheels in all curriculum guides.

According A.Miller, teachers who use cooperative, integrated methods will produce students more competent in using problem-solving techniques, in communicating effectively and in working cooperatively. Finally, it can be mentioned that at the heart of the interdisciplinary educational philosophy (interdisciplinary science education) is the psychological theory of constructivism.

Tasks (assignments)

1. Name the advantages of integrated science education:

Subject field	**Social field**

2. What is the basis for classifying subjects into two groups presented in the integrated model of science education K. Pigdon and M. Woolley (1993)?

Case study

In state X, following the approved educational curriculum developed for comprehensive school, primary school classes are taught a course on the world study covering 2 parts - *Social Education* and *Science Education* – which are relatively singled out to underline the problems and links between the topics occurring in every field of education. The course book on this subject freely operates the topics included in both parts and retains notional and subject coherence. In turn, the area of science education consists of 4 components:

- research of nature;
- animate nature (component of biology);
- substances and their variations (component of chemistry);
- physical phenomena (component of physics).

Moreover, science education closely relates not only to social but also to technological-artistic training, mathematics and languages. These subjects either complement one another or make the complete entirety. The concentre of basic school is divided into three parts having a different degree or extent of sciences integration:

- integrated course on sciences *Nature and Human* including biology, physics, chemistry, earth science, healthy living, ecology, technology and agriculture is taught in forms 5 and 6. The course on sciences is properly integrated considering all subjects taught;
- still maintaining close interdisciplinary relations in forms 7 and 8, biology, chemistry and physics are taught as separate subjects;
- revision courses on biology, chemistry and physics are taught in forms 9 and 10;
- from the point of view of structure, the field of education in forms 11 and 12 consists of 4 subjects:

1. biology;
2. chemistry;
3. physics;
4. integrated sciences.

The students choose an appropriate course on sciences – physics, chemistry, biology or integrated sciences. Those who are not intend to study sciences in the future or do not think of any other activity related to sciences but still want to gain more knowledge about this area of study, choose either general courses on separate sciences or the integrated course on sciences. The students interested in carrying on the studies of sciences or those who would like to keep proceeding with this field choose the advanced courses on separate sciences. Although the courses on physics, chemistry and biology are most frequently taught separately in secondary school, these sciences have much in common – concepts and conceptions, methodological principles, solving science and practical issues etc. Thus, a deeper ***integration*** of the content of science education is pursued. In addition, the content of science education often relates to the problems of ecology, healthy living, demographical situation and the use of technologies and nature. Plenty of contacts can be noticed between sciences and mathematics.

The integrated course on sciences for secondary school students of forms 11 and 12 focuses on the learners preferring a humanitarian profile and those who are not going to proceed with professional science activities in the future. This course concentrates on modern achievements in science, life experience and environmental problems. All topics are examined in broad outline, the evolution of sciences is discussed as a method of acknowledging nature, the issues of personal and public life are highlighted, natural phenomena and scientific ideas are carefully analysed and observation and experimentation are carried out. The integrated course on sciences is devoted to help the student with pursuing general science education and developing the ability to distinguish between scientific and non-scientific issues as only a sufficiently sophisticated person can be actively involved in solving the problems of a modern country. The course assists the learners in perceiving the significance of sustainable development ideas and protecting biosphere and the quality of public life.

Questions to Case Study

1. What is the level of integration at every stage of comprehensive school?
2. Indicate the observed key components having influence on your position.

Summary

There are different models of integrated science education. Teachers can choose suitable model of integration depending on different circumstances. The main circumstances - a level of knowledge of students, presence of accompanying didactic materials, quantity of students in a class, support of administration of school, etc. In a school practice more often as a core of integration three main subjects - chemistry, physics and biology - act. Science teachers can use interdisciplinary integration or integration inside teaching subject. The real problem to teaching integrated science courses is that there are no enough appropriate models or widely-accepted materials available. Integrated science courses gives for teachers a chance to really take a broader look at the nature of science in new ways. It is not the simply teaching. It is obvious that primary goal of integrated science is to teach students how science is done, how to analyze problems and situations, and how to investigate scientific (or pseudo-scientific) claims. Educators and researchers agree that teaching integrated science is a suitable approach for producing scientifically literate citizens. In general, integrated science is a great idea for the students.

Frequently Asked Questions

What makes integrated science a unique subject?

It is evident that integrated science emphasizes organization of learning experiences around a topic/theme. It is likely that this unification of concepts around a theme makes integrated science unique. The learning experiences and concepts of integrated science are organized around the different themes. Organising concepts around common themes is a good way of deliberately removing the subject mater boundaries.

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Unit 8

The Integrated Science Education Curricula and its Designing Principles in Comprehensive School

VINCENTAS LAMANAUSKAS

Objectives

- To perceive the integral and systemic nature of the content of science education;
- To analyze different types of science education curricula, to know the qualities, drawbacks and degrees of integrity of the curricula;
- To define the concepts of *educational content* and *educational curriculum* and to know their framing principles;
- To have knowledge of conditions ensuring the possibility of successful implementation of science education curriculum.

Natural science is a subject that seeks to set out conditions for schoolchildren to adopt the basis of contemporary natural science knowledge, to cherish a modern culture of scientific thinking and activity and ability to refer to it in practice. It is very important that natural sciences should help learners to formulate a clear concept of natural history based on the latest knowledge of the world strongly emphasizing the character of the correlation between nature and society, civilization and culture. The world is multidimensional, and therefore we must strive to acknowledge it. This is a winning goal of contemporary natural science education. The objectives as concretization of this goal are supposed to be formulated at different levels. According to A.Tõldsepp (2003), the main of natural science education is to prepare young people for a full and satisfying life in the world of the 21st century. The others underline natural science-technological literacy for all and mastery for professionals (Broks, 2002).

Public society approach to natural science education (general needs, general level of culture, traditions in the light of interaction with nature, the need to have society and the young generation of a privileged natural science background, etc.), **its optimal conditions of implementation** (the standards of natural science education and material, human, etc. resources undertaking their success), **the development of the needs and motivation of nature study (in a broad sense)** (improving the need to perceive nature throughout all studies in comprehensive school, enhancing cognitive relation with nature, etc.), **natural science results: knowledge, abilities, relations** (studying natural sciences, etc.) are the crucial components of natural science education.

Natural science and natural science education are closely and specifically interrelated at school. Natural science education can be perceived as the synthesis of the components (Lamanauskas, 2001).

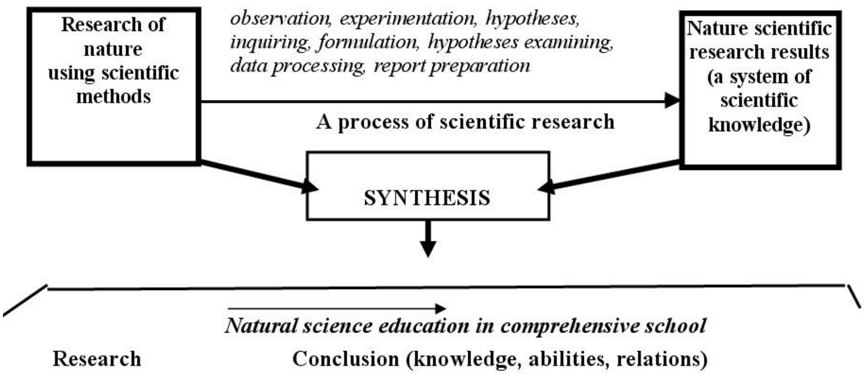


Figure 4. Natural science and natural science education at school.

As can be seen from figure 1, natural science education is a specific synthetic, integral, systemic subject.

The science curriculum need to be based on such important didactic principles as:

- **humanism** (fosters respect for nature and human being, the creation of a healthy and safe environment, etc.);

- **democracy** (in terms of education methodology, content, etc. both the pupil and the teacher are given the option and a freedom);
- **spiral** (similar issues are discussed at higher level in higher forms. Training material is broadened and deepened);
- **integration** (training material is integrally produced (the complete wholeness). Educational content as well as the process and the teacher-pupil activities are sought to be integrated);

In addition, the following principles are underlined in the majority of the countries:

- **regional studies** (based on schoolchildren's knowledge and visuals acquired investigating terrene, digging, weather phenomena, waters, soil etc., of a region);
- **a seasonal principle** (objects, phenomena and their alteration of animate and inanimate nature are observed in autumn, winter, spring and summer).

Training (educational) content is defined by the curricula. They can vary and perform different functions. For example, in Lithuania the components of general natural science education are described by the General curricula indicating that the content of natural science education is constructed of the following central components (General curricula… p.289):

I. Natural research:

1. The methods of scientific research.
2. Scientific thinking and creativity.
3. Natural sciences and society.

II. Animate nature (biology):

1. Organism.
2. Organism and environment. Biosphere and human being.
3. Continuation and variety of life.
4. Human being.

III. Substances and their alteration (chemistry):

1. The structure and composition of a substance.

2. The subordination of the properties of substances considering their composition and structure.
3. Chemical transformation.
4. The main substances used in nature, daily life and technologies.

IV. Physical phenomena (physics):

1. Physics as a natural science.
2. Substance and its structure.
3. Motion and force.
4. Energy and physical processes.
5. Physical transformations.
6. The Earth and the Universe.

The first component of natural research is integrated into the next three.

The content of natural science education gives a chance to the dynamics and structure of the educational process. However, the adaptation of natural science knowledge system depends on both the teacher (choosing and applying teaching methods and forms, etc.) and the pupil (the methods of learning, motivation, general abilities). The diversity of teaching and learning content, forms and methods, activities are typical of natural science education. All that makes the educational process effective: develop intellectual knowledge and skills, set out conditions for intense pupils' activities, shape thinking, foster aesthetic feelings, etc.

The natural science knowledge and skills gained by pupils in the educational process form the content of teaching natural science. Anyhow, the process of natural science education includes the teacher and children's activity based on direct and indirect relations. Children are interested in the classes of science when the content of the taught material is comprehensible, attracts attention and imagination, encourages to intensively work and is problematic. A highly effective component of natural science education is the presentation and examining of problems. It can be expressed in three ways: ***1) asking questions about the relevant subject; 2) presenting demanding tasks; 3) facing serious problems.***

Some fundamental moments can be emphasized:

- successful natural science education is a sample of the most important concepts of natural sciences (natural science). They explain the main structure of natural sciences and increases the learner's natural science perception moving to the higher form;

- successful natural science education is a sample and discernment of the concepts that deepen and broaden general natural science understanding;
- the understanding of concepts plays a leading role at school as well as in everyday life as they create an opportunity for people to better understand each other, predicates about verbal communication (Arends, 1998);
- in order to explain concepts and phenomena, primary school pupils' thinking peculiarities (ontogenetic aspect) definitely require picturesque specific cases. The most advantageous way to reach an effect is practical children's activities.

In addition, integrated natural science education is examined in the context of the ideas of constructivism. A basic premise of constructivism is that knowledge is not passively received but developed as students construct their own meanings (Treagust, 1996). Teachers who valued their students existing ideas` and attempted to link learning to them (i.e., using a constructivist premise about learning) were more able to make relevant links and transfer of skills across curriculum areas. They were more likely to involve integration as a framework in their teaching (Waldrip, 2001). According to Bentley and Watts, learning is always an interpretative process involving individuals` constructions of meaning. New constructions are based upon previous experience and prior knowledge (Bentley, Watts, 1994, p.24).

It is possible to indicate some basic principles for science education curricula:

- scientific character;
- unities of the substantial and remedial party of training;
- structural unity;
- conformity of the basic components of the contents to structure of culture of the person;
- socialization;
- practical importance;
- optimum combination of an educational material of regional and global character;

- conformity and necessary sufficiency etc.

According A.Toldsepp (2003) the ideal paradigm of science education today is the teaching balanced science according to balanced curricula and syllabi in strongly social context based on psychological and didactical treatment. There should be balance between:

- governmental and non-governmental education;
- formal and informal education;
- subject oriented and student oriented teaching;
- algorithmic and non-algorithmic activities;
- objectivity and attractivity.

Also we can notice three main other principles for designing of curricula:

- process orientation;
- holistic approach;
- learner centredness.

Experience and research have shown that success in curriculum innovation depends upon the active involvement of teachers in curriculum development. The curriculum of natural science should reflect not only the integration of content, but the process should be seen as well. Integrated courses of natural sciences should agree with systematic courses, and all presented information should be bound together by sensible meaning. The efficiency of the integrated learning is directly dependant on the activities of students. Integrated courses should be well supported by a set of teaching /learning aids such as textbooks, workbooks, visual/ demonstration aids, teacher's books, etc. (Lamanauskas, 2003). Integration also presupposes the increase of the abstract. The younger are the students, the less is their knowledge. Consequently, the degree of integration should be limited in this respect. The integration of content should be combined with differentiation and individualization of teaching, because every child has his / her own ways or models for learning.

In general, all of the definitions of integrated curriculum or interdisciplinary curriculum include (Lake, 1994):

- a combination of subjects;
- an emphasis on projects;
- sources that go beyond textbooks;

- relationships among concepts;
- thematic units as organizing principles;
- flexible schedules;
- flexible student groupings.

Future science curricula should recognize the interaction of science, technology, and society and should give students the skills for learning and applying scientific knowledge, an awareness of ethics and values in science, and a future perspective (Robinson, 1982). Science curricula have been criticized for ignoring the relevance of science to the health, wealth, happiness, security and curiosity of humanity and neglecting all accounts of the numerous ways in which science based technologies contribute to society (Sjøberg, 2000). It is important to state that:

- although the educational curricula are the basis of integration, they cannot cover the whole education. Moreover, natural sciences are rather complex and the integration of a few stages (levels) only is possible. Thus, scrupulous attention should be paid to the textbooks in the field. A qualitatively prepared and experimentally based textbook improve the schoolchild's knowledge, develop his/her intelligence. Finally, teaching is one of the main conditions that determine the quality of learners' knowledge;

- the teacher is a central figure of the educational process. The quality of natural science background acquired by pupils depends on his/her competence;

- teachers' thinking has to fundamentally change and develop. Learning should predominate over teaching. The process of sciences teaching-learning should be more holistically oriented and directed towards synthesis. The research of natural science education system requires the holistic approach. It is of a complex character and demands an experimental basis (from practice to theory). Training the whole child's personality is a contemporary educational issue. The solution mainly depends on the educational process in which the usage of the pupil's experience in imparting knowledge about the world plays an important role. Classified knowledge that helps to perceive the correlation between nature and society becomes the means linking personality and environment, helping to acknowledge reality (changing methods) as well as the basis of the learner's individual social singleness. The creation of the knowledge system depends on the following crucial points such as the level of information perception, thinking method, the development of a schoolchild's cognitive activity and individuality, a value-based system of the student and at last curiosity which is a driving force of his/her cognition, thinking and behaviour.

Some types of curriculum can be mentioned:

The curriculum of the constructive (based on a particular subject teaching) system. A strict interpretation of the subjects is characteristic of the curriculum. All subjects are taught individually, the content of teaching and the methods of activities are absent. The curriculum has its own advantages and disadvantages. The top qualities of the curriculum should be as follows:

- a constructive approach to teaching is admissible to pupils' parents;
- the curriculum is rather convenient if managed; teachers accept it more willingly than integrated teaching;
- individual scientific subjects impart specific knowledge and abilities to schoolchildren. Bright pupils that have high motivation in terms of natural sciences gratefully acquire it;
- learners' knowledge is more thorough as professional teachers work and face a higher quality, outstanding schoolchildren's achievements;

The major drawbacks of the curriculum:

- a pupil's workday is broken into many fragments (for example, 7-8 classes) that usually do not correlate (or weakly correlate);
- teachers' time planning and learners' demands disagree;
- the content of training does not reflect reality outside school as it is full of facts, most frequently uninteresting for children and hardly understandable.

The curriculum of parallel (adjacent) teaching of subjects. The exposition of the classes of an individual subject (for example, biology) correlates with other classes of the subjects of the same field (for example, chemistry, physics, geography). Moreover, teaching order changes. However, the content itself practically remains the same. The curricula of natural sciences do not artificially correlate. The main advantages of the curriculum should be:

- teachers need to change the time of the presentation of curricula rather than the curricula themselves;
- partial reconstructions are not complex, and therefore often acceptable to teachers;
- this is the way to implement the internal integration of content.

The main disadvantages are supposed to be:

- subjects correlate in passing;
- the presented concepts of phenomena are separated, do not correlate notionally, etc. (for example, “Photosynthesis”, “Breathing”, “Combustion”, etc.);
- schoolchildren themselves have to establish the correlation between a reason and a result among unlike phenomena and cognitive fields.

The curriculum of supplementary (parallel) subjects. A characteristic feature of the curriculum is that relative natural sciences are combined into a single class or even an individual module (course). The degree of integration increases. On the other hand, the subjects of a different format correlate as much as they can explain or supplement each other. Lithuanian comprehensive secondary school applies such modules under the circumstances of profile teaching.

The following advantages can be accentuated:

- the material of the curricula can be easily linked;
- the course of such a format is understood by the participants of the educational process with no effort;
- the administration of the planning process itself is simple, pupils are given opportunities of choice.

The obvious disadvantages are:

- learners are made to reconsider a traditional approach to their knowledge and studies;
- the school syllabus of the educational process is changed, the methods of payment alter, the control of the educational process becomes more complex, etc.
- in general, the approaches to the introduction of the supplementary subjects vary. The supporters of extracurricular activities state that this kind of activities cannot be devoted to scientific education.

Interdisciplinary curricula. All teaching subjects (including those of natural sciences) correlate in the school syllabus. Classes and other occupations take place a certain amount of time, i.e. periods (some days, weeks, etc.). Clear advantages are as follows:

- versatile pupils’ epistemological experience is encouraged;

- natural science courses are better scheduled;
- a timetable of classes alterates according to the opportunities and situation of a school;
- perfect conditions to apply other forms of teaching, for example, designed teaching (projects are launched and carried out) are imposed. For instance, such curricula are extremely effective when preparing long-term projects.

Serious drawbacks are as follows:

- such an activity requires many efforts and changes, high teachers' competence;
- schoolchildren's parents often hardly accept that a curriculum of interdisciplinary education is valuable. They frequently want to see a result "here and now";
- the curriculum requires much time and endeavour to work with a school community. School executive must be able to effectively organize, administer the educational process and to constantly encourage teachers to such activities.

The curriculum of the integrated day. In the light of integrated education, this curriculum is really valuable. The majority of the followers of the latest movement (Stainer, Frene, etc.) have successfully applied it. A key point is that the organic approach to a class life is emphasized. The issues and interests of the child are the focus of the educational process the main advantages of which are:

- the day of an integrated activity is natural;
- learners' concernment is quite high;
- time planning and pupils' needs are in chime.

The main drawbacks are:

- teachers have to work a lot, they have to be experienced professionals and possess the skills of cooperation;
- a class activity and work in groups are complex to be administered (when a few forms or students' groups participate in the process in particular);
- frequent deviations from the didactic attitudes and educational objectives of the main curriculum in general.

A completely integrated curriculum. This is an extreme form of interdisciplinary work. Schoolchildren's life is completely coincident with school life. Work is very complex if followed this curriculum. A traditional (classic) school can hardly accept it. Nevertheless, the main advantages are:

- the curriculum is properly integrated;
- to reveal pupils' self-sufficiency excellent conditions are set out;
- the main idea of the educational process is a schoolchild's life at school or in other educational institution.

The major disadvantages are:

- the curriculum requires close cooperation and reciprocal understanding between children's parents and school;
- qualitative mastering of the whole educational curriculum is hardly ensured;
- this is a boarding school that suits to a certain group of schoolchildren.

Fogarty has described ten levels of curricula integration (1991).

Different researches shows the positive effects of curriculum integration. Lipson (1993) summarizes the following findings:

- integrated curriculum helps students apply skills;
- an integrated knowledge base leads to faster retrieval of information;
- multiple perspectives lead to a more integrated knowledge base;
- integrated curriculum encourages depth and breadth in learning;
- integrated curriculum promotes positive attitudes in students;
- integrated curriculum provides for more quality time for curriculum exploration.

School science curriculum reform is a global phenomenon, with change in the form and/or content of science courses often being allied to the specification of standards, goals or levels of attainment that students should achieve at particular stages of their schooling (Jenkins, 2000).

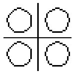
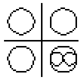
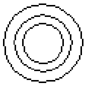
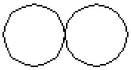
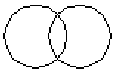
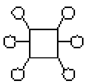
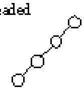
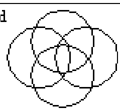
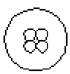
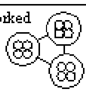
Name	Description	Advantages	Disadvantages
Fragmented 	Separate and distinct disciplines	Clear and discrete view of a discipline	Connections are not made clear for students; less transfer of learning
Connected 	Topics within a discipline are connected	Key concepts are connected, leading to the review, reconcept-ualization and assimilation of ideas within a discipline	Disciplines are not related; content focus remains within the discipline
Nested 	Social, thinking, and content skills are targeted within a subject area	Gives attention to several areas at once, leading to enriched and enhanced learning	Students may be confused and lose sight of the main concepts of the activity or lesson
Sequenced 	Similar ideas are taught in concert, although subjects are separate	Facilitates transfer of learning across content areas	Requires ongoing collaboration and flexibility, as teachers have less autonomy in sequencing curricula
Shared 	Team planning and/or teaching that involves two disciplines focuses on shared concepts, skills or attitudes	Shared instructional experiences; with two teachers on a team it is less difficult to collaborate	Requires time, flexibility, commitment and compromise
Webbed 	Thematic teaching, using a theme as a base for instruction in many disciplines	Motivating for students, helps students see connections between ideas	Theme must be carefully and thoughtfully selected to be meaningful, with relevant and rigorous content
Threaded 	Thinking skills, social skills, multiple intelligences, and study skills are "threaded" throughout the disciplines	Students learn how they are learning, facilitating future transfer of learning	Disciplines remain separate
Integrated 	Priorities that overlap multiple disciplines are examined for common skills, concepts, and attitudes.	Encourages students to see interconnectedness and interrelationships among disciplines, students are motivated as they see these connections	Requires interdepart-mental teams with common planning and teaching time
Immersed 	Learner integrates by viewing all learning through the perspective of one area of interest	Integration takes place within the learner	May narrow the focus of the learner
Networked 	Learner directs the integration process through selection of a network of experts and resources	Pro-active, with learner stimulated by new information, skills or concepts	Learner can be spread too thin, efforts become ineffective

Figure 5. Ten levels of curricula integration (Fogarty, 1991)

Tasks (assignments)

1. Motivate the statement that an assessment of science content clearly shows it has integral and systemic nature.

2. One of the components of the content of science education is creating optimal conditions for learning sciences. Refer to the circumstances ensuring the possibility of successful implementation of science education curriculum?

3. Define and compare the concepts '*content*' and '*curricula*'. Fill in the table to reach sufficient clarity:

The basic principles of science education	**The basic principles of science education curriculum**

4. Identify and describe the already known types of science education curricula and put them in sequence starting from the lowest level (1) to completed integrity (6):

Curriculum title	**Curriculum specificities**
1.	
2.	
3.	
4.	
5.	
6.	

5. What are the possible reasons for science curriculum reformations in many countries in Europe at secondary level?

Case study

A week of integrated education *Forest* is organized at school X. When integrating natural sciences with other educational subjects, knowledge of sciences is introduced and educational content is related to the questions considering school environment and students' living place, customs and traditions. The learners are encouraged to show their interest in surroundings, a wish for inquisitiveness is stimulated and a positive children's attitude towards nature and science education is adopted. Following a weekly plan of integrated education prepared by teacher A, the first day of the week involves the classes on the mother tongue, world study and music and discusses the topics dealing with the national lifestyle, forest birds, voices of birds, spelling of future tense verbs and folk songs about birds (listening and singing). The second day of the week includes the classes on the mother tongue, world study, music and a trip to the forest. The learners have to analyse an extract from a literature piece about forest, to get acquainted with the book *Forest Fairy-tales* by a national writer, to describe forest, to observe forest changes in spring, to collect material about nature and to prepare for coming creative work. The activities of the following week days are arranged in a similar way. Such arrangement of work at school evidently helps with acquiring a new knowledge as well as assists in broadening world outlook and forming acceptable behaviour in nature. Applying this educational form works for close relations between students' cognitive and practical activities.

Questions to Case Study

1. Establish the form of the currently designed curriculum and reason your position.

2. What are the difficulties a teacher can face when implementing the above introduced curriculum?

Summary

Training (educational) content is defined by the curricula. They can vary and perform different functions. The science curriculum need to be based on such important didactic principles as humanism, democracy, spiral, integration. Worldwide experience of science education is long and diverse. Detailed implementation of the ideas started only in the second half of the 20th century. School science curriculum reform is a global phenomenon, with change in the form and/or content of science courses often being allied to the specification of standards, goals or levels of attainment that students should achieve at particular stages of their schooling (Jenkins, 2000). Science education curricula can differ in format and purpose. They are distributed into the science education curricula of a particular country and specific integrated educational curricula of sciences. The curricula devoted to natural science development in a particular country differ from the specific curricula dedicated to teach integrated natural sciences. The assessment of science curricula of various countries reveals an essential consistent pattern – the majority of them are much the same. Therefore, the debate on these curricula discloses that they are not suitable for all sociums and ethnic-cultural regions and certainly for educational situations.

Frequently Asked Questions

Why it is necessary to improve science education curricula?

The modern curriculum must focus on various activities which enable students to get to know more about their environment. The new curricula should be interesting for students. The main point of integrated science curricula is that natural science is now studied as a whole.

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European Dimension in Science Education

Executive Editor prof. RNDr. Tomáš Opatrný, Dr.
Responsible Editor Mgr. Lucie Loutocká
Layout doc. RNDr. Oldřich Lepil, CSc.
Cover Design Jan Svoboda

Published and printed by Palacký University, Olomouc
Křížkovského 8, 771 47 Olomouc
http://www.upol.cz/vup
E-mail: vup@upol.cz

Olomouc 2010

ISBN 978-80-244-2488-0