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EDITORIAL

M. Fatih Taşar, Associate Editor
Gazi Üniversitesi, Ankara, TURKEY

Dear readers and contributors of EURASIA,

In this issue we have eight articles again from different parts of the world. As the editorial team we are very happy to serve our larger community in this way and glad to see that the journal is getting a wide spread readership from around the world. In fact the figures also support this claim. The journal web site is receiving over 15,000 hits per month and article files are being downloaded thousands of times. The number of downloads for individual articles on the average exceeds several hundreds. For our authors that means a wide dissemination of their scholarly works which is indeed the aim of journal publishing.

Achieving these results in a relatively short time period has only been possible with the continued support of our authors, readers, and the last but not the least our editorial board members. We thank them all and would like to share our pride. Thank you for being there and for the wonderful job you all have been doing!

We have several ideas to improve the journal in the coming issues. First of all, we will open a new section titled **Interview/Conversation** starting with the next issue. This section will include scholarly talks with the eminent professors who have contributed immensely to the field in the past. The talk does not necessarily have to be only in a structured interview style. The interviewer can and should contribute to the topic by discussing issues with the interviewee. The interviewer is also expected to widen the readers' understanding by referring to relevant literature and clearing up the meaning of cited events, concepts, terms, issues, and the like. This section, thus, will include a discussion and the transcription of the interview/conversation together with its audio recording and if desired pictures of the individuals involved. We hope that such a format will allow us to better take the advantage of the online publishing.

The first of this kind of publication will include an interview/conversation with Professor Norman G. Lederman. For future interview/conversation proposals to be published in EURASIA please directly consult myself first.

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Science Education for the Twenty First Century*

Jonathan Osborne
King's College London, London, UK

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This paper argues that the dominant form of science education that is common across the world rests on a set of values that have no merit. Moreover, such practice has a negative impact on students' attitudes to science. It makes the case that the primary goal of any science education should be to develop scientific literacy and explores what that might consist of and why such an education is necessary in contemporary society. It concludes by examining some of the challenges that such a change might require.

Keywords: Science Education, Aims and Purposes, Educational Norms, Fallacies

INTRODUCTION

Any talk of this nature obviously holds out a promise of a vision of a science education for the future – one that meets the needs and goals of contemporary society. Knowing where you want to go is, I would argue, dependent not only on a vision of where you are now, but how you got there in the first place – that is what are the values and norms embedded in current practice. It is, after all, well worth remembering the Santayana's cautionary remark that 'those who forget the lessons of history are condemned to repeat the mistakes of the past'.

As currently practised, science education rests on a set of arcane cultural norms. These are 'values that emanate from practice and become sanctified with time. The more they recede into the background, the more taken for granted they become' (Willard, 1985)). The most fundamental of these is the tension that exists between *training* (and the choice of this word is quite deliberate) the future scientist and *educating* the future scientist. The former will become the producer of scientific knowledge whilst the latter will remain a critical consumer of scientific knowledge. The problem for science education is that there exists an uneasy tension between these two aspirations – that is between the needs of the minority who will continue the study of science and the needs of the majority who will not. The needs of the future scientist are met by an education which is essentially foundationalist – that is one which attempts to educate the neophyte student in all the basic concepts of the discipline. This is necessary because entering into the practice of science requires a long apprenticeship in which the conceptual foundations of the domain are acquired. For, as scientific knowledge is cumulative each generation builds on the discoveries of its forebears requiring each generation to learn more and more. The consequence is two fold: First, as Cohen (1952) has argued, is that 'all too many science courses have attempted to make students memorise a series of dry facts which no practising scientist readily memorizes such as the density of various substances, the atomic weight of different chemical elements, conversion factors from one system of units to another, the distance in light years from the Earth to various stars (and so on).' Second, because time is finite, and only a certain amount of knowledge can be acquired in a given time, science degrees become ever more specialist. Degrees in botany or zoology which provided a broad overview of major aspects of the life sciences have been replaced by degrees in genetics, molecular biology and immunology which have a narrow specialist focus. The consequence is that many scientists have a specialist education making them very proficient within their

* This paper is the basis of the author's keynote speech given in September 2006 at the 7th National Science & Mathematics Education Conference in Ankara, Turkey.

Correspondence to: Jonathan Osborne, Professor
King's College London
Strand, London
WC2R 2LS, UK
E-mail: jonathan.osborne@kcl.ac.uk

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specialist domain but with no broad education about science.

The fundamental flaw with this approach to teaching science is that, whilst the unity and salience of such information is apparent to those who hold an overview of the domain, its significance is simply incomprehensible to the young student. Only for those who finally enter the inner sanctum of the world of the practising scientist will any sense of coherence become apparent. As a consequence only those that ever reach the end get to comprehend the wonder and beauty of the edifice that has been constructed. Or, as has been argued elsewhere:

> To borrow an architectural metaphor, it is impossible to see the whole building if we focus too closely on the individual bricks. Yet, without a change of focus, it is impossible to see whether you are looking at St Paul's Cathedral or a pile of bricks, or to appreciate what it is that makes St Paul's one of the world's great churches. In the same way, an over concentration on the detailed content of science may prevent students appreciating why Dalton's ideas about atoms, or Darwin's ideas about natural selection, are among the most powerful and significant pieces of knowledge we possess. (R. Millar & Osborne, 1998, p. 13)

In contrast to the needs of the next generation of scientists, the needs of the future citizen are different. Such individuals require more than a knowledge of the basic concepts of science but also a vision of *how* such knowledge relates to other events, *why* it is important, and *how* this particular view of the world came to be. Any science education, therefore, which focuses predominantly on the intellectual products of our scientific labour – the 'facts' of science – simply fails to offer what is required.

The phrase that is commonly used to embody this vision of science education is that we should provide an education for 'scientific literacy' – a view that Robin Millar and I articulated in the report 'Beyond 2000: Science Education for the Future' (Millar & Osborne, 1998) when we argued that:

> the primary and explicit aim of the 5-16 science curriculum should be to provide a course which can enhance 'scientific literacy', as this is necessary for all young people growing up in our society, whatever their career aspirations or aptitudes.

As many have pointed out, however, the term 'scientific literacy' has a diverse range of meanings and there is a lack of an explicit and consensually agreed articulation. My task here is to argue that through the work I and others have conducted over the past 10 years, there is an emerging consensus of both what we mean and why such an education matters.

However, before I expand on what is currently understood by education for scientific literacy, I need to convince you that the science education as practised is not appropriate for the needs of contemporary youth. The argument here is that this failure is caused by a set of seven unquestioned norms of practice or values, all of which when examined are found wanting – a set of fallacies on which contemporary practice rests. These are:

1. The foundational fallacy
2. The fallacy of coverage
3. The fallacy of a detached or value free science
4. The fallacy that science education promotes critical thinking
5. The fallacy that there is one scientific method
6. The fallacy that scientific knowledge is useful
7. The fallacy that all children should have the same science education (the homogenous fallacy)

1. The foundational fallacy

This is the fallacy that because scientific knowledge itself is difficult and hard won, learning and understanding science requires a similar process where the student's knowledge and understanding are assembled brick by brick, or fact by fact. As a consequence only those that reach the end ever get to comprehend the wonder and beauty of the edifice that has been constructed. Current practice, therefore, is rather like introducing a young child to jigsaws by giving her or him bits of a one thousand piece puzzle and hoping that they have enough to get the whole picture, rather than providing the simplified 100 piece version. In effect, although the pupils can see the microscopic detail, the sense of the whole, its relevance and its value – the things that matter to the pupil (Rowe, 1983) are lost. Chown (1998) provides a good example of a tale which the foundationalist approach offers only to undergraduates or postgraduates taking courses in stellar nucleosynthesis-the grand ideas of science which are reserved only for those who complete the course.

> But if all these examples of our cosmic connectedness fail to impress you, hold up your hand. You are looking at stardust made flesh. The iron in your blood, the calcium in your bones, the oxygen that fills your lungs each time you take a breath - all were baked in the fiery ovens deep within stars and blown into space when those stars grew old and perished. Every one of us was, quite literally, made in heaven. (Chown, 1998, p. 62)

Yet there is nothing about such a story which is intrinsically difficult. The failure to communicate such ideas in compulsory science education simply reinforces Claude Bernard's, the famous 19th century philosopher, view that science is a 'superb and dazzling hall, but one which may be reached only by passing through a long and ghastly kitchen.'

2. The fallacy of coverage

School science is suffering from a delusion that the science we offer must be both broad and balanced. The result is an attempt to offer a smattering of all sciences and to cram more and more into an oft-diminishing pot. Quite clearly, as the bounds of scientific knowledge expand from evolutionary biology to modern cosmology, more and more knowledge vies for a place on the curriculum. However, just as those teaching literature would never dream of attempting to cover the whole body of extant literature, choosing rather a range of examples to illustrate the different ways in which good literature can be produced, has the time not come to recognise that it is our responsibility to select a few of the major *explanatory* stories that the sciences offer? And surely it is the *quality of* the experience, rather than the quantity, which is the determining measure of a good science education?

3. The fallacy of a detached science

Science education persists with presenting an idealized view of science as objective, detached and value free. This is wrong on three counts. First the public, and particularly young people, do not distinguish between science and technology. Second, science is a socially-situated product and the language and metaphors it draws on are rooted in the culture and lives of the scientists who produce new knowledge. Thirdly, those that engage in science are not the dispassionate, sceptical and disinterested community that Merton (1973) portrays. Science is a social practice, engaged in by individuals who share a 'matrix of disciplinary commitments, values and research exemplars' (Delia, 1977). Within the contemporary context, where scientists are employed by industrial companies with vested interests, it is hard to advance a case that science is simply the *pursuit of truth* untainted by professional aspirations or ideological commitments. For these days scientists are judged as much by the company they keep as the data they may gather (Durant, 1999).

Finally, the separate portrayal of science from technology (in curricula and teaching) eliminates all considerations of the societal implications for society and individuals. For, as Ziman (1994) argues, if science education fails to make the small step from science to its technological applications, how can it take the much larger step to the implications for the society in which it is embedded?

4. The fallacy of critical thinking

This is an assumption that the study of science teaches students reflective, critical thinking or logical analysis which may then be applied by them to other subjects of study. It is based on the fallacious assumption that mere contact with science will imbue a sense of critical rationality by some unseen process of osmosis. It is also an assumption questioned by the Wason 4 card problem and the Wason 2, 4, 6 problem (Wason & Johnson-Laird, 1972) both of which require a standard scientific strategy of falsification to determine the correct answer and, which very few, including scientists, use.

Secondly, the notion that science develops generalizable, transferable skills is also an assumption questioned by the body of research which suggests that people's use of knowledge and reasoning is situated within a context (Brown, Collins, & Duiguid, 1989; Carraher, Carraher, & Schliemann, 1985; Lave, 1988) and that detached knowledge is of little use to individuals until it has been reworked into a form which is understood by the user. This is not to say that there are no general intellectual skills. Rather, that such skills need a knowledge base for individuals to demonstrate their capability – a knowledge base which must be acquired in a given context.

5. The fallacy of the scientific method

This is the myth that there exists a singular scientific method whereas the record of those who have made the important discoveries of the past shows not only that scientists rarely attempt any such logical procedure, but that the methods vary considerably between the sciences. The methods deployed by the palaeontologist working out in the field are about as similar to those used by the theoretical physicist as chalk and cheese. Yet the science that increasingly confronts the individual in the media, with its focus on environmental or biological issues, is predominantly based on correlational evidence and uses methodological devices such as clinical trials with blind and double-blind controls. Yet where, and when, is there any treatment of the strengths and limitations of such evidence (Bencze, 1996)? Is it not time to give up any notion that there is such a singular entity and turn instead to presenting a range of ideas about science and its working? Moreover, when so much of the science reported in the media is based on epidemiological research and associative findings – probability and likelihood rather than causal relationships and certainty – is it lot time to teach about such data, its interpretation and evaluation?

6. The fallacy of utility

This is the myth that scientific knowledge has personal utility – that it is essential to the mastery of the technology; to remedy its defects; and to live at ease in the culture of technology that surrounds us. Yet as machines become more intelligent they require less care and thought for their effective use. Even the economic value of scientific knowledge is questionable as current employment trends, at least in the UK and USA, suggest that, although we will need to sustain the present supply of scientists, there is no indication that there is any need to significantly improve the number going into science, which remains, as ever, a small minority of the school cohort of around 10- 15% (Coles, 1998; Shamos, 1995).

7. The homogeneous fallacy

Increasingly, in many countries, science education labours under the fallacy that its clientele are an entity who, whilst they might differ in aptitude and ability, nevertheless are best served by one homogeneous curriculum. With its emphasis on pure science – and then predominantly the exact sciences, a foundationalist approach, and a high-stakes assessment system, the result is too often a pedagogy based on transmission (Hacker & Rowe, 1997; Lyons, 2006). By the onset of adolescence, the imperative of relevance increasingly challenges the delayed gratification on which such a curriculum rests leading to a lack of motivation and interest (Osborne & Collins, 2001). Pupils, therefore, need to be offered a diversity of science courses to meet their disparate needs.

The effect on student attitudes

That this form of education singularly fails to engage contemporary youth in advanced societies is apparent from a growing body of research. For instance, the ROSE project (Sjøbeg & Schreiner, 2005) has surveyed students' attitudes to school science across more than 40 countries. In all developed countries, school science was found to be less popular than other school subjects (Figure 1). Indeed the effect is so pronounced that there is a 0.92 negative correlation between student's response to this question and the UN index of human development which measures factors such as GDP/capita, literacy rates and mortality statistics.

In a study undertaken with 20 focus groups in England with school students age 16 (Osborne & Collins, 2001), the negative features of such a curriculum were found to be that it was reliant on a default pedagogy of transmission consisting of too much repetition, copying notes from the board and a lack of space for students to engage personally or discursively with the subject. Students felt as if they were being force marched across the scientific landscape with no time to stand and stare.

Scientific Literacy – the goal of science education?

Bybee (1997), DeBoer (2000) and Laugksch (2000) provide brief reviews of the historical use and meanings of the term 'scientific literacy' in science curriculum writings, drawing on sources from several countries. Its first use is generally attributed to Hurd (1958), in the context of proposing goals for science education in the post-Sputnik era. At its simplest level, 'scientific literacy' is a shorthand for 'what the general public ought to know about science' (Durant, 1993, p. 129). As Bybee (1997) puts it:

> The phrase 'scientific literacy for all learners' expresses the major goal of science education – to attain society's aspirations and advance individual development within the context of science and technology. (p. 69)

DeBoer in an extensive review of the use of the term suggests that there are 9 different meanings of the term. The consequence is that the distinction between the term and science education itself becomes blurred – the two effectively becoming synonymous and little more than a rallying cry behind which those who advance the case for reform, such as myself, can unite.

However, this is not a position that I wish to espouse. Rather, Norris and Phillips (2003) in a careful analysis of the term develop a powerful argument that 'scientific literacy' must be grounded in the fundamental sense of literacy as the ability to analyse and interpret text. Science, they argue, could not exist as an oral

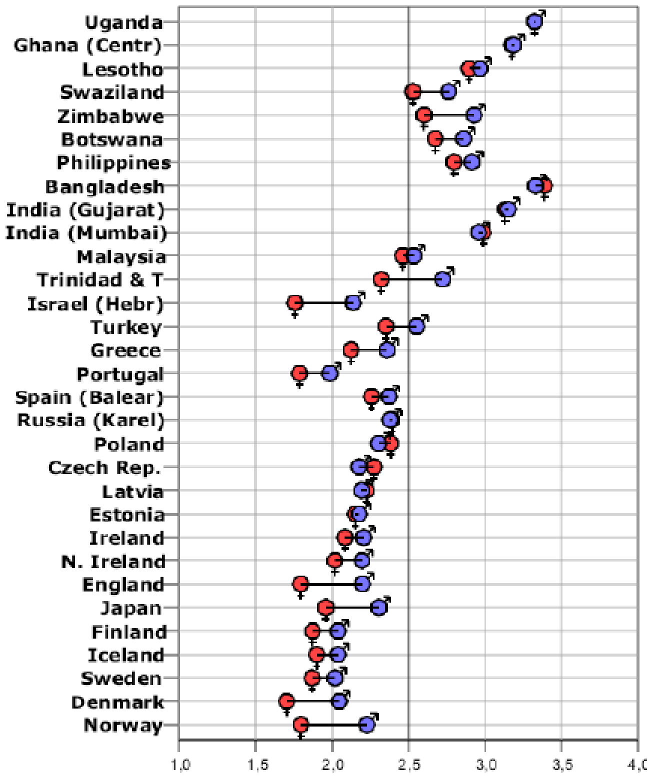

Figure 1. Student responses to the question 'I like school science more than other school subjects' on a scale of 1 (negative) to 4 (positive) (red – girls; blue-boys) (Sjoberg, 2005).

tradition; texts are essential, not optional. They are a constitutive feature of science – just as empirical data collection is. An understanding of science therefore requires the ability to read texts, and hence, literacy is at the core of scientific literacy. Together we have advanced a view of science education which sees the role of interpretation and argumentation in scientific inquiry as central (S. Norris, Phillips, & Osborne, 2006 (in press)). Interpretation is concerned with questions of meaning and explanation. Argumentation is concerned with justifications of what to conclude and what to do.

To interpret and critically evaluate writing in science and writing about science – in short to become a critical consumer of scientific knowledge, science education requires a triumvirate of a knowledge and understanding of:

a. the scientific content
b. the scientific approach to enquiry
c. science as a social enterprise – that is the social practices of the community

Such an understanding is also needed because it is science which will pose the political and moral dilemmas of the twenty first century (Financial Times Editorial, 1999; Independent Editorial, 1999). The issue of what to do about global warming, whether stem cell research should be permitted, or how we restrict the spread of viruses such as avian flu are just some examples of the contemporary dilemmas confronting our societies. Resolving these requires both a knowledgeable and a critical disposition to engage in public debate of the applications and implications of scientific advances. Without such critical engagement, public distrust of scientific expertise is in danger of placing unwarranted restrictions on future research and technological development. Fear of the worst is leading the public to demand a naïve application of the precautionary principle to scientific research potentially limiting the advancements that science may offer for solving the plethora of problems that face contemporary society.

For our future citizens, their science education should enable them to live and act with reasonable comfort and confidence in a society that is deeply influenced and shaped by the artefacts, ideas and values of science – rather than feeling excluded from a whole area of discourse, and, as a corollary marginalised. This viewpoint is most clearly expressed in the European Commission *White Paper on Education and Training* (European Commission, 1995) which argues that:

> Democracy functions by majority decision on major issues which, because of their complexity, require an increasing amount of background knowledge. … At the moment, decisions in this area are all too often based on subjective and emotional criteria, the majority lacking the general knowledge to make an informed choice. Clearly this does not mean turning everyone into a scientific expert, but enabling them to fulfil an enlightened role in making choices which affect their environment and to understand in broad terms the social implications of debates between experts. There is similarly a need to make everyone capable of making considered decisions as consumers. (pp. 11-12)

In addition, there for those of us who are committed to the notion of a liberal education as an experience that should offer access to the 'best that is worth knowing', there is a powerful argument that science represents one of the major cultural achievements of contemporary society (Cossons, 1993). Such an education would offer insights to the knowledge, practices and processes of science. In essence a science education that pursues *depth rather than breadth*, *coherence rather than fragmentation,* and *insight rather than mystification*. In such a curriculum, the study of the history of ideas and the evidence on which they are founded must lie at the core.

An Education for Scientific Literacy

Any education in science – whatever its primary goals consists of four elements: the conceptual which builds students understanding of the knowledge and ideas of science; the cognitive which attempts to develop students' ability to reason critically in a scientific manner; 'ideas-about-science' which is an attempt to develop students' understanding of both the epistemic – how we know what we know – and the processes, values and implications of scientific knowledge; and the social and affective which attempts to develop students ability to work collaboratively and to offer an engaging and stimulating experience. In a course which attempts to develop the notion of scientific literacy that I have elaborated, what might these elements address?

Conceptual

Science provides the best explanations of the material world that we have. It is those explanations that have rid us of myriad diseases such as smallpox, diptheria, tuberculosis, polio and others. The discovery of penicillin has saved at least a million lives in the UK alone and across the world an order of magnitude more. It is these explanations that have built the planes, trains and cars which permeate contemporary life and the information technology which sustains it. More importantly, it is this knowledge which will help us meet the challenges posed by global warming, growing world population and environmental degradation. This is not to argue for any kind of scientism – but rather to make the case that the knowledge generated by science is one of the major cultural achievements of Western societies in the past 400 years and its impact on our daily lives has been profound. As such it is a major foundation of our societies, and therefore, it is an essential aspect of any education that seeks to pass on its cultural heritage to the next generation. This view is essentially akin to that which, at least in English speaking countries, requires some knowledge and understanding of Shakespeare to be offered to all students because the metaphors and language of Shakespeare so permeate our common culture that those who lack knowledge of them are culturally deprived unable to participate fully in the discourse of daily life.

But accepting the argument that some conceptual knowledge of science raises another question – a question which so far has had only one answer. This is exactly what kind of conceptual knowledge is appropriate for today's world? This question must be asked and answered for several reasons.

First, scientific knowledge would appear to follow some form of Moore's Law. Moore was the man who predicted in 1965 that there would be a doubling in the density of transistors on a silicon chip every 24 months. Likewise, scientific knowledge in the past 40 years has advanced apace. Whilst we might see the development of scientific knowledge as resting on a set of stepping stones consisting of the major scientific discoveries of the past 200 years, contemporary students see the significance of scientific knowledge as residing in the objects and ideas that surround them. Consequently, there is a growing gulf between the landscape of school science – science-as-it-is-taught and the features of contemporary science – science-as-it-is-practised. How then, can the content of school science present itself as the science of today rather than the science of yesteryear?

The problem is not that science does not have narratives to tell. It is that they are not told. The challenge for us all then, is how are those narratives to be told in a manner that provides the key message first and the detail second. For instance, that you look like your parents because every cell in your body carries a chemically coded message of how to reproduce yourself. That we live on a small planet orbiting a very ordinary star half way through its lifetime. Or that all matter in the Universe consists of just 92 elements. Moreover, these messages need to be situated in contemporary contexts – the science of air pollution, genetic modification and astrophysics.

Cognitive

Let me move to the second of my goals for the teaching of science. This is developing the ability to reason. Few would deny that this is important. Not only that but the form of reasoning developed by science lies at the heart of Western rationality. For at its core, scientific thinking is based on a commitment to evidence as the means of adjudicating competing knowledge claims. Thus when a major disaster such as the recent Tsunami occurs, we no longer ascribe such events to unfortunate acts of God but look for mechanistic explanations which are justified by scientific evidence.

Now reasoning in science uses particular forms of argument. Argumentation is a verbal, social, and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of one or more propositions to justify this standpoint (van Eemeren, Grootendorst, & Henkemans, 2002). Current research into the activities of scientists shows that argument is a central feature of the resolution of scientific controversies (Fuller, 1997; Taylor, 1996). Although the final reports that appear in journals and textbooks may typically portray science as purely analytical and logical, studies of science in the making (e.g., laboratory studies) demonstrate that much of science involves dialectical and rhetorical argumentation in writing, research, and the production of knowledge (Latour & Woolgar, 1986; Sutton, 1992). Scientists devote their energies to persuading others that what they have perceived is important and that their interpretations are valid (Cunningham & Helms, 1998).

Yet if argument is the predominant form of critical thinking in science, science education itself has paid it little attention. Although many have highlighted the importance of argument for providing opportunities to learn about science, not merely science content (Driver, Newton, & Osborne, 2000; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000), to make students' scientific thinking and reasoning more visible (Bell & Linn, 2000; Chinn & Anderson, 1998), and to support students in developing scientific thinking (Kuhn, 1992, 1993; Kuhn, Shaw, & Felton, 1997).

Arguments in science are dependent of particular forms of reasoning. They may be causal as in explaining why rainbows appear only when it is raining and the sun is shining; they may depend on notions of covariation as in explaining how force and acceleration are related; they may be correlational as in justifying why smoking is likely to cause lung cancer; or they may be probabilistic such as when justifying the likely outcome of a thousand throws of a dice or the result of crossbreeding two different coloured varieties of the same plant.

However, how do we develop the cognitive abilities of students to engage in these forms of critical thinking? The correlate of the argument that learning science means learning to talk science *is that* learning to reason scientifically means asking students to reason scientifically. In the case of empirical work, observation of science lessons in England indicated that much of the time spent on practical work is devoted to carrying out the practical procedures themselves (Newton, Driver, & Osborne, 1999). Some studies found that the fundamental concern of many students in the laboratory is just completion of the given task (Berry, Mulhall, Loughran, & Gunstone, 1999; Edmondson & Novak, 1993). In Korea, a survey of the features of practical work in physics in middle school science textbooks reported that only 3% of the practical work was intended to help students to learn how to use data to support a conclusion and only 9.5% on learning to communicate the results of their work (Kim, Kang, & Song, 2003). Indeed Watson et al (2004) found that there was virtually no argumentative discourse present in any of the work conducted in a set of science lessons whose discourse examined exhaustively.

Hence, if we want our students to develop the ability to think critically about scientific evidence, then we must offer them that opportunity. In particular we must break the tie so strongly embedded in the cultural habitus of teaching science that the primary task is to persuade students of the validity of the scientific world view – where experiments are performed simply to confirm the theoretical predictions elaborated by the teacher. Students need the opportunity to consider data which has no clear interpretation and to consider plural alternatives. Simply presenting scientific knowledge as a body of authoritative knowledge which is to be accepted and believed means that the contemporary science classroom has, ironically, is still firmly rooted in pre-Enlightenment times where:

> 'the grounds for accepting the models proposed by the scientist is often no different from the young African villager's ground for accepting the models propounded by one of his elders. In both cases the propounders are deferred to as the accredited agents of tradition. ... For all the apparent up-to-dateness of the content of his world-view, the modern Western layman is rarely more 'open' or scientific in his outlook than is the traditional African villager.' (Horton, 1971)

Ideas-About-Science

What is it about the manner in which scientific knowledge is produced that makes it reliable knowledge? How do we know what we know and why it should be valued? Understanding the epistemic aspect of science is an essential part of any comprehensive science education. That it is currently underemphasised comes from asking what at first place seems to be the simplest of questions 'How do we know that day and night are caused by a spinning Earth? This so-called trivial piece of knowledge is such a commonplace that it is included in primary school science curricula. The lack of response reveals the shallow foundations on which so much of our knowledge rests. Why, you might ask, should it be believed? After all, there are good arguments against.

- If the Earth was spinning, you should not land on the same spot.
- If it is spinning, once a day, the speed at the equator is over 1000 miles an hour which should fling most people rapidly into space.
- And, surely, at that speed, there should be the most enormous wind as the earth runs ahead of the atmosphere which drags behind.

The empirical evidence for our beliefs was first demonstrated by Foucault in 1851 in the Pantheon in Paris. Other evidence comes from long exposure photographs of the night sky showing all the stars appearing to rotate around the pole star. The scientific explanation stands because (a) it is impossible to refute such evidence and (b) we can justify why the arguments for a moving Sun are wrong. Scientific literacy depends as much on the ability to refute and recognise poor scientific arguments as much as it does on the ability to reproduce the correct scientific view. Argument is, therefore, a core feature of science and, as a corollary, should be a distinctive feature of any science education (Driver et al., 2000; Newton et al., 1999).

More fundamentally, there is a moral case for the epistemic basis of belief to be a significant feature of any science education (Norris, 1997):

> To ask of other human beings that they accept and memorize what the science teacher says, without any concern for the meaning and justification of what is said, is to treat those human beings with disrespect and is to show insufficient care for their welfare. It treats them with a disrespect, because students exist on a moral par with their teachers, and therefore have a right to expect from their teachers reasons for what the teachers wish them to believe. It shows insufficient care for the welfare of students, because possessing beliefs that one is unable to justify is poor currency when one needs beliefs that can reliably guide action.

Exploring the ways in which scientific knowledge is obtained, checked and refined raises other issues about other aspects of the nature of science that should be a feature of an education for scientific literacy. There is now an emerging consensus from both our work (Osborne, Ratcliffe, Collins, Millar, & Duschl, 2003) and others (McComas, 1998) that the following features should be essential elements of any compulsory school science education.

Scientific methods and Critical Testing;

The Creative nature of scientific work;

Historical development of Scientific Knowledge;

Science and Questioning;

Diversity of scientific thinking;

Analysis and Interpretation of data;

Science & Certainty;

Hypothesis and Prediction;

Cooperation and Collaboration.

Only through exploring such aspects will students be introduced to the idea that the scientific community is a highly moral community; that scientists report their findings through conferences and journals; that scientific findings are only accepted once they have been evaluated critically by other scientists; that explanations are not simply derived from the data; that two scientists may legitimately come to different conclusions from the same data or may be influenced by his or her interests; and that they are rarely immediately abandoned when confronted by anomalous data.

Moreover, secondary science must offer some opportunity to discuss and explore the meaning of the concepts that it is attempting to explain, and their social implications. Here again is a pupil articulating that view:

> Like this morning we were talking about genetic engineering and Miss told us about this article, about how they're going to make clones of each baby that gets born. They're going to make a clone of it – so say if it needs a transplant, kidney transplant or whatever he could get if from his clone. And she didn't want to hear that it is wrong. She didn't want to know our opinions and I don't reckon that the curriculum lets them – lets us discuss it further. I mean science- okay – you can accept the facts, but is it right, are we allowed to do this to human beings.

Exploring such issues also requires developing a better understanding of risk – that nothing is risk free and that new technologies or new medicines often have unknown risks associated with them. In addition that the mechanisms for assessing risks are too reliant on one feature of statistics – mortality rates rather than reflecting less minor injuries. And that individuals are often make poor judgements of risk, over assessing unfamiliar risks and under assessing familiar risks (Adams, 1995). The goal here is to make students aware that risk is an inherent feature of life and to improve students' ability to make better assessments of what risks are acceptable.

Social & Affective

However, all of this argument is of little value if it fails to address the social and affective component of science education. In short, how do we ensure that what we offer is intellectually engaging and appealing? Undoubtedly, science offers insights into the material world that generate a sense of awe and wonder. A sense of awe and wonder which is captured by the following quotation:

> We learnt all these amazing things in year 7 that we'd never heard of before, like molecules and atoms and electrons. I don't know about you guys but I got really excited about it, I rushed home and told my mum about it.

Contemporary science education must also recognise the theoretical and empirical evidence which see knowledge and understanding as something which is developed, at least in part, through dialogue. This perspective, rooted in the work of Bakhtin and Vygotsky, sees dialogic interaction as a means by which students can construct meaning not only from the interplay of new experiences with what they already know, but also from discursive interaction with their peers or teachers. Such dialogue, when appropriately scaffolded by their teachers, enables students to work in the zone of proximal development and internalise meanings which are developed and constructed interpersonally to form new understandings intra-personally (Vygotsky, 1962). Dialogic enquiry is central to learning as it demands the use of the epistemic processes – describing, explaining, predicting, arguing, critiquing, explicating and defining (Ohlssson, 1996) – all of which are central to science and all of which are features of dialogic interaction. A dialogic approach to pedagogy therefore seeks to develop a classroom environment which is *collective* in that teachers and children address learning tasks together; *reciprocal* in that teachers and children listen to each other and consider alternative viewpoints; *supportive* in that children articulate their ideas freely helping each other to reach common understandings; *cumulative* in that teachers and children build on their own and each others' ideas; and *purposeful* in that teachers plan and facilitate dialogic teaching with well-defined educational goals in view (Alexander, 2005).

The value of such an approach for students' affective response comes from research by Nolen (2003) who studied the relationship between 322 ninth grade school students' perception of the classroom environment and their motivation, learning strategies, and achievement. Her findings showed that 'students in science classrooms where teachers were perceived to endorse independent scientific thinking and to desire deep understanding of science concepts had higher achievement and greater satisfaction with their science learning.' Likewise the research of Osborne and Collins (2001) found that the lack of opportunity to explore and discuss ideas in science was one of the reasons that students cited for their disaffection with school science.

Toward Science Education for the Twenty First Century

Any teaching and learning situation is a product of three elements – curriculum, pedagogy and assessment. In the case of the curriculum, the major development within the UK is of a course aptly called *Twenty First Century Science* whose rationale and content has been fully articulated by Millar (2005). The basic principle of this course has been to break the knot that ties school education to serving the dual function of educating all students for citizenship and, simultaneously, educating the next generation of scientists. This has been achieved by designing a course which explicitly addresses science for citizenship in the belief that all students will benefit from a broad education about science. The course has two key components – a set of explanatory themes (the content of science) and a set of 'ideas-about-science' which are addressed through topics such as air pollution, food matters, you and your genes, Earth in the Universe and more.

Students can then choose to do additional academic science, a course in applied science or, alternatively, no more science whatsoever. Preliminary data that we have gathered for the evaluation of this course would suggest that it is perceived by teachers as being a more enjoyable course to teach, by students as significantly more relevant and topical, and has led to more students expressing the intention to sustain the study of science post 16. Nevertheless, the difference is not significant and it would be a mistake to think that a change in the curriculum will lead to a substantive change in the uptake of science. Especially when all the research points to the fact that it is teacher quality which is the biggest determinant of student engagement with science (Osborne, Simon, & Collins, 2003).

Changing the curriculum is one thing. Asking teachers to change their pedagogy to meet the demands of such a curriculum is another. The evaluation conducted of the innovative post-16 *Science for Public Understanding* Course (Osborne, Duschl, & Fairbrother, 2002) found that whilst the course was successful in sustaining and developing student enjoyment of, and interest in, science, teachers struggled to adapt their pedagogy. For too often

> teachers found it difficult to break free of the modes of interaction with students that are acquired by teaching standard science courses. Too many lessons were observed where explaining the science predominated to the detriment of exploring other aspects of science, in particular the ideas-about-science component and the underlying major science explanations.

For instance, the use of small group discussion was not a technique that was widely used. This quotation beneath, drawn from an interview with teachers of the course, illustrates the nature of the problem.

> **Teacher**: Um. Discussion in small groups, umm it's a fairly small group anyway. Yeh I have done that but tend not to.
>
> **Int**: Because?
>
> **Teacher**: It's … I don't know really. It's just that … the type of topics don't necessarily lend themselves to small group discussions. I mean I have done it once or twice. Whole class discussions I find better.
>
> (Male experienced biology teacher, girls' grammar school)

Likewise, in another project (Bartholomew, Osborne, & Ratcliffe, 2004) where we worked with a group of twelve teachers to explore how some of the ideas-about-science emerging from our Delphi study (Osborne et al., 2003) of what should be taught about science, similar difficulties were found. There was, however, an enormous diversity of practice. Hence, we began to ask ourselves what characterised these differences. From a repetitive reading of the data we came to the view that these could be characterised in terms of a set of 5 dimensions (Fig 2).

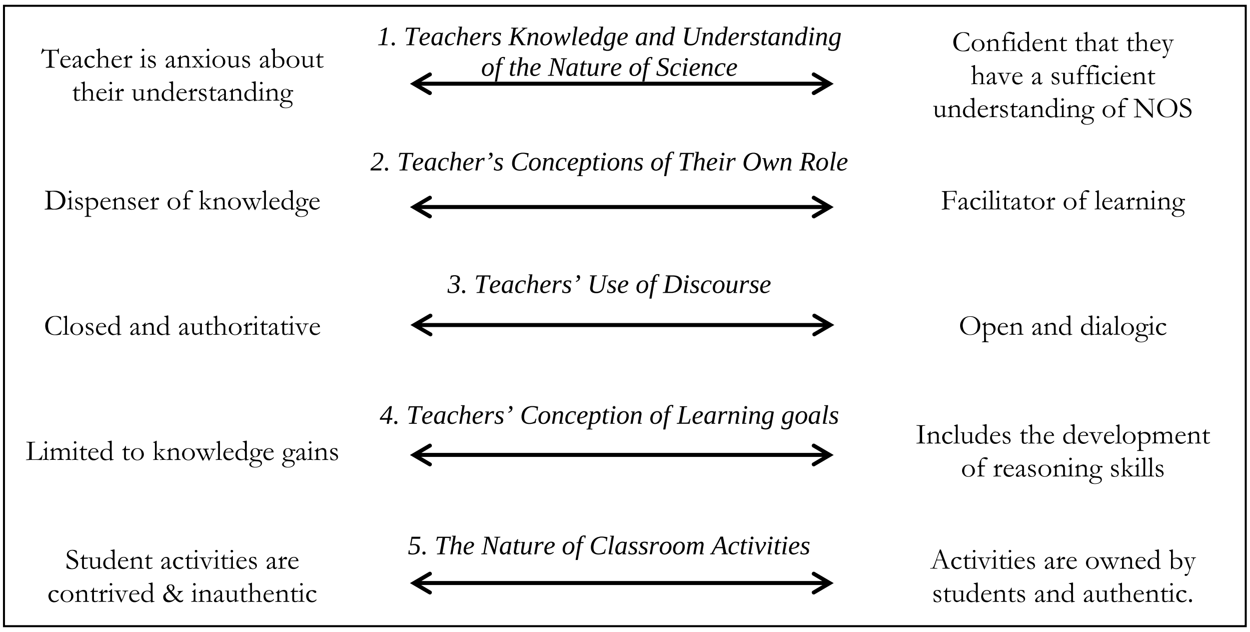

Figure 2. The 5 Dimensions of Practice that influence teachers' pedagogy when teaching about science.

Those teachers who appeared to us to be more successful at generating activities that opened up the discourse space for students to develop their knowledge and understanding of ideas about science lay to the right on this spectrum. Thus, it is not enough just to transform the curriculum; we must also transform teacher's pedagogy. The teaching of school science has become habituated to one where science is taught as dogma and not as a body of knowledge to be approached, discussed and evaluated.

Finally, we have to remember that there is a third component to transforming the teaching of science. Practice is a combination of the triumvirate of curriculum, pedagogy, *and* assessment. So far, the research community has displayed far less interest in this component than we have in the other two. However, in a context of increasing accountability, it is to assessment that teachers look for the intended curriculum, not the curriculum itself. There is some limited work that has been undertaken such as the Iowa Assessment Handbook (Enger & Yager, 1998) which is a compilation of items that assess the understanding of science in 6 domains – one of which is the nature of science. However, there is no statistical data to suggest that the reliability or the discrimination of these items have been tested. A small scale project to explore different ways of assessing 'ideas-about-science' was undertaken by Osborne and Ratcliffe (2002). The nature of this work was essentially exploratory and produced a range of items some of which were effective and some which were statistically less reliable. We see this work as the first step of a much larger project which needs to develop a range of generic frameworks for assessing student understanding of ideas-about-science. Some of this knowledge of effective means of assessment will emerge through the work that examiners undertake to develop items for the summative and terminal course examinations. The problem is simply that the science education community currently lacks the body of knowledge or 'know-how' to assess student understanding effectively and efficiently at a desirable level. The primary goal of this work is to develop schemes of assessment which have, at worst, a benign effect on the curriculum.

Only an approach that interrelates these three elements – curriculum, pedagogy and assessment – can ensure that students are offered a fundamentally different experience from that which currently predominates throughout the world. It is the need to recognise that these elements cannot be seen in isolation, that developing assessment items is not an afterthought, and that we must take a more holistic view of curriculum change to achieve a science education for the twenty first century. In the words of E. M. Forster – 'only connect, the prose and the passion, and both will be exalted, and human love will be seen at its height. Live in fragments no longer.'

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The Mathematics and Science Integration Argument: A Stand for Teacher Education

Joseph M. Furner and David D. Kumar
Florida Atlantic University, FL, USA

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This paper explores the question, should we integrate mathematics and science in reforming science education? As science, especially physical science involves mathematics, and both subjects involve process skills, integrating science and mathematics methods courses might be a way to improve science education. Considerations and recommendations for mathematics and science integration are addressed.

Keywords: Mathematics, Science, Integration, Teacher Preparation, Policy, Interdisciplinary, Standards, Technology

INTRODUCTION

The quality of education that teachers provide to student is highly dependent upon what teachers do in the classroom. Thus, in preparing the students of today to become successful individuals of tomorrow, science and mathematics teachers need to ensure that their teaching is effective. Teachers should have the knowledge of how students learn science and mathematics and how best to teach. Changing the way we teach and what we teach in science and mathematics is a continuing professional concern. Efforts should be taken now to direct the presentation of science and mathematics lessons away from the traditional methods to a more student centered approach.

In an era dominated by mathematics, science, and technology, it is essential that science and mathematics be taught in K-12 and that classroom teachers are equipped with the knowledge and skills to teach both science and mathematics meaningfully to students. However, in a test driven curriculum where students and teachers are evaluated on student performance based on reading and mathematics standardized test scores, teaching meaningful science remains a challenge.

Correspondence to: Joseph M. Furner,
Associate Professor of Mathematics Education
Florida Atlantic University, 5353 Parkside Drive,
EC 2021, Jupiter, FL 33458, USA
E-mail: jfurner@fau.edu

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A young person's ability and confidence to do mathematics and science is critical for their future success in our high-tech globally competitive age. In this context, this paper will explore integrating science with, not at the expense of mathematics in reforming science education.

According to the Report of the 2000 National Survey of Science and Mathematics (Weiss, Banilower, McMahon, and Smith, 2001), the condition of science and mathematics in pre-college education follows. At K-4, mathematics (95%) is taught more frequently than science (69%). About 67% of K-4, 42% 5-8 and 37% 9-12 teachers are "not at all familiar" with the National Science Education Standards, where as in mathematics about 38%, 27% and 15% of teachers in respective grade levels are not familiar with the National Council of Teachers of Mathematics Standards.

While 1% of mathematics teachers at the elementary level do not feel well qualified to teach mathematics, 21% physical science, 11% earth science and 10% life science teachers feel the same. At K-4, 20% of science teachers and twice as many mathematics teachers perceive themselves as "master" teachers. This gap is smaller at grades 5-8 (39% science, 57% mathematics) and at 9-12 (64% science, 69% mathematics). On the other hand, 77% K-4, 78% 5-8 and 89% 9-12 science teachers consider well qualified to make connections between science and other disciplines. Mathematics teachers considering the same about integration of content include 83% K-4, 78% 5-8 and 68% 9-12. Interestingly, a far lesser number of teachers, that is

20% K-4, 27% 5-8, and 19% 9-12 in science classes, and 23% K-4, 17% 5-8, and 12% 9-12 in mathematics classes reported that they help students see connections between science and other disciplines on a daily basis. How to successfully integrate science and mathematics remains a critical question.

Integration

Research indicates that using an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners (Frykholm & Glasson, 2005; Koirala & Bowman, 2003;Jacobs, 1989). Interdisciplinary teaching depends on the way students best acquire knowledge, the important role of not only reaching students during their developmental stage but influencing the teaching of subjects, and (c) the cooperative involvement of both students and teachers planning and learning together to modify the instruction of the end product-the students (Jacobs, 1989; Antonellis & James, 1973). More and more educators are coming to realize that one of the fundamental problems in schools today is the "separate subject" or "layer cake" approach to knowledge and skills. Often students cannot solve problems because they do not understand the context in which the problems are embedded (Frykholm & Glasson, 2005). The separate subject curriculum can be viewed as a jigsaw puzzle without any picture. If done properly, integration of math and science could bring together overlapping concepts and principles in a meaningful way and enrich the learning context. Learning situated in such enriched (macro) contexts often lead to meaningful learning experiences. Carefully designed interactive videos are suitable for creating real-life contexts for problem-based learning in mathematics integrated with science (Kumar and Sherwood, 1997).

Integrating mathematics and science in the schools has become a central issue by such organizations as School Science and Mathematics Association (SSMA), the National Council of Teachers of Mathematics (NCTM), the American Association for the Advancement of Science (AAAS), and the National Research Council (NRC). These organizations strongly support the integration of math and science, which is reflected in the recommended national standards documents, such as *National Science Education Standards* (NRC, 1996) and the NCTM *Standards* (1989 & 2000). NCTM (2000) makes "Connections" one of its process standards and advocates the use of integrating subjects like mathematics and science. Berlin & Kyungpook (2005) state how more integration is now taking place in teacher education programs in mathematics and science methods courses, making these connections results in implementing this approach at the middle and secondary levels when in the classroom. Koirala & Bowman (2003) found in a three year study of preservice middle school integrated math and science methods course that preservice teachers appreciated the emphasis on integration used in the course, but at the same time when concepts did not integrate easily thy were frustrated and despite the frustration, it was found that the preservice teachers' understanding of integration was enhanced as a result of the integrated course. Pyke & Lynch (2005) found in a study of mathematics and science teachers' doing preparation for the National Board for Professional Teaching Standards (NBPTS) certification enrolled in an integrated prep course clearly indicated that a collaborative approach produced higher scores and higher passing rates for most respondents. The data from the study indicated that the collaborative preparation is highly valued for motivational and instrumental support. In a study by Utley, Moseley, & Bryant (2005) a relationship between science and mathematics teaching efficacy of preservice elementary teachers was found. Data revealed that as science and mathematics teacher education in a methods course progressed, science and math teaching efficacy significantly increased. So, where should the implementation cycle begin? Hence, research indicates that methods courses profoundly impact how a teacher will teach (Haigh, 1985); therefore, it is essential to introduce preservice teachers to a contextual way of understanding the curriculum when learning how to teach mathematics and science (Frykholm & Glasson, 2005).

Beane (1992) suggests moving away from the straight subject area approach to involve the identification of a central theme and to ask what each subject area can contribute to it. Also, the involvement of students in an integrated science and math unit lends itself to motivating students (Friend, 1985; Wolfe, 1990) and increases student achievement in both disciplines (McBride & Silverman, 1991). This idea relates directly to the constructivist approach of hands-on minds-on learning. Recent technological advances in user-friendly software, such as SimCity, and ArcView--Geographic Information Systems (GIS) are two excellent programs, which connect math, science and social science concepts (Furner & Ramirez, 1999). There are a number of resources for teachers that provide curricula and activities to integrate math and science. Berlin and White (1992) provide a CD-ROM database of integrated science and math curriculum materials and lessons. Great Explorations in Math and Science (GEMS) is a series of activity books for students in grades pre-school through high school integrating math with life, earth, and physical sciences. Activities in Math and Science (AIMS) is another well know resource of activities for grades K-9 with specific themes. Also, the use of Internet Field Trips/Webquests where the educators can connect the math, science and technology is critical in this day and age at all school levels (Furner, Doan-Holbein, & Scullion-Jackson, 2000). Although the research and resources are available to support the integration of math and science, in many classrooms neither of them is actively used. This could be based on the fact that teachers do not know how.

Considerations and Recommendations

In defining how to integrate math and science, White and Berlin (1992), and Sunal and Furner (1995) made the following recommendations.

- •Base integration on how students experience, organize, and think about science and math.
- •Take advantage of patterns as children from the day they are born are looking at patterns and trying to make sense of the world.
- •Collect and use data in problem-based integrated activities that invoke process skills.
- •Integrate where there is an overlapping content in math and science.
- •Be sensitive to what students believe and feel about math and science, their involvement and the confidence in their ability to do science and math.
- •Use instructional strategies that would bridge the gap between students' classroom experiences and real-life experiences outside the classroom.

The integration of math and science encompasses a number of considerations, for example, teaching math entirely as a part of science, math as a language and tool for teaching science, or teaching science entirely as a part of math. Also, teachers' confidence level in teaching math and science needs to be addressed. In some instances, a math teacher may not feel prepared to teach science or vice versa. Also science teachers may not feel confident teaching all science disciplines. Beane (1995) defines curriculum integration as a way of thinking about the purpose of schools, the sources of curriculum, and the basis of knowledge. Beane believes in order to define curriculum integration; there must be a reference to knowledge.

According to Jacobs (1989) and the Association for Supervision and Curriculum Development (1989), planning and teaching interdisciplinary lessons involve two or more teachers, common planning time, the same students, teachers skilled in professional collaboration, consensus building, and curriculum development. As Robinson (1994) pointed out, the following considerations are necessary for the preparation of interdisciplinary instruction.

- •An understanding of the nature of subject field and the need for teachers, for example, single subject field/single teacher; single subject field/multiple teachers; multiple subject fields/single teacher; or multiple subject fields/multiple teachers.
- •A deeper knowledge of methods of interdisciplinary subject matter correlation (unified subject field, theme, topic, problem-based, etc.)
- •Strategies for motivating students to use process skills, such as reading, writing, reporting, research, problem solving, mathematical application, data collection, data analysis, an drawing conclusions.

The following set of conditions is essential for interdisciplinary instruction (Robinson, 1994).

- •The lesson or unit should complement or support some aspect of instruction in the subject area.
- •The lesson or unit should complement or support the content and/or learning skills in at least one other subject field.
- •The lesson or unit should be constructed in a manner that encourages students to integrate and use the new knowledge and skills from several areas of competence.

Zemelman, Daniels, and Hyde (2005), have arrived at the following research-based list of "best practices" for teaching math and science: (a) use manipulatives/hands-on (make learning concrete and active); (b) use cooperative group work; (c) use discussion and inquiry; (d) use questioning and making conjectures; (e) use justification of thinking; (f) use writing for thinking, feelings, and problem solving; (g) use problem-solving approach to instruction, making content integration a part of instruction; (h) use technologies such as calculators and personal computers; (i) promote the role of the teacher to that of a facilitator of learning; and (j) use assessment as a part of instruction. As noted above, problem solving is an area where frequently math and science are integrated, and problem-based learning might be a successful instructional strategy for integration.

Problem-based learning invoking process skills instead of rote learning must become a classroom norm in integrated science and mathematics. Teachers should be able to incorporate more problem solving/inquiry approaches to instruction as well as assessment rubrics that take into account processes. NCTM (2000, 1995, & 1989) and NRC (1996) suggest that the methods and tasks for assessing students' learning should be aligned with the curriculum's goals, math and science content, instructional approaches, and hands-on activities including manipulatives. Also, appropriate assessment must be practiced based on the type of information sought, how the information will be used, and the developmental level and maturity of each student. Teachers need to employ alternative forms of assessment such as observations, interviews, performance tasks, self-assessments of students, portfolios, and standardized tests. Students must be given multiple opportunities to demonstrate their understanding of mathematics and science aligning assessment with curriculum and instruction. Teachers benefit children most when they encourage them to share their thinking process and justify their answers out loud as they engage on problem-based learning.

End Note

There is optimism for improving science teaching through integration with mathematics. Yes, we should integrate mathematics and science wherever it is possible in the curriculum. Problem-based learning is an area where successful integration of mathematics and science could be achieved. The critical role of mathematics in understanding the relationships between scientific concepts especially in the physical sciences cannot be underestimated. In this context, student success depends on the degree to which math and science are integrated in order to motivate and engage students in meaningful learning. In today's high-tech world, it is important that our young people grow to become confident in their ability to do mathematics and science in an ever-increasingly high-tech globally competitive society.

Educators who help students develop their confidence and ability in mathematics and science would have a positive impact on students' lives in the long term. Our students' careers, and ultimately most of their decisions in life, could rest upon how we decide to teach mathematics and the sciences. It really is our obligation as an educational community to make the difference for the future of our students in an ever-growing competitive global environment, which depends so heavily on mathematics, technology, and the sciences. If schools do more in terms of integrating mathematics and the sciences they may impact the lives of their students forever. In the near future, when asking our students how they feel about math and science, we will hope they will say things like: "I love math" or "Science was my favorite subject" or " I am a good problem solver" or " I got first place at the county-wide science fair" or "Mathematics is the tool I use as a scientist."

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Field-Based Internship Models for Alternative Certification of Science and Mathematics Teachers: Views of Interns, Mentors, and University Educators

Fran Arbaugh, Sandra Abell, John Lannin, Mark Volkmann
University of Missouri-Columbia, MO, USA

William Boone
Miami University, Miami, FL, USA

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In response to shortages of science and mathematics teachers in the U.S., many states have promoted alternative routes to certification in which individuals with non-education undergraduate degrees can become certificated in shorter timeframes than in traditional programs. One consideration in designing alternative programs is how to arrange field-based internships that help provide transformative pathways to non-traditional students in becoming a teacher. The purpose of this study was to understand the views of interns, their mentor teachers, and university personnel who participated in one alternative certification program regarding the best structures for field experiences. Through an analysis of artifacts collected in a meeting where we discussed the pros and cons of five different intership models as well as interviews with individuals in each stakeholder group, we were able to understand the various viewpoints. We found that, although perspectives were consistent within each group, they differed across the three groups. These differences were grounded in the personal needs and experiences of each group. Although our findings point to no "perfect" internship model to support the transformation of alternative certification students into teachers, they have implications for the design and enactment of field-based internships in such programs.

Keywords: Alternative Certification, Field-based Internship Models, Mathematics Teacher Education, Science Teacher Education

INTRODUCTION

We face a critical shortage of qualified teachers in the United States. This shortage is especially evident in the areas of mathematics and science, where nationally figures for those who lack state certification in their field range from 28-33% for mathematics teachers and 18-20% for science teachers (Ingersoll, 1999; Olson, 2000). In response to the teacher shortages, many states have endorsed alternative certification programs at the post-baccalaureate level that prepare individuals with non-education undergraduate degrees to become K-12 classroom teachers.

Post-baccalaureate certification programs create new challenges for teacher education programs. Post-baccalaureate students enter teacher education with experiences and learning needs that differ from those of traditional preservice teachers. Post-baccalaureate students are likely to have strong content knowledge, having worked in a content-based career for a number

Correspondence to: Fran Arbaugh Assistant Professor of Mathematics Education
303 Townsend Hall Columbia, MO 65211, USA
E-mail: arbaughe@missouri.edu

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of years. However, they often have little to no experience in the classroom other than their own experiences as students, and they are often far removed chronologically from this experience.

Consequently, teacher educators are presented with a dilemma: Do we treat post-baccalureate students as we do our traditional pre-service teachers, or do we create new program structures tailored to their differing needs?

In this paper, we report on one aspect of our efforts to address this dilemma in the design and implementation of a post-baccalaureate, alternative certification program for mathematics and science teachers. Our program was originally conceived in response to a call, from the Missouri Department of Elementary and Secondary Education, for teacher preparation institutions across the state to develop alternative post-baccalaureate teacher preparation programs. With the support of funding through the National Science Foundation (DUE0202847), the science and mathematics education faculty at the University of Missouri-Columbia (MU) developed post-baccalaureate teacher certification programs for grades 5-12 science and mathematics under the auspices of the Science and Mathematics Academy for the Recruitment and Retention of Teachers (SMAR²T).

We faced many challenges as we designed and began implementing this program (Authors, 2006). One challenge that arose was in the design of field experiences for the students. Like traditional preservice teachers, post-baccalureate students arrive in teacher education programs with conceptions about effective instruction, conceptions shaped by their previous experiences as students (Crawford, 1992; Stein, Smith, & Silver, 1999). Thus, both undergraduate and post-baccalaureate preservice teachers need to "unlearn" how to teach (Ball, 1988). However, due to the shortened time frame of most alternative certification programs, post-baccalaureate students do not benefit from the early field experiences that occur in many traditional teacher development programs. The internship for these students becomes a critical part of their teacher education experience, and their relationship with a mentor teacher can be an important part of their transition into a teaching career (Chesley, Wood, & Zepeda, 1997; Dill, 1996).

In designing the SMAR²T program,we took seriously the importance of the classroom-based internship for our students. As a result, we have worked over the last two years to investigate aspects of the internship; these investigations served as formative assessments for us as we continually work to improve the program. We believe that other science and mathematics educators can benefit from our investigations.

Thus, the purpose of the study reported in this paper was to understand the views of alternative certification interns, their mentor teachers, and university personnel regarding how various field experiences structures could serve as a means to understand and experience what it means to be a teacher. Specifically, we addressed the following research question: In what ways do student interns, mentor teachers, and university faculty view five different internship models for post-baccalaureate mathematics and science certification students?

Considering the Literature

As teacher educators, we ground many decisions about program design in the teacher education literature. Two literatures informed this study: the research that has been conducted on preservice teachers' internships, and the research on teacher knowledge. Because the context of our study is U. S. teacher education, we restricted our search of the literature to studies conducted within U. S. teacher education programs.

Most of the research in the U. S. that has been conducted about preservice teachers' internships has occurred in the context of traditional teacher education programs. While our study is set in the context of an alternative certification program, we believe it appropriate to include this discussion as a way of situating our study.

Historically, reform movements have called for increased amount of field or clinical experience for teacher preparation (Conant, 1963; Berliner, 1985). A few studies examined the structure of field experience (McIntyre, 1983; Reiman & Parramore, 1993), but the findings of these studies did not support an increase in the length or number of clinical experiences. Researchers indicate that field experiences are often disconnected from the image of teaching that is portrayed in university methods classes (Wilson, Floden, Ferrini-Mundy, 2001). Preservice teachers can have difficulty linking theory to practice in field settings (Moore, 2003) and mentor teachers often provide little instructional support in these areas (Shulman, 1987).

Despite these potential shortcomings, evidence exists that carefully designed field placements have the potential to engage preservice teachers in exploring different instructional methods (Bullough, et al., 2002), increase pre-service teacher self-efficacy (Cannon & Scharmann, 1996), and connect university coursework to classroom decision-making (Schoon & Sandoval, 1997). In addition, field placements offer opportunities to engage in professional discourse with practicing teachers (da Ponte & Brushier, 2001), serving as a "transformative pathway" through which preservice teachers come to understand and experience what it means to be a teacher (Goodfellow & Sumsion, 2000).

Goodfellow and Sumsion (2000) suggest "an ecological perspective that recognises the interconnectedness of the diverse influences and different contexts that are instrumental in student teachers' personal-professional development. This interconnectedness reveals numerous transformative pathways that can guide student teachers in their journeys as developing professionals" (p. 252). Among other influences, Goodfellow and Sumsion explicate the following: student teachers' prior experiences, beliefs and images of teachers and teaching; the university context; skilled practitioners; and field-based education. The SMAR²T program also considers these influences; this research focuses on the field-based education component of the program.

Because we believe that teacher preparation should be based on a comprehensive model of teacher knowledge and be performance-based, we also considered the research on teacher knowledge to inform the design of our program. Our beliefs about teacher knowledge come from the work of Lee Shulman and his colleagues (Grossman, 1990; Shulman, 1986). Shulman proposed that teachers need to have a strong command of subject matter knowledge, pedagogical knowledge, and knowledge of the context, which they synthesize and translate into pedagogical content knowledge (PCK), or subject-specific knowledge for teaching. PCK is what distinguishes the teacher from the content specialist, and includes "an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). PCK also includes curricular and assessment knowledge as well as knowledge of the conceptions that K-12 students bring with them that influence learning.

This grounding in the literature on field experiences and teacher knowledge led us to design a program of study that combines university coursework with school-based field experiences. In designing the program of study, we took into consideration that most alternative certification students had little classroom experience beyond their own K-12 schooling. Thus, we developed an intensive, year-long internship experience for students (interns) in addition to university coursework (see the discussion of the program of study later in this paper).

Over the course of the first year of the alternative certification program, we engaged in many conversations with the interns and their mentor teachers regarding the intensive internship model and how it supported a transformative pathway into teaching. Through these conversations, we came to see that there were differing views of what would help interns experience what it means to be a teacher. Our desire was to understand the differing views of internships to determine what pathway would "best" serve our students in their transformation to becoming teachers.

CONTEXT

The SMAR2T Program of Study

The SMAR²T program for the APB-track students consists of campus-based coursework in science/mathematics content, general pedagogy, and subject-specific pedagogy, accompanied by an intense year-long internship in a partner school (see Table 1). The individuals enrolled in this track are full-time students and finish their certification and Masters of Education (MEd) in 15 months. SMAR²T also enrolls full-time teachers in an Alternative (ALT) track that takes 24 months to complete. (See Authors, in press, for a discussion of the different tracks SMAR²T students can take toward certification.) Our first cohort entered the SMAR²T program in Summer 2003, and graduated in Summer 2004 (Table 1).

Cohort 1 Interns and Field Placements

Thirteen APB students enrolled in Cohort 1 of the SMAR²T program. These individuals worked toward certification in mathematics or science teaching at one of the following levels: a content-specialized certification in grades 9-12 (e.g., 9-12 Mathematics); a 9-12 certification with a second endorsement in grades 5-9 (e.g., 9-12 Biology and Middle Grades Science, called a dual endorsement); or subject specific certification in grades 5-9 only (e.g., Middle Grades Mathematics). Table 2 contains a description of the certifications sought by the 13 Cohort 1 students (Table 2).

Cohort 1 students who pursued a 9-12 certification or a 5-9 certification were placed in one school, with one teacher, for four hours per day, five days per week for 32 weeks (2 academic semesters). We required that the four hours be comprised of three content classes and one period of common planning with the mentor teacher. Interns and their mentor teachers, working within those restrictions, arranged a time period during the day that was mutually beneficial to both parties.

Cohort 1 students who pursued a dual certification (9-12 with a middle grades endorsement) were placed at a middle school for 10 weeks and at a high school for 22 weeks, with the same restrictions on daily attendance of four hours. Consequently, these students worked with two different mentor teachers over the course of the academic year.

From a program design perspective, we were influenced by two factors in our decision-making regarding the internship experience. The first was philosophical and related to our groundings in Shulman's work and the framework of transformative pathways. We strongly felt that a year-long field-based experience would provide a transformative pathway for students to develop PCK as well as knowledge of

Table 1. SMAR²T APB Program of Study

The SMAR²T Accelerated Post-Baccalaureate Program (APB) is designed for individuals with an undergraduate degree in mathematics, science, or a related area who desire a high quality teacher preparation program in an accelerated time frame. APB students attend two concentrated summer sessions on the MU campus and spend one school year interning at a partner school, during which they are part of a learning community with other interns, mentor teachers, and MU faculty members.

Mathematics Only	Mathematics and Science	Science Only
	Summer #1 (11 credits)	
(3 credits) Intro to Teaching Mathematics in Middle and Secondary Schools	(8 credits) Advanced Educational Foundations of Teacher Preparation	(3 credits) Teaching Science in the Secondary School, Part I OR (3 credits) Middle School Science I
	Academic Year, Fall (8-11 credits)	
(3 credits) Teaching Mathematics in Secondary Schools: Focus on Geometry & Statistics OR (3 credits) Teaching and Modeling Middle School Mathematics Math content course (secondary only)	(3 credits) Reading in the Content Areas (2 credits) Advanced Internship	(3 credits). Teaching Science in the Secondary School, Part II OR Middle School Science II
	Academic Year, Winter (9-12 credits)	
(3 credits) Teaching Mathematics in Secondary Schools: Focus on Algebra (secondary only) Math content course (3 credits) (middle only)	(6 credits) Advanced Internship	(3 credits) Teaching Science in the Secondary School, Part III (secondary only) Science course (4310 Environmental Analysis) (3 credits)
	Summer #2 (5-8 credits)	
Mathematics course (Geometry, Algebra, or Statistics) (3 credits)	(2 credits) Integrating Mathematics and Science Instruction (3 credits) TEAMS (middle level only) Finalize and submit portfolio	Science course (Exploring Physics) (3 credits)

context, assessment, and the conceptions students have that influence learning. The second governing factor was logistical; we had to meet certain state requirements for number of field hours and fit the internship and coursework into a reasonable time frame for completion of certification (Authors, in press).

Table 2. Certification Distribution of Cohort 1 SMAR²T APB Students

	SECONDARY	MIDDLE	DUAL
Mathematics	1	2	2
Science	3	2	3

THE STUDY

Data Collection

We collected data for this study from two sources. The first data set resulted from a meeting of SMAR²T APB student interns, their mentor teachers, university supervisors (who completed the student teaching evaluations), and university mathematics and science education faculty (who designed and enacted the program). This half-day meeting (the last of a series of such meetings) was held in February 2003 on the MU campus. Mentor teachers were provided with release time to attend the meeting. Eighty-five percent (11/13) of the student interns attended the meeting; sixty-five percent (11/17) of the mentor teachers attended the meeting[1]. Six university personnel attended the meeting. To facilitate discussion of internship models during that meeting, we divided the participants into five groups, each containing at least one student intern, one mentor teacher, and one university person. Each small group was assigned one of five internship model options (see Table 3) to discuss. Fundamentally, all of the options met the requirements as explicated by the design team (discussed above), and thus were somewhat similar. However, on closer inspection, a number of subtle differences among options appear. For example, all five options require interns to be in a classroom for 32 weeks; options A and E place students in the same classroom for both semesters, while options B, C, and D require students to change classrooms at semester. Options A, B, and E are based on a half-day, every day requirement; options C and D contain full days, but limit the number of days per week during one or both semesters. Options A, B, C, and D include student teaching supervision in the second semester only; option E would provide supervision throughout the school year. Option A represents the internship model that was in place for Cohort 1.

At the meeting, each group discussed and then recorded "pros" and "cons" of their specific option on flip chart paper. They presented their discussion to the entire group, and the meeting facilitator recorded their ideas on a master chart. Those recordings comprised part of our data corpus for this study.

The second data source was exit interviews, conducted by the project external evaluator (W. Boone) with 10 student interns, 10 mentor teachers, and three university personnel toward the end of the internship year. All interviews were audio-taped and transcribed for analysis.

Data Analysis

To begin analysis, we re-recorded the data from the flip chart paper added a fourth column to Table 3 called "pros and cons." This allowed us to see the options and the stated pros and cons for each option. We identified each comment in the "pros and cons" column as originating from one of three stakeholder groups: student interns, mentor teachers, or university persons. Once all comments were identified, we separated the data into three groups as defined by the three stakeholders.

We reduced the data from the interviews by coding those sections in which the comments matched our research question about internship models. We then reduced the data set by separating it into three parts, each defined by the source of the comment (student intern, mentor teacher, or university person) and added the resulting pieces of transcript data to the three groups of data as defined in the paragraph above. The sorts resulted in three distinct sets of data: the comments regarding internships from 1) the student interns, 2) the mentor teachers, and 3) the university personnel. Finally, we examined the data in each group, looking for commonalities and overall themes.

FINDINGS

Our data analysis revealed that APB student interns, their mentor teachers, and the university personnel had distinctly different ideas about what is important when considering the 4-hour per day, 5-day per week, year-long intensive internship required in the SMAR^{2}T program. We present our results in the next section by describing each stakeholder group's perspectives with regard to important components of an internship.

APB Student Interns

The interns expressed their preferences for the internship models that allowed them to be in a classroom for the entire year, but limited the internship to half-day (options A and E). Their comments fell into four distinct categories that described the ways in which they felt they benefited from this internship option: 1) Developing relationships with students; 2) experiencing the scope of what teachers do across the year; 3) seeing more content taught; and 4) managing logistics with the on-campus program, jobs, and/or family.

Overall, the APB interns appreciated the long-term nature of the internship and the influence it had on their ability to develop relationships with the students. The interns found that being with a group of students over the course of the year, every day of the week, allowed them to experience a sense of continuity with the students. They appreciated being able to form teacher/student relationships; they did not think this would typically happen without the intensive and long-term nature of this internship. Katrina explained:

> I thought it was great! I liked seeing things from start to finish and I felt like if I wasn't there for the year, I wouldn't get to see the students from the beginning to the end. You develop a better rapport with them as well as the parents.

Kelly agreed: "Just the fact that I was there all year, I got to know the kids so well…and dealing with kids diverse backgrounds and things they bring to the table in the classroom."

[1] The difference in the attendance of APB students and mentor teachers is a result dual certification APB students who worked with two different teachers over the course of the internship year. Many of the mentors from the first placement did not attend this session.

Table 3. Internship Options

Option	Middle or Secondary Certification only	Secondary Certification with a Middle Endorsement
A: Model used for Cohort 1	• 32 weeks (2 semesters) in the same classroom • Student teaching evaluation occurs in the 2nd semester • 4 hours per day (including time to plan with the teacher) • 5 days per week	• 10 weeks in a middle grades classroom • 22 weeks in a high school classroom • Student teaching evaluation occurs in the 2nd semester • 4 hours per day (including time to plan with the teacher) • 5 days per week
B	• 16 weeks (1 semester) in 1st classroom • 16 weeks (1 semester) in 2nd classroom • Student teaching supervision occurs in the 2nd semester • 4 hours per day (including time to plan with the teacher) • 5 days per week	• 10 weeks in a middle grades classroom • 22 weeks in a high school classroom • Student teaching evaluation occurs in the 2nd semester • 4 hours per day (including time to plan with the teacher) • 5 days per week
C	• 16 weeks (1 semester) in 1st classroom • 16 weeks (1 semester) in 2nd classroom • 10 hours per week in the 1st semester (arranged by the teacher and intern) • Full days, 5 days per week during the 2nd semester • Student teaching evaluation occurs in 2nd semester	• 16 weeks (1 semester) in middle grades classroom, with an emphasis on independent teaching during the last 5 weeks • 16 weeks (1 semester) in a high school classroom • Student teaching supervision occurs in the 2nd semester • 10 hours per week in the first semester (arranged by the teacher and intern) • Full days, five days per week during the 2nd semester
D	• 16 weeks (1 semester) in 1st classroom • 16 weeks (1 semester) in 2nd classroom • Student teaching evaluation occurs in the 2nd semester • Full day both semesters; 2 days per week in the 1st semester, 4 days per week in the 2nd semester	• 16 weeks (1 semester) in a middle grades classroom, with an emphasis on independent teaching during the last 5 weeks • 16 weeks (1 semester) in a high school classroom • Student teaching evaluation occurs in the 2nd semester; Full day both semesters; 2 days per week in the 1st semester, 4 days per week in the 2nd semester
E	Same as option A, except that student teaching supervision would occur over both semesters	Same as option A, except that student teaching supervision would occur over both semesters

Kelly also found that the year-long experience helped her establish a teacher role: "And they thought I was Mrs. Adams. I was the teacher – no ifs, ands, or buts about that fact. I wasn't a student in there – I was the teacher." Interns did not seem to feel that they were the "real teachers" until many weeks of their internship had elapsed. Their need to identify themselves as the "real teacher" partially influenced their preference for options A and E, the options that allowed them the opportunity to spend an extended amount of the year in one classroom.

The interns also commented that the year-long nature of their internship allowed them to experience the scope of what teachers and students do across an entire school year. Katrina commented,

> There were things that schools do in the spring semester that they don't do in the fall semester. If you were only there for three months, one semester, you wouldn't get those other experiences that I got that were so valuable…[for example], we don't attend field trips in the first half of the year.

Without the long-term nature of her placement, Katrina felt that she would be missing important experiences of being in a school community.

Finally, in relation to the year-long aspect of the internship, the interns commented that the long-term nature of the experience provided exposure to a great deal of middle/high school mathematics or science content – content that they had not thought about in many years. Although all of the interns had an undergraduate degree in mathematics or science, their use of some of the subject matter in Grades 6-12 over recent years had been infrequent and their knowledge was rusty.

The interns also preferred the half-day nature of the internship, feeling that the organization in options A and E provided needed time for completing SMAR²T course requirements, working on a part-time basis, and/or attending to family responsibilities. These alternative certification students felt that a full day of internship would cause a number of difficulties with other responsibilities of on-campus courses and family commitments. Sharon said, "I liked it [the half-day arrangement] for me as a student because I had my mornings free and I could, if I wanted, get another job or work on my coursework or basically anything I wanted in the morning." In a similar vein, the APB interns were not supportive of a full day, two or three day a week organization (as in option D) because it would not allow continuity in planning or with the students.

Furthermore, the APB interns felt that the half-day internship allowed them a degree of flexibility with regard to the time of day they were required to be at their internship school. Some interns appreciated having time to transport their own children to school before having to go to their intern school. Other interns appreciated the chance to complete their internship by noon. For example, this allowed Rebecca to teach a course at a local college in the afternoon.

In the end, our analysis revealed that the interns preferred the option (E) that was most similar to what they were in the midst of experiencing (option A). We find it interesting that their reasons for this preference were based on issues not common among our undergraduate student teaching interns in our traditional program. Most undergraduates have no difficulty attending full days during their semester-long internship. None are enrolled in on-campus coursework during their internships, and few have to balance family responsibilities with their studies. Further, we strongly discourage our undergraduates from working part-time while they are completing their student teaching internship. These data provide evidence that our post-baccalaureate certification students have a different set of needs than our traditional students when it comes to the field-based internship.

Mentor Teachers

The mentor teachers' comments focused on the same two characteristics of the internship: the year-long nature and the half-day arrangement. They saw both benefits and disadvantages to the current model (option A) with the year-long arrangement. They found only disadvantages with regard to the half-day nature of the current model.

The mentor teachers felt that the long-term nature of the current model had certain benefits. They thought interns benefited from being in the field on the first day of school, and during the first week, so that they could experience setting the classroom tone for the year. They also expressed that interns benefited from the opportunity to see the long-term organization of teaching over the course of a year. Paul, for example, said,

> I wouldn't change it [the year-long internship] for anything, because [my intern] was here to meet the kids and to see how the structure was set up in the classroom and she got to see the growth over the year from beginning to end.

Many of the mentor teachers also spoke of the mentoring relationships they were able to establish with their year-long interns. For example, Janet said, "I do feel like I've had more of an impact with this [intern]…It's been really nice to have a long-term relationship with someone and watch them grow through the classroom."

However, while the mentor teachers understood the value of the year-long experience for the APB interns, they were unsure as to whether that experience needed to be in one classroom, or split between two classrooms (one each semester). In response to options B, C, and D, in which the APB students would change classrooms at semester, the mentor teachers saw a number of advantages. First, they thought more mathematics and science teachers might participate in the SMAR²T program if they only had to commit to hosting an intern for just one semester.

Further, a number of the mentor teachers felt that it would be good to "get their classes back for part of the year." When asked if they would host an APB intern the following year, many of mentor teachers were hesitant and referenced the year-long commitment. For example, Paul, who teaches at a middle school where the teachers "loop" with their sixth-grade students into seventh grade, explained,

> I have these kids for two years of math. Two years of their life depends on what I do as a teacher, and I feel like most of this year has been me turning it over to her as the teacher. If I had another [SMAR²T intern] next year, I'm not sure I would feel like I actually had [an impact on these] kids.

Similarly, Rita said that she would "definitely do this [host an intern] again, but I would do it every other year…because I like to teach." Although these teachers expressed hesitation at being "repeaters," we did have Cohort 1 mentor teachers who hosted a Cohort 2 intern the next year.

Laura expressed a different concern about the year-long arrangement. She was worried that she would be assigned an intern with whom she did not "match." Prior to her involvement in the SMAR²T program, Laura reported, "I had a student teacher before and I wasn't going to let anybody talk me into this again." She and her prior intern did not "match" personalities very well. Thus, she was worried that she would be "stuck" for a whole year with an intern where "we have such a personality conflict, and we cannot function in the same classroom and the same set of rules."

Overwhelmingly, the mentor teachers reacted negatively to the half-day organization of the internship model. They spoke of disadvantages for both themselves and the APB interns. For example, the mentor teachers felt strongly that the APB interns needed to experience full days of teaching. They believed that the half-day arrangements did not prepare the interns for teaching full time. They argued that the interns were missing out on important components of the teaching profession, as Lena expressed:

> [My intern] did not attend faculty meetings or department meetings because she was always here in the mornings. And she really couldn't touch base with the student discipline issues because all of those take place in the afternoon – detentions and stuff.

Rita echoed those sentiments:

> In four hours, you can't do everything that is expected of a full-time teacher. For example, things like recording grades… there are aspects of the job that she's missed out on and she's just going to have to do trial by fire when she gets her first position.

Dennis saw a different disadvantage to the half-day arrangement: "They oftentimes don't get a sense of how you have to work with other teachers if you're not there for the whole day." Laura saw yet another disadvantage. In describing her intern, she said,

> I know he's going to do fine [teaching next year], but those first couple of months are going to be killers just trying to adjust to [teaching a full day]. He's going to remember, 'oh, it's not so bad. I taught three hours.' And then, boom, he's going to be teaching all day long, and possibly looking for a coaching position… and it's a mental challenge to teach all day.

Thus the mentor teachers expressed concerns about developing stamina and experiencing the full scope of teachers' work.

Other disadvantages of the half-day organization, from the mentor teachers' perspectives, included the potential for the half-day arrangement to disrupt the mentor teachers' schedules and planning, and the interns' loss of experience with the variety of students and classes they would get with a full schedule. Further, Lena, who had hosted student teachers in the past in the traditional program (in a semester-long, all-day internship), expressed concern about the amount of responsibilities her intern had outside of the internship classroom: "I just felt like she was overextended. She had too may things going on. She would give my class a test and it would be a week and a half later before they'd get the test back." While Lena felt strongly about the worth of the program overall, her experience with this intern had an impact on her willingness to host future SMAR²T interns:

> I really believe in the program and I believe to effectively teach math and science we have to have people who are grounded in everyday math and science careers before they come in to teach. I really believe that. So I would be willing to do it again, but only if we can have them first semester, all day long. I don't like this half-day business.

Like Lena, many of the mentor teachers had hosted traditional, undergraduate interns in past years. Like the SMAR²T interns, the mentor teachers appeared to be most comfortable with what they had experience with; for the mentor teachers, that experience consisted of a full-day, semester-long internship experience with students who had no outside-of-school commitments. Many of their comments about the current "different" model for an internship may have stemmed from being in unfamiliar territory.

University Personnel

The university personnel consisted of mathematics and science education faculty members who designed and implemented the SMAR²T program and doctoral students who were engaged in supervising the APB students during the second semester of their internships. The faculty had designed the year-long, half-day internship to provide sufficient hours to meet state certification requirements, but also to allow students time to complete on-campus coursework. In reflecting upon their experience with the first cohort of SMAR²T students, they expressed views on both the year-long and half-day nature of the experience.

Like the interns and mentor teachers, the university personnel thought the year-long internship (options A and E) allowed for continuity in the interns' experiences. In particular, they wanted the interns to observe and understand student learning across the school year. The subject specific pedagogy courses that they developed and taught focused on student learning as the framework for thinking about teaching. Because some of these pedagogy courses took place concomitantly with the internship, there would be opportunity for cross-talk about student development.

Further, the university personnel felt that a benefit of interns being at the same school for an entire year was that the intern could develop relationships within the school system, with principals, guidance counselors, and other teachers. This was important partly because, in the design of the alternative certification program, they had eliminated a course on the culture of schools that was part of the traditional program, opting instead for increased subject specific pedagogy coursework. According to the program director,

> Whether or not that will prove to be a good decision, we don't know. But I think part of that just stemmed from our belief that you learn to teach science or math by thinking about teaching science and math, not by thinking about general pedagogical issues.

In order to have the program approved by their College of Education colleagues, the science and mathematics education faculty agreed that the learning outcomes in some of the general pedagogy courses, such as the course on culture of schools, would be addressed in the year-long internship.

From a logistical perspective, the university personnel perceived disadvantages to year-long placements with a single teacher. They thought it might be easier to find teachers who were willing to host an APB intern for a single semester (as in options B, C, and D) rather than for an entire school year (options A and E). Semester-long placements would also 'free up' teachers for other needed placements in the traditional program. According to the program director, there was some concern among College of Education colleagues that the alternative program would compete with the traditional program for placements.

> Because every time we place somebody, we are taking away a placement for some undergraduate. Because we have three courses plus student teaching in which we place people in the undergraduate program for math and science. So, we really have to be careful about how we get the placements made.

However, university personnel also remarked that, if the SMAR^{2}T program changed to semester-long placements, they would need for twice as many school placements, which could create much more work on their part.

The university personnel also commented on the supervision aspect of the year-long internships. They were concerned that, in the model enacted for Cohort 1 (option A), APB interns had not received sufficient support from the university in the fall semester of their internship year. They thought that waiting until the second semester to have an official university supervisor might be too late to have an impact. They saw the benefit of an extended period of internship supervision that would cover both semesters, as in option E. Both of the university supervisors for Cohort 1 stated that starting supervision in the first semester would allow relationships among the intern, mentor teacher, and university supervisor to form early, which would help build open channels of communication.

Regarding the half-day format of the internship, the university personnel saw only advantages. Like the interns, they felt that the half-day organization allowed ample time for the interns' commitments to on-campus coursework. They recognized that the interns were older students who needed to support themselves and, in many cases, their families. They knew that many of the interns held other jobs (as teaching or research assistants on campus, as instructors at a local college, in local businesses) that they would need to maintain during their internship. For these reasons, the university personnel thought the viability of the program in terms of student recruitment depended on finding a way for student interns to continue working part time while enrolled.

DISCUSSION

The purpose of this study was to understand the views of various field placement models from the perspective of alternative certification interns, their mentor teachers, and university personnel who deliver alternative certification programs. We found that, although perspectives were quite consistent within each group, they differed across the three groups. We were surprised to find that subtle, but important, distinctions existed among the underpinnings of each groups' perspectives.

One factor that appeared to impact the perspectives of the three stakeholder groups (interns, mentor teachers, and university personnel) was the personal needs of the individuals within each group. The student interns needed to have time for work and coursework and were most concerned that their internship would be arranged temporally to facilitate their lives. The mentor teachers desired to teach their own science/mathematics students and were concerned about their personal relationships with the interns. The university personel attempted to please many masters (Authors, in press), including: adhering to their philosophical groundings for the program; meeting state and College of Education requirements for certification, finding sufficienct numbers of quality placements for the interns, and sustaining their program by recruiting sufficient numbers of students.

Even where it appeared that the three stakeholder groups agreed on advantages and disadvantages of various internship models in their support for transitioning the interns into the teaching profession, the origins of their perspectives were distinctly different. For example, all of the stakeholder groups agreed that the continuity afforded by the year-long experience was an advantage of the current model. However, their reasons differed in what they viewed as important for supporting their transformations into teachers. The interns felt that the year-long internship supported them to build their identity as a teacher in the eyes of the students. For the interns, the advantage of continuity was the opportunity to build their relationships with students. The mentor teachers focused on interns' ability to see all phases of the work of teachers and to realize that teaching takes stamina and dedication. To the mentor teachers, the benefit of continuity was the interns' indoctrination into the work of being a teacher. The university personnel focused on the interns' opportunity to observe student learning over time, in order to build PCK for science and mathematics teaching and learning.

Not only were stakeholders' views influenced by their perspectives what it means to become a teacher, they were also influenced by past experiences. Mentor teachers, who had previously supervised student teaching interns in the traditional program and who themselves had completed their own student teaching in a similar format, had developed a comfort with the full-semester, all-day model. This comfort and familiarity confronted them when they agreed to become part of the new internship model in the alternative certification program. On the other hand, the interns, who knew nothing of either model prior to entering the SMAR²T program, more easily accepted the year-long half-day design. Thus, one role of the university personnel associated with alternative certification internships for full time students is to help mentor teachers understand the differences between these students and those in traditional programs, and recognize how those differences can be addressed through different internship options.

In the end, we are no closer to finding the "perfect" internship model that supports the transition of our alternative certification students into the teaching profession. Each option that we presented and examined through the perspectives of three stakeholder groups has advantages and disadvantages associated with it. What we have learned from this study is that a key to supporting a successful experience for all stakeholders involved in the internship process is making explicit the expectations and perspectives of the members of the three groups.

Based on this study, we took action in the form of an adaptation of the option A internship model for SMAR²T Cohort 2 interns. We felt it was important to address the major concerns raised by the interns and the mentor teachers in a manner that was also viable for the university personnel who administer the program. Consequently, for Cohort 2 we enacted an internship model similar to option E. We still required interns to be in a school for four hours per day, five days per week, which satisfied the interns' need for continuity and provided time for other responsibilities. To address the mentor teachers' concern about interns needing to experience the gamut of the work of teachers, we required Cohort 2 interns to complete a number of school-related activities outside of their internship classrooms. These activities included, but were not limited to: attending a school-wide faculty meeting each semester; attending an IEP (Individual Educational Plan) meeting for a special needs student; attending an extra-curricular activity in which their students participate; and doing bus duty, lunch duty, and/or hall duty with their mentor teacher. To address the university personnel's need for providing continuing classroom-based university support, we implemented formal university supervision in both semesters.

We believe that supporting university-school collaboration is a critical component of providing our preservice students, whether at the undergraduate or post-baccalaureate level, with a quality teacher education program. We feel that the findings from this study helped us to understand better the importance of this particular transformative pathway, the internship, for our post-baccalaureate, preservice science and mathematics teachers. Further, this study aided our local efforts as we worked to enhance our post-baccalaureate students' opportunities to build PCK and develop into highly qualified science and mathematics teachers. We have found little research in the mathematics and science education literature that addresses internship experiences for this type of post-baccalaureate certification student (one who is not a full time teacher). We believe that our study begins to fill a gap in the literature, and our hope in presenting this research is that it supports other science and mathematics educators who are designing internship programs for post-baccalaureate science and mathematics certification students.

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Curriculum Reform in Turkey: A Case of Primary School Mathematics Curriculum

Mehmet Bulut
Gazi Üniversitesi, Ankara, TURKEY

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The purpose of this study was to analyze the newly developed elementary school (grades 1 through 8) mathematics curriculum by considering 5th grade students' and classroom teachers' views. The analysis of the curriculum was realized in three dimensions; (1) Classroom management – classroom physical and emotional environments, teacher and student roles, and interactions, (2) Instruction – objectives, planning, implementation, method and techniques, instructional media, and measurement and evaluation, and (3) Strengths (and/or benefits) and weaknesses (and/or limitation). Qualitative case study method was utilized with the participation of three elementary school teachers and their forty-three fifth grade students were invited. The responses gathered from the participants were content analyzed and then the codes were categorized. The findings indicated that several changes have been done and reflected into the classroom implementation and student-centered approaches have been incorporated into the instruction. On the other hand, some difficulties emerge during the implementation due to lack of infrastructure.

Keywords: Elementary Mathematics Curriculum, Reform, Teacher Change, Qualitative Research

INTRODUCTION

A Brief Overview of Turkish Educational System and Ongoing Reform Efforts

Turkey has a population of 72 million. According to estimations, it will be about 82 million by year 2015. According to the statistics by the Ministry of National Education (MONE) there are about 13 million students at the primary and secondary education levels with more than 500,000 teachers (MONE, 2001).

Pre-primary education in Turkey involves the education of children in the age group of 3 to 5 who have not reached the age of compulsory primary education, on an optional basis. Primary education involves the education and training of children in the age group of 6 to 14. Primary education is compulsory for all male and female citizens and is free at public schools. Primary education institutions consist of eight-year schools where continuous education is provided and primary education diplomas are awarded to the graduating students. Secondary school is not yet compulsory (MONE, 2006).

In the last ten years, some development and improvement efforts have been attempted in the education system. In 1997, compulsory education was increased from 5 to 8 years. There are 10,673,935 students receiving compulsory primary education with 389,859 teachers (MONE, 2006). In 2005, Secondary school years were extended from 3 to 4 years. In 2002, preschool curriculum for 36-72 months-old children was developed. On the other hand, even though these continuous efforts to improve the education system of Turkey, international are benchmarking studies such as Third International Mathematics and Science Study - Repeat. TIMSS-R (1999), The Progress in International Reading Literacy Study PIRLS (2001) and Programme for International Student Assessment PISA (2003) have shown that Turkish students' performed below the

Correspondence to: Mehmet Bulut, Research Assistant, Gazi Universitesi, Gazi Eğitim Fakültesi, İlköğretim Bölümü, Matematik Öğretmenliği AD, Teknikokullar 06500, Ankara, TURKEY
E-mail: mbulut@gazi.edu.tr

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international average (Berberoglu, G., Celebi. O., Ozdemir, E., Uysal, E., & Yayan, B. 2003; Is, 2003; TIMSS, 1999).

New curricula have been developed and are being implemented for primary and secondary schools with ongoing changes since 2004 in Turkey. The idea behind these curricular reforms is to change the curriculum from a subject centered to a learner centered one and change the pedagogies from a behaviorism to more constructivism. The purpose of the curriculum reform is to change considerably the focus and content of the whole national curriculum. The basic objectives of the curriculum reform in Turkey are;

- to reduce the amount of content and number of concepts
- to arrange the units thematically
- to develop nine core competencies across the curriculum
- to move from a teacher-centered didactic model to a student-centered constructivist model
- to incorporate information communications technologies (ICT) into instruction
- to monitor student progress through formative assessment
- to move away from traditional assessment of recall, and introduce authentic assessment
- to enhance citizenship education (Board of Education(BoE), 2005)

One of the curricula started to be developed since 2004 is Primary School mathematic curriculum. The curriculum has been developed under the guidance of a committee consisted of academicians, teachers, and educational specialist. Further, feedbacks and opinions were gathered from other teachers, parents, students, and non-governmental organizations (NGOs). The Curricula developed for 1st to 5th grade students were firstly pilot tested in 120 pilot schools in 2004. One year after piloting, it was revised based on feedback obtained through the pilot administration, and implemented nation-wide. During this process, textbooks and instructional materials for grades 1st – 5th have been designed for use. Similarly, the math curriculum for grades 6th to 8th have been still developed and implemented in pilot schools gradually. Furthermore, basic education course schedule is being redesigned (Karip, 2005). As a following to the attempts in primary level, on-going reform attempts has been also reflected in secondary schools (changes in the courses and time of the secondary education) and universities (new courses were added and changes are done in the content of existing courses) as well.

In Turkey, exploratory teaching and memorization are still dominant in mathematics classrooms. Previous mathematics curriculum was based on behaviorist theory. The recently developed elementary school mathematics curriculums can be labeled as a reform based attempt to achieve the contemporary educational changes in the world. (Umay et.al, 2006)

Basic characteristics of new elementary school mathematics curriculum in Turkey

According to rationale of program, scientific studies, national and international evaluation reports, the experiences of teachers, the reports related to the current mathematics program and the findings of the non-governmental organizations state that there are problems about mathematics teaching in Turkey (MONE, 2004). The main reason for this is that educational methods, which are applied, are not programs where the students are mentally and physically active. The Vision of the Newly Developed Mathematics curriculum are stated in the guide book as training individuals who can be able to use the mathematics in their lives, who can be able to solve problems, who share their solutions and ideas, and who enjoy learning mathematics (MONE, 2004).

The principle entitled "Every child may learn mathematics," is the main focus of the curriculum. A conceptual approach, which aims to develop the mathematical concepts as well as developing mathematical expression problem solving skills, communication skills and other important abilities, has been incorporated in the curriculum (BoE, 2005)

These all attempts aim to enhance students' active participation in learning mathematics and its principals. The program highlights the importance of a learning environment where the students may research, discover, solve problems, and where they can share and debate their solutions and approaches. Also it adopted the idea of associating mathematics within itself as well as other subjects and disciplines. Concepts in mathematics have abstract characteristics due to its nature. It's hard for the children to gain these concepts directly when their development level is considered. Therefore the concepts discussed within this program have been selected from factual and finite existence mode. In case the students realize that mathematics is an indispensable tool for everyday life, then they shall develop a positive attitude towards it. The program has been prepared by considering the integrity of elementary schools and the topics have been prepared according to the development level of the students for each class. (MONE, 2004)

Newly developed Mathematics curriculum is different from the old one by some aspects (BoE, 2005). New Curriculum;

- follows a conceptual approach in order to enable the students to comprehend and consider mathematics abstractly by using their institutions and experiences,

- is based on the fact that the students shall actively participate in the learning process,
- enables the students to express their individual differences and abilities via projects and specific homework,
- aims to prepare environments where students may research, discover and where they may discuss their solutions,
- aims to develop the students psychomotor abilities via using materials at activities,
- aims to provide the students with an education appropriate for the environment they live in via activity samples adaptable to different periphery environments.

The primary mathematics curriculum has many characteristics: it has four learning areas supported by skills, understanding and attitudes; there is a spiral approach for each learning areas; mainly based on the constructivist approach; enriched with teaching activities and multiple assessment methods and techniques. The four learning areas are the following: Numbers, geometry, data and measurement. (MONE, 2004)

The *numbers* learning area aims; to develop the ability of using the numbers and digits, to develop the estimation and operation abilities via understanding the four arithmetical operations, to ensure that the students associate the fractions, percentages and the decimal fractions, to ensure that the students determine the relations within patterns and that they apply all these information to the problem situations.

The *geometry* learning area aims; to develop the spatial (situation – location, direction – angle) abilities, to ensure that the students determine the relations between the geometric shapes and objects, to teach decorating with planar shapes, to teach them to determine and use symmetry, to teach them to use geometry tools and materials.

The measurement learning area consists of the measurement units, which the students shall face and need during their lives. The development of the estimation abilities for the students has been emphasized as much as the development of the concepts of measurement.

While forming the *data* learning area the starting point was based on the fact that the students should be conscious citizens and they should be able to analyze the data they come upon during their everyday lives. The data gathering, organizing and interpreting abilities were emphasized. The probability topic has been taught at a intuitional base starting from the 4th grade (BoE, 2005).

The students shall develop more creative and constructive attitudes as they become successful at the problem solving process and as they feel that their own ways for solving problems are appreciated, because their confidence about their mathematical abilities shall increase. When they learn to communicate by using mathematics they shall restructure what they learnt and by this way they shall develop their high level thinking abilities. The students shall realize that mathematics does not only consist of rules and memorizing but that it is an entertaining, meaningful and logical profession.

The program is open for technology usage. The students are encouraged to use calculators for problem solving but not for doing basic operations. It is believed that by this way an opportunity for working on more realistic problems shall become possible and they shall conclude the operations quicker and save from time. With the developing computer technology of our day the education software creates new opportunities for students to learn mathematics more meaningfully. There are also sources on the Internet for the teachers.

The program aims to provide that the mathematics teachers determine the running time and order of the learning areas and sub-areas. According to this while preparing the sections the main point to be considered is to consider the learning areas and their earnings together. While preparing the sections' activities these associated earnings should be brought together.

The mathematics program emphasizes on learning with cooperation, problem solving, discovering, and the importance of diversity. The main principle for determining the educational methods is to be sure that to the activities planed should ensure that the students are mentally and physically active (MONE, 2004).

The program has positive effects on teachers, students and parents, because students are active in lessons, has positive attitude towards mathematics. However, teachers have some problems about assessment methods in practice (Temiz, 2005). Students' higher order thinking level can improve by new program but there are problems about learning activities and assessment (Baykul, 2005).

According to Ozdas, A. Tanisli D., Kose, N.Y. & Kilic C (2005), teachers believe that changes about the content of old program is necessary and new program's subjects such as patterns, tessellation and probability are useful and interesting for students. Also, teachers believe that mathematical content connected with real life by means of newly developed mathematics curriculum.

The existing literature revealed that there are a few study pertaining to the implementation of new mathematics curriculum. In this regard this study was significant because it is believed that the findings of the study would shed on light the future studies and provide several feedbacks to decision makers on curriculum development.

Purpose of the study

This study aimed at analyzing the primary school mathematics curriculum, started to be developed in 2004, based upon the views of teachers and students. The analysis of the curriculum was realized by considering the issues of (1) Classroom management – classroom physical and emotional environments, teacher and student roles, and interactions, (2) Instruction – objectives, planning, implementation, method and techniques, instructional media, and measurement and evaluation, and (3) Strengths (and/or benefits) and weaknesses (and/or limitation). Furthermore, based upon the teachers' views, whether the change in the primary school math curriculum is required (necessary) or not was also tried to be revealed.

METHODOLOGY

This is a qualitative case study facilitating to obtain in depth information not only from the teacher but also from the students who experienced the new primary school mathematics curriculum. For this study, qualitative methodologies were selected because, as stated by Patton (1987), using qualitative methods provide insights, understandings and deep information about the issue under investigation.

The teachers were firstly asked to mention about in-service training in which they participated to get informed on newly developed primary school mathematics curriculum. They were required to respond where and when it was done and which aspects of the new curriculum were introduced. The in-service training was performed in one of the universities' (METU-Middle East Technical University) Cultural and Conservation Centre on the dates of 1st-14th September, 2004 in Ankara. The training lasted fourteen days. Throughout the in-service training, new mathematics curriculum was overall introduced to the participants. Further, they were informed on the main philosophy underlying the curriculum, the topics (units and subjects) to be covered, guide book to be used, activities and implementation of those activities, and measurement and evaluation methods. In addition to general aspects of the newly developed mathematics curriculum, an understanding of relating course topics with real life and of learning by doing and living were mentioned as well.

Participants

The participants of the study included three primary classroom teachers and forty-three fifth grade students. The participants were selected based upon purposeful sampling procedures from one primary school in Ankara in Turkey. Because of the confidentiality, the name of the school was not stated here. The school was one of pilot schools that the new developed mathematics curriculum was implemented. One teacher was male and the others were female. Their experiences were different from each other. One of the female teachers was working as a teacher for 17 years. The other one had 18-year-experiences in teaching profession. On the other hand, the male teacher who was the most experienced one had 27-years-experiences. Of the students, 23 were girls whereas 20 were boys. Their ages ranged from 10 to 11.

Data Collection

The qualitative data collection procedures were used for obtaining data from the participants. One semi-structured interview consisting of six open-ended and three demographics questions was developed for classroom teachers serving fifth grade courses (mathematics, science, social sciences…etc). The teachers were asked to give information about in-service training done, the reasons why changes in mathematics curriculum was needed, differences between existing and new curriculum, affirmative aspects of newly developed curriculum, the problems that they faced with during the implementation of newly develop curriculum. At the end, they were required to provide their suggestions for other classroom teachers that would implement new curriculum for next years. In order to collect data from the students, an instrument in which one open-ended question was asked to the students so as to describe the differences between last year mathematics course and current course was developed. Student allowed responding the question either by writing or by drawing picture or by using both methods. These two types of instruments were reviewed by three curriculum developers to ensure content coverage; that is, content validity. Based upon their suggestions, the last forms of the instruments were developed. Having obtained the necessary permissions from the schools, the instruments were sent to the one of pilot school in Ankara in the academic year of 2004-2005. Before administering the instruments, pre-interviews were carried out with teachers in order to make them inform about purpose of the study. Also, the clear directions were given to in the instruments. Once they completed the forms, they sent those back to the researchers. Even though the instruments were developed for conducting interview, since teachers did not want to carry out face-to-face interview, they were requested to write their responses for each question.

Table 1. The comparison of existing and new mathematics curriculum by teachers

Themes	Existing Mathematics Curriculum	Newly Developed Mathematics Curriculum
Teachers' roles in classroom	(1) Dominant in class and (2) information-giver	(1) Facilitator, (2) Guide, and (3) not active as before
Students' roles in Classroom	Passive	(1) Active, (2) Skillful, (3) Learner by doing and living, (4) logical thinker and (5) interpreter
Interaction (Between Students-Students / Teacher-Students)	Lack of interaction	(1) Cooperation, (2) Helping each other, (3) Knowing themselves and their skills
Course Content	(1) Abstract, (2) Hard to understand and (3) Excessive topics to be covered	(1) Diminishing course content, (2) Enhancing some topics (symmetry, pattern construction…etc)
Methods and Techniques	(1) Lecturing and (2) Questioning-answering	(1) Induction methods and (2) Group working
Knowledge acquisition process	Transmitted	Constructed by students
Students' attainments	Product-oriented	(1) Easy to reach, (2) Reasonable and (3) Process oriented
Evaluation Procedures	Product-oriented	(1) Integration of Evaluation into Instruction, and (2) Process-oriented as well as product

Data Analysis

The data were analyzed by using one of qualitative research analysis methodologies; content analysis. Once the responses were collected, they were complied and then, they were coded under each question. In order to ensure reliability of results, the methods of inter-rater reliability was used. That is, the complied data were coded by two experts; one is expert on mathematics education and the other one is expert on curriculum development. Codes emerged by two experts indicated similar results. The inter-rater reliability was high.

RESULTS

The results were broken down into two main categories; *te*achers and students. Then themes were constructed by considering the codes emerged from the data. The themes of teachers' role, students' roles, interaction between students-students and teacher-students, course content, methods and techniques, knowledge acquisition, students' attainment and evaluation procedures were mentioned under these categories.

Teachers' views

As clear from the background information of the teachers, they had long experiences in classroom teaching profession. Their experiences ranged 17 years to 28 years.

Teachers participated in this study believed the importance of the change in the previous math curriculum. They thought that the basic reasons underlying the curriculum reform and/or change in mathematics curriculum were abstractness and hardness of the topics (subjects in previous curriculum) to students' development level. They also reported that students did not understand why to learn what were covered, because these topics had been covered without their real life implications. There reasons why the reform in curriculum was required were abstractness and hardness of the topics, and the lack of real life implementations. They believed that the changes in the curriculum provided students with opportunities to learn the topics by doing and living. They indicate that new curriculum provides the students with plenty of practice in their studies. In addition, new curriculum contributes the students to understand the importance of subjects taught in classroom and to relate them with real life.

For the sake of comparison, the teachers were asked to mention about the distinct differences between previous and new curricula based on the aspects of teacher and student roles, interaction, course content, method and techniques, knowledge acquisition process, objectives, and evaluation process. Teachers' responses are summarized in table 1. They reported that teachers in the existing curriculum were active and information-giver, and had more work load while they have started to act as facilitator and guide in implementing new curriculum. Their work loads seem to be lessened in implementing new curriculum.

The active role taken from the teachers has been given to the students. Students have been placed at the centre of the education. In other words, students have been activated. They have undertaken active roles in the classroom. In this way, they have realized their skills and capacities, as claimed by teachers. This helps the student develop self-awareness. Students have been started to execute their duties by living, doing, interpreting and logically thinking.

The teachers seem to have difficulty in arranging the physical classroom environment since they are so many students in the classroom. In spite of crowded classrooms, newly developed curriculum provides the students with more interaction and cooperation by offering group work and discussion activities. It seems that the interaction between student and student, and teacher and students has been encouraged with new mathematics curriculum. As mentioned by the teachers, the interaction enables the students to communicate, cooperate (with) and help each other and teacher. Looking at the content of the course in the new curriculum, some topics were taken from course content and some (e.g. symmetry, pattern construction, and prediction …etc) were enhanced. Further, some topics that were abstract to the students were taken out as well. In the implementation process, since there were no mathematics books written in line with new approaches on which the new math curriculum based, the teachers were generally prone to use internet web site constructed for new mathematics curriculum by the Board of Education.

The teachers believe that the topics in new primary school mathematics curriculum are more in line with the students' development level. Since the students have not received the knowledge from the teachers passively and they have reached knowledge by doing, living, and searching, the students have constructed their own knowledge by themselves. As also indicated by the teachers, the knowledge constructed and thus gained are more permanent because the students have opportunities to solve problems and to do activities, and also to relate theoretical knowledge with their real life. In this respect, the attainments, called objectives in previous curriculum, related to units and topics are comprehended in a process. Teachers believe in that students would be more successful with the new curriculum. Students' outcomes were assessed by diversity of evaluation procedures. Since instruction and evaluation is tied in new curriculum, students' performance was evaluated in each step of the instruction. The evaluation goes hand in hand with instruction. The evaluation procedures used focus upon process-oriented methods as well as product-oriented methods. However, the crucial problem in implementing new curriculum that the teachers faced in relation to grading students' performance is the inadequate use of rubric. In addition, since, as teacher indicated, the time allocated for the evaluation was not substantial, they have difficulty in evaluating students' performance.

The teachers were also asked to review whole mathematics curriculum and to explain the strengths and weaknesses of the curriculum based upon their experiences during the pilot administration of the curriculum. Their responses are summarized in following Table 2.

Table 2 presents that the newly developed mathematics curriculum has many strengths as well as some weaknesses. In relation to strengths mentioned by teachers, the new curriculum serves many visualized and student-centered activities. The topics to be covered are not much more detailed as it was before. In addition, the other positive aspect of the curriculum is that it enables the students to construct their own knowledge by living, doing, searching, sharing, and experiencing. These processes provide the opportunities for the students to self-express, to be self-confident and self-awareness. Also, with new curriculum the teachers adopt the roles of guide and facilitator. Being guide and facilitator promote the teacher to develop and equip themselves with necessary skills. The new curriculum encourages cooperation among groups (for example between teachers in math group and teachers in science group) in schools in order to overcome the problems and difficulties faced. All the processes emphasize the importance of participation of each student in class activities. In other words, the new curriculum emphasizes the understanding of "*no students left behind*".

Despite the fact that the newly developed mathematics curriculum has several strengths, it has some weaknesses, as claimed by teachers, as well. According to them, the in-service training given before pilot testing was not adequate to make understand the vision and mission of whole curriculum, and philosophy underlying. They believe that the activities suggested are not applicable in crowded classrooms. The infrastructure facilities of schools were not sufficient for the realization of the activities suggested. They complained that no books prepared in line with new mathematics curriculum provided for the teachers. In addition, they believed that they left alone with new curriculum without any supports.

At the end, the teachers were required to provide suggestions based upon their experiences with new curriculum for the other teachers who would implement the new curriculum next years. They suggested for their colleagues to consider some issues in relation to time, evaluation procedures, visual materials, group working and activities. They suggested that the teachers be careful about the time devoted both for instruction and

Table 2. The strengths and weaknesses of the newly developed mathematics curriculum

Strengths **of the newly developed mathematics curriculum**	***Weaknesses*** **of the newly developed mathematics curriculum**
(1) Learning by doing and living	(1) Inadequacy of in-service training
(2) Encouraging the students to construct their own knowledge by living and doing	(2) Unsuitability of activities for crowded classroom
(3) Encouraging the students to share their knowledge with others	(3) Lack of mathematics books
(4) Student-centered rather than teacher- or subject-centered	(4) Lack information given about the evaluation procedures during in-service training
(5) Visualized	(5) Lack of Infrastructure of schools
(6) Not detailed	(6) Insufficient use of technological devices
(7) Suitable to students' development level	(7) Leaving the teachers alone with new curriculum
(8) Enabling the students to self-express, to be self-confident, and self-awareness	
(9) Encourage the teacher to develop themselves	
(10) Emphasizing the understanding of "no students left behind"	
(11) Encouraging the cooperation among the teachers	

evaluation processes. They added that the lessons should be enhanced with visual and technological equipments to get attention and curiosity. The group work activities should be encouraged so that interaction among the students can be ensured. In addition, they suggested that the teachers seek for new materials that can be easily found, and for play (game) activities relevant to students' development level.

Students' views

The students were required to compare the previous mathematics course and new mathematics course (newly developed mathematics curriculum) by considering all aspects of the course; teachers, classroom, evaluation…etc. Their responses varied. Students' responses were consistently parallel to teachers' responses. Most of them are satisfied with the chances in the curriculum, but a few was not. The students' responses are summarized in table 3.

Students found the last year mathematics course boring and unpleasant due to some reasons. One of those reasons was the extensive topics covered. They claimed that it took plenty times to cover some of the topics. This made the student bored. Since the teacher preferred to use the methods of lecturing and expression, the students just listened to the teachers and wrote some notes. The information was transmitted from teacher to students. As claimed by the students, teachers just tried to complete the topics to be covered without considering whether the students understood the subject studied. Further, they asserted that it was difficult for them to understand and learn some of the subjects; especially the subjects of geometry (e.g. *triangles*). During instructions, it seemed that the teachers were active in classroom rather than students. In this regard, parallel to teachers' claims, the students reported that they had lack of self-confidence in classroom since the teachers were dominant in class and the interaction between students-students and students-teacher were not adequately encouraged. They got bored because they had difficulty in solving questions and doing homework, they were not encouraged to participate in classroom activities, and they generally used traditional materials like paper, pencil, blackboard rather than visualized and technological materials.

They asserted that problem solving activities were done in classroom. As understood from the picture drawn by students coded 34, the questions studied seem to be more related to developing lower level of cognitive skills of students in last years (*seeFigure 1*).

The activities done in classroom were not student-centered. Further, the students sometimes did not understand why they were doing such activities. It seems that the objectives of the course were not shared with the students and it was not clear what was expected of the students at the end of the instruction as claimed by *students-33*. The course book was always used as a reference source. There seemed to be book dependency in classrooms. The students claimed that the assignment given were somewhat difficult for themselves. For this reason, they sometimes did not do their assignment by themselves and they tended to cheat from their peers. They had an exam-anxiety since they felt that they were going to be unsuccessful in the exam. In order to assess students' performance, the teacher always preferred to use traditional evaluation procedures (such as written and oral exams) as mentioned by students.

Table 3. The comparison of existing and new mathematics curriculum by students

Aspects	Existing Mathematics Curriculum	Newly Developed Mathematics Curriculum
Teachers' roles in classroom	Active	(1) Not completely active, (2) Facilitator
Students' roles in Classroom and their characteristics	(1) Passive, (2) Listener, (3) Not attentive, (4) Lack of self-confidence	(1) Active, (2) Self-expressive, (3) Self-confident, (4) Self-aware, (5) Researcher, (6) Sharing with peers, (7) Participative, (8) active thinker
Interaction	Inadequate	Encouraged
Course Content	(1) Difficult to understand, plenty of topics to be covered, (2) Dependency of books, (3) long topics	(1) Easy to understand, (2) Enhanced topics, (3) Extracting some topics, (4) Use of activity sheets
Methods and Techniques	(1) Lecturing, (2) Memorization of subjects, (3) Questioning-answering, (4) reading and writing	(1) Problem solving, (2) Play, (3) estimation making, (4) Researching
Classroom Activities	Subject- and teacher-centered	Visualized and student-centered activities
Knowledge acquisition process	(1) Transmitted from teacher to students, (2) Passively received	Actively constructed by students under the guidance of teacher
Students' attainments	(1) Not clear, (2) Not shared with students, (3) Lower level thinking	(1) Clearly stated and shared with students, (2) Higher level think
Evaluation Procedures	Traditional methods (written and oral exams)	Portfolio

On the other hand, looking at the new mathematics curriculum depending on students' responses, most of the students seem to be satisfied with new one compared to the existing one. The reform in the mathematics curriculum has brought rise to many chances in classroom environment as understood from the students' responses. These changes are realized by students and they reflect their views through the pictures, and writings. *Student-3* and *student-42* explicitly mentioned about the entrance to new system. Similarly, *students-23* said that "*this year, mathematics course is funny. Our teacher has changed his teaching style*". In the new system, as perceived by students, the teacher is not active, as he was before, any more. The teacher acts as facilitator, and motivates the students toward mathematics. The active role of teacher in existing curriculum is given to the students. The students are undertaken to the role of researcher, active thinker and

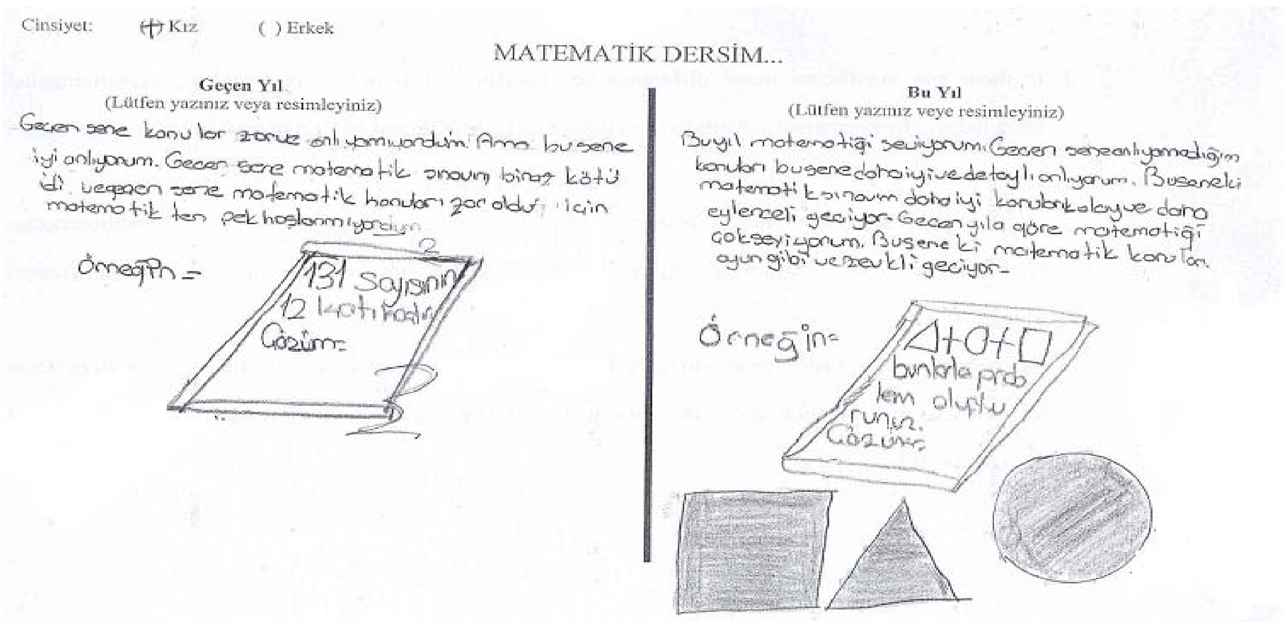

Figure 1. A Picture drawn by a student on comparison between last years and now (student # 34).

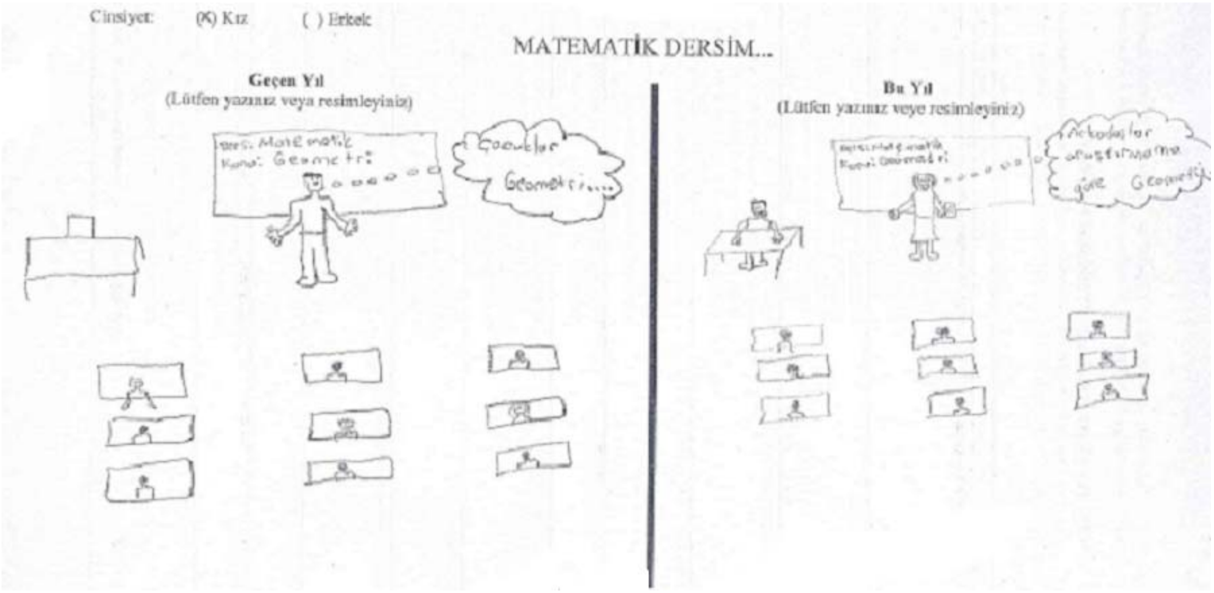

Figure 2. A Picture drawn by a student on comparison between last years and now.

interpreter as well. The students are aware of this situation and they seem to be as active as possible. To them, being encouraged by teachers and being active in classroom makes them interact with teachers and their peers, share their knowledge with others and participate voluntarily in the classroom activities. In this way, they seem to become aware of their skills and capacities. Further, starts to share their knowledge, experiences and their research findings in front of classroom (see Figure 2).

By doing so, as claimed by students, they have started to express themselves (*self*-expresses). Also, they seem to deal with the problem of self-confidence as they had lack before (last years).

As indicated by most of the students, they enjoy funny times during lessons since the visualized and students-centered activities are used in classroom and technological devices are integrated into the course implementation. The students are given opportunities to involve in practice activities by encouraging class participation. In the process of making instruction easier for students, and of making the topics concrete and relate with the real life, they generally play games in the classroom. They prepare play cards for their activities. Playing games enable the students to easily understand the subject studied and to grasp main points. In addition to playing activities, they have actively constructed their knowledge in writing, reading, applying and researching as well.

The students believe that the topics covered in this year are easy to understand since they are related and similar to the topics in last year mathematics course. Some topics are enhanced and improved, but some topics were extracted from the curriculum. The topics are studied with the support of visualized materials and technological devices; especially OHP.

In contrast to previous curriculum, the students seem to believe that they have improved their mathematics and these improvements has reflected on their exam results. In the classroom, they solve many problems by playing games and sharing with others. The teacher provides many materials to the students and wants them to create their own questions so as to develop students' creative thinking. Further, the teacher encourages the students to estimate the problems given by logically thinking. As understood from the students' drawings, the questions asked in the classroom seem to be related to developing higher order thinking skills (see Figure 1). During the learning process, the teacher requires the students to use separate sheets for activities instead of notebooks. Then, the activity sheets written by students are collected and they are filed in the students' portfolio. The portfolio here is used as a learning tool as well as assessment tool.

DISCUSSION & CONCLUSIONS

This was qualitative case study seeking for in dept information about the implementation of math curriculum. The study was realized with fifth grade students and classroom teachers who experienced pilot administration of new mathematic curriculum. The results of the study revealed so many significant findings addressing to the classroom design, teachers' and students' new roles, classroom implementation, and instructional delivery. Further the study indicated that the teachers had several difficulties.

The findings of the present study were so much parallel to the findings found by Toptas (2006) who conducted a study with classroom teachers to determine their difficulties with implementing the new curricula. He found that the main problems confronted by teacher were regarded as insufficient sources, lack of instructional medium, insufficient time for instruction and evaluation, and insufficient number of activities.

According to Güzel & Alkan (2005), students had positive opinions about the application of the constructivist learning approach utilized in the new program. For instance, the students reluctantly behaved in sharing responsibility. These are parallel to the findings of the present study. On the other hand different from teachers' views in this study, they found that , the students could not establish relation with the science, the real world and the school.

In relation to strengths mentioned by teachers in this study, the new curriculum emphasizes the understanding of "*no students left behind*". Similarly Çakmak & Bulut (2005) stated that teachers can enable children to learn and understand what is taught effectively if teachers have effective strategies. Consequently, newly developed mathematics curriculum gives opportunities for students and teachers about effective teaching and learning.

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Analysis of new Zambian High School Physics Syllabus and Practical Examinations for Levels of Inquiry and Inquiry Skills

Frackson Mumba, Vivien Mweene Chabalengula and Kevin Wise
Southern Illinois University, Carbondale, USA

William J. F. Hunter
Illinois State University, Normal, USA

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The purpose of this study was to analyze the new Zambian high school physics syllabus and practical examinations for levels of inquiry and inquiry skills. Several inquiry skills are explicitly emphasized in the introduction, aims, content objectives and assessment sections in the national high school physics syllabus. However, the syllabus is less explicit on levels of inquiry. The syllabus has no suggested inquiry activities and guidelines for inquiry-based teaching. As such, teachers are expected to create inquiry activities for their physics lessons to address the content and inquiry skills outlined in the syllabus. The experiments in the practical examinations were restricted to structured and confirmation/verification inquiry levels. The inquiry skills emphasized in the practical examinations were the same as those outlined in the physics syllabus. Implications for science teaching, learning, and curriculum design have been stated.

Keywords: High School, Inquiry, Physics, Practical Examinations, Syllabus

INTRODUCTION

On the advent of independence in the 1960s, many African nations revamped their school curricula with a view to satisfy the aspirations of their citizens. Zambia, like many African countries, made changes to its high school science curriculum that had been inherited from Britain. Recent changes to the national high school science curriculum were made in 1998 to align it with then current trends in science education. These changes gave birth to the new national high school physics syllabus which was implemented in schools in 2000 (Curriculum Development Center [CDC], 2000). One other major change in the high school physics curriculum was the introduction of practical examinations. The national physics practical examinations are taken by all high school students at the end of grade twelve as a requirement for their school certificate. The physics practical examinations are prepared using the national physics syllabus as a guide. The introduction of the physics practical examinations underscores the importance of developing and assessing scientific inquiry skills among Zambian high school students (Ministry of Education, 1996). To date, the new national physics syllabus and practical examinations have undergone seven cycles of implementation since their introduction in high schools. However, these new curriculum materials have not been evaluated for the four inquiry levels C*onfirmation, Structured, Guided and Open* (Tafoya, Sunal & Knecht, 1980) and inquiry skills (Tamir & Luneta, 1981) that are emphasized in science education. This lack of evaluation of the new Zambian

Correspondence to: Frackson Mumba, Department of Curriculum and Instruction, 625 Wham Drive, Southern Illinois University Carbondale, Illinois 62901, USA.
E-mail: Frackson@siu.edu
Phone: 618 453 6162, Fax 618 453 4244

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physics syllabus and practical examinations for inquiry levels and skills was the main justification for this study.

The analysis of the Zambian high school physics syllabus and practical examinations for inquiry levels and inquiry skills is desirable, not only to Zambian science educators but also to science educators elsewhere, who have, or plan to implement a similar physics syllabus and practical examinations at high school level. It was also assumed that the findings would provide important implications for teaching, learning and curriculum design. This study was guided by the following questions: (a) What levels of inquiry are emphasized in the new national high school physics syllabus and practical examinations? (b) What inquiry skills are emphasized in the new physics syllabus and practical examinations?

Definitions and previous research on inquiry

In science education, inquiry has two separate identifiable meanings which are *teaching and learning science by inquiry* (Tamir, 1985) and *science as inquiry* (Eltinge & Roberts, 1993). Teaching and learning science by inquiry involves the means by which students gain knowledge. It includes the development of inquiry skills, such as the abilities to: identify and define a problem, formulate a hypothesis, design an experiment, collect and analyze data, and interpret data and draw meaningful conclusions. On the other hand, science as inquiry extends the image of science beyond that of a collection of facts, to include viewing science as a method by which facts are obtained. Both of these types of inquiry approaches are important in science education. However, this study focused on teaching and learning science by inquiry, because the purpose of the study was to evaluate the high school physics syllabus and practical examinations for levels of inquiry and inquiry skills.

Science educators from around the world have examined science curriculum materials for inquiry levels and skills. For example, in Israel, Tamir and Luneta (1981) analyzed high school science textbooks and found that the activities in the textbooks lacked opportunities for students to investigate and inquire. In another study of curriculum materials used in Israel, Friedler and Tamir (1986) analyzed high school science laboratory manuals and classroom observations and found that most activities were at lower levels of inquiry. Friedler and Tamir further found that rarely were students required to: identify and formulate problems and hypotheses, design experiments, and work according to their own designs. In a Nigerian study, Okebukola (1988) reported that the activities in the revised pupils' textbooks and workbooks I and II of the Integrated Science Project were highly structured and deductive in approach with a high emphasis on low level inquiry skills. In the USA, Pizzini, Shepardson and Abell (1991) analyzed activities in commercial junior high school science textbooks and their accompanying supplemental activity guides for inquiry. They found that most of the activities were at the confirmation and structured levels of inquiry. However, there was a statistically significant difference in the frequency of inquiry level of activities among the science textbooks, supplemental activity guides, and disciplines. In another study on curriculum materials used in the USA, Germann, Haskins and Auls (1996) found that high school laboratory manuals only rarely called upon students to use their knowledge and experience to ask questions, solve problems, investigate phenomena, construct answers or make generalizations. In Western Australia, Staer, Goodrum and Hackling (1998) examined the laboratory activities undertaken by lower secondary school science students in an attempt to determine the openness to inquiry of these activities. They found that most activities were at lower levels of inquiry, despite science teachers being aware of the benefits of using higher levels of inquiry. Many teachers cited time constraints, management problems, and equipment demands as reasons for not using open inquiry activities in their classrooms. In a Caribbean study, Soyibo (1998) analyzed the practical activities prescribed in eight process-oriented integrated science textbooks for pupils of grades 7-9 for the structure and skill level of the tasks. The results suggested that most of the tasks were structured and deductive in approach with an emphasis on low level inquiry skills. Soyibo observed that the continued use of the activities provided in the textbooks in Caribbean schools may not effectively facilitate the development of inquiry skills among students which they would need to carry out open-ended scientific investigations in the future.

This review of previous studies from around the world indicates that many science curricula offered few opportunities for open investigation work and development of high-order scientific inquiry skills that are emphasized in science education reforms (American Association for the Advancement of Science [AAAS], 1993; Ministry of Education, 1996; National Research Council [NRC], 1996). It is also evident from literature that science educators have mainly examined textbooks and laboratory manuals for inquiry levels and inquiry skills. Science syllabi and practical examinations have not be examined for inquiry levels and skills. Yet, in many countries like Zambia, national science syllabuses and examinations are used by teachers as main guides for instruction in their classrooms. The practical examinations are also used as tools for assessing scientific inquiry skills among students. Therefore, this study went beyond previous research studies by examining the national physics syllabus and practical examination papers for inquiry levels and inquiry skills.

Overview of Zambian high school physics education

Zambia has a centralized education system and all high schools follow one national curriculum. High school education starts in grade ten and end in grade twelve. Students' admissions to high school are based on their performance in the national junior high school examinations, which they take at the end of grade nine. Physics is a compulsory subject and all students are required to take it for three years in high school. The national physics syllabus serve as one of the main resources for physics teaching and learning in high schools. Each physics teacher is given a copy of the national physics syllabus as a guide for the scope and depth of the content to be taught. There are five periods of physics instruction in a week per class and each period is forty-five minutes long. There are three school terms in a year: January to April, May to August, and September to December, and each term is thirteen weeks long. At the end of twelfth grade, students take national examinations which are equivalent to the Ordinary-Level standard in the British education system for certification, admission to post-secondary school education, training, and employment. In physics course, students take three examination papers namely: Paper 1 (40 multiple-choice questions), Paper 2 (8 structured and essay questions) and Paper 3 (4 laboratory-based experiments). This study is focused on the physics syllabus and Paper 3 which is the physics practical examination. The national physics examinations are prepared by experienced high school physics teachers and physics lecturers from a local national university in conjunction with the Examination Council of Zambia. The examiners use the national physics syllabus as the guide for preparing these examinations.

METHODOLOGY

Sample

Data sources were the new national high school physics syllabus and six physics practical examination papers that were written by high school students between 2000 and 2005. The physics syllabus is fifty pages long and has five main sections: introduction, general aims, topics, content, and assessment objectives. There are twelve main topics namely: Measurements, Mechanics, Thermal physics, Light, Sound, Wave motion theory, Magnetism, Static electricity, Current electricity, Electromagnetic induction, Basic electronics, and Atomic physics. Under each topic, there are content objective statements. The numbers of content objective statements vary from topic to topic, and part of the reason for such variation could be due to the amount of content to be covered. The national high school physics practical examination is a two-hour laboratory-based examination, printed on seven pages. Each physics practical examination paper has four main experiments (questions) on different topics, and has two sections, A and B. Section A has three experiments while section B has one. Therefore, a total of twenty-four experiments in the six practical examinations papers written by students between 2000 and 2005 were examined for levels of inquiry and inquiry skills.

Analysis frameworks

Levels of inquiry in the new national physics syllabus and practical examinations were determined by using the analysis framework and procedure that was developed by Tafoya, Sunal and Knecht (1980). Pizzini, Shepardson and Abell (1991) also used this framework to examine junior high school science textbooks for inquiry levels. The framework classifies the inquiry level of activities as Confirmation/verification, Structured, Guided, and Open. Confirmation/verification-inquiry level activities require students to verify concepts through a known answer and given procedure that the students follow. Structured-inquiry level activities present students with a problem in which they do not know the results, but they are given a procedure to follow in order to complete the activity. Guided-inquiry level activities provide the student only with a problem to investigate. Students are given a chance to determine the procedure to use and the data to collect. Open-inquiry level activities allow students to formulate hypotheses or problems and the procedure for collecting data for interpretation and drawing conclusions.

The physics syllabus and practical examination papers were further analyzed for inquiry skills using a modified Laboratory Structure and Task Inventory (Tamir & Luneta, 1981). The original Laboratory Structure and Task Inventory have two main sections:
(a) Laboratory organization with 14 categories in four sub-sections and (b) Laboratory tasks with 24 inquiry skills statements in four inquiry task sections. This is a valid and reliable framework and several science educators have used it to analyze science textbooks for structure and levels of inquiry (Okebukola, 1988; Soyibo, 1998). We only adopted the second section and modified it by decreasing inquiry tasks statements to 20 in order to meet the needs of this study (See Table 3).The four Inquiry task sections in the framework are: Planning and design [Inquiry task section 1], Performance [Inquiry task section 2], Analysis and interpretations [Inquiry task section 3] and Application [Inquiry task section 4]. Each Inquiry task section has inquiry skills outlined.

Analysis procedures

Since a variable in determining the inquiry levels and inquiry skills is the content of the textual information presented, the sections analyzed in the physics syllabus were introduction, general aims, notes to teachers, and content and assessment objectives. These sections were read and matched with inquiry levels and inquiry skills outlined in the two analysis frameworks. Similarly, the physics practical examination papers were analyzed for levels of inquiry by coding textual information on each experiment such as background information, aims, list of materials, instructions and procedures. Then the codes from each experiment were matched with the characteristics of the four levels of inquiry stated above. A total score was obtained for each level of inquiry and percentages for each year were calculated. The procedure for analyzing inquiry skills emphasized in physics practical examinations involved analyzing the experiments. All parts of the experiments including instructions, aims, questions, procedures, diagrams, figures and tables in the examination papers were coded by placing a check in the appropriate inquiry skill statement in the modified framework. If a statement in the experiment called for more than one inquiry skill, more than one check was made. For each inquiry skill statement the checks were tallied. Then this number was divided by the total number of inquiry skills identified in each paper and expressed as a percentage for each year.

Two physics educators independently coded the physics syllabus and practical examination papers for levels of inquiry and inquiry skills using the procedures described above. An intercoder agreement coefficient was calculated using Cohen's Kappa (Cohen, 1960). This coefficient factors in chance agreement and represents a measure of reliability.

RESULTS

Intercoder agreement

As shown in Table 1 below, the percentage agreement between the two raters for the physics syllabus and practical examination papers analyses ranged from 85% to 93% with a corresponding range of kappa values from 0.82 to 0.92. These statistics suggest a high degree of agreement between the two raters in categorizing the levels of inquiry and inquiry skills in the physics syllabus and practical examination papers. The values above 75% indicate excellent interrater agreement while kappa values below 0.4 indicate a poor coefficient (Chiappetta, Sethna & Fillman, 1991).

Table 1. Intercoder agreement coefficients for physics syllabus and examination papers.

Course Material	*Percent Agreement*	*Kappa*
Physics Syllabus	89	0.88
2000 (N= 208)	93	0.92
2001 (N= 200)	89	0.88
2002 (N= 123)	88	0.86
2003 (N= 190)	91	0.90
2004 (N= 173)	89	0.88
2005 (N= 184)	85	0.82

Note: This data is from two raters who conducted the coding. N= Number of codes in each year.

Inquiry levels and inquiry skills in the physics syllabus

Inquiry is explicitly emphasized in the introduction and aims sections in the high school physics syllabus as shown below:

> This syllabus aims at stimulating pupils' curiosity and sense of enquiry which will in turn not only provide suitable basis for further study of the subject but also provide pupils with sufficient knowledge and understanding to make them become useful and confident citizens. The essence of such an enquiry is related to problem solving and reflecting on scientific enterprise. During this course pupils should acquire practical abilities associated with investigation of certain phenomena and principles in physics. Pupils should develop scientific attitudes such as open mindedness and willingness to recognize alternative points of view (CDC, 2000. p. vii).

Several inquiry skills and some inquiry levels are outlined in the introduction, aims, notes to teachers and content objectives sections in the high school physics syllabus as shown below:

> During the course students should know how to: follow instructions [Structured & confirmation Inquiry levels & Inquiry task section 2]; use techniques, apparatus and materials; observe, measure and record [Inquiry task section 2-Performance]; plan investigations [Inquiry task section 1- Planning and Design; Open Inquiry]; interpret and evaluate observations and results [Inquiry task section 3- Analysis and Interpretation]; evaluate methods and suggest possible improvements [Inquiry task section 4-Application; Guided Inquiry] (CDC, 2000. p. xii).

The assessment section also states that the physics practical examinations will focus on assessing students' knowledge, understanding and application of:

> …scientific apparatus and instruments and their safe operation [Inquiry task section 2-Performance]; translating information from one form to another manipulate numerical data, plotting results graphically, identify patterns and

draw inferences from information' give reasonable explanations for patterns and relationships, [Inquiry task section 3- Analysis & Interpretation], make predictions and hypotheses, and experimental methods evaluation and possible improvements [Inquiry task sections 1 & 4, Guided Inquiry] (CDC, 2000. p. viii & xi).

Although the physics syllabus outlines several inquiry skills and some levels of inquiry, it has no suggested inquiry activities and guidelines for implementing inquiry-based science teaching. As such, teachers are expected to create inquiry activities for their physics lessons to address the content and inquiry skills outlined in the syllabus.

Inquiry Levels in the physics practical examinations

The analysis revealed that across the six year period the experiments in the practical examinations were at structured inquiry level (50% to 100%) and confirmation/verification inquiry level (0.0% to 51%). One example of a structured inquiry activity was question 1 in the 2002 examination paper in which students were asked to determine the density of a piece of rock. The procedure provided involved Archimedes' principle and moments of force. Students measured distances of a standard mass and rock away from the pivot after the beam balanced (Y_1) and after (Y_2) submerging a rock in water. Then, students calculated the density of a rock using a given formula $(1-Y_1/Y_2)^{-1}$. An example of a confirmation activity was question 2 in the 2004 examination paper in which students were asked to verify that the distance of an object in front of a mirror is equal to a distance of its image behind the mirror. Table 2 also shows that in 2001 and 2002 all the experiments in the practical examinations were at structured inquiry level. In 2003 and 2005 structured and confirmation inquiry levels had equal representation (50%).

Only two (0.08%) experiments in the physics examination papers analyzed had two levels of inquiry though the levels were not equally represented in each experiment. For example, in the year 2004 question 4 had structured inquiry and confirmation/verification inquiry levels. The aim of the investigation was to study the relationship between the length and period of pendulum and determine the value of gravitational acceleration, g. The second part of this statement was a confirmation/verification activity because most students already knew, from their previous work in the course, that g on earth is 9.8 m/s^2.

Inquiry skills emphasized in the examinations

Each experiment started with the aim, instructions and list of materials. Some questions also had diagrams showing how the apparatus should be assembled or used. Safety precautions were also stated for experiments on heat and electricity. In most cases, standard data and formulae were provided by the examiners. Students were further instructed that an account of the method of carrying out the experiments was not required; instead, they were asked to perform all four experiments in the examination papers following the procedure provided and write a report for each investigation. For each three experiment in section A, students were only allowed to work with the apparatus for a maximum of twenty minutes.

For the question in section B, students were allowed to work with the apparatus for a maximum of one hour. Additional materials such as graph papers, electronic calculators, scrap papers, and answer booklets were provided. Table 3 below shows the percentage of inquiry skills distribution in the physics practical examinations.

Table 3 shows some consistency across the six years on inquiry tasks students were asked to perform in the practical examinations. The most emphasized were Performance (Inquiry task section 2) and Analysis and Interpretation (Inquiry task section 3). In Inquiry task section 2 (82.1% to 93.2%) students were mostly asked to, in decreasing order, take measurements or make observations, manipulate apparatus, record results, and draw and label diagrams following the instructions provided. The inquiry skills emphasized in Analysis and

Table 2. Percentage of inquiry levels in physics practical examinations.

	Inquiry levels			
Year	Confirmation/ verification	Structured Inquiry	Guided Inquiry	Open Inquiry
2000	28.8	71.3	0.0	0.0
2001	0.0	100	0.0	0.0
2002	0.0	100	0.0	0.0
2003	50.0	50.0	0.0	0.0
2004	31.3	68.8	0.0	0.0
2005	50.0	50.0	0.0	0.0

Interpretation (6.2% to 14.0%) were, in decreasing order, performing calculations and determining quantitative relationships, stating conclusions, stating precautions, transforming data and graphing data. In Inquiry task section 4 (Application) (0.0% to 1.1%), students were mainly asked to use their graphs to make predictions using given data. Students were neither asked to apply the experimental techniques they learned to a new problem nor to determine the accuracy of their experimental data. However, in some experiments students were asked to state and describe underlying assumptions, precautions or limitations of the experiments. In Inquiry task section 1 (Planning and design) (0.5% to 4.3%) the only task students were asked to perform, in some investigations, was to design tables in which to record their observations and measurements.

CONCLUSIONS AND DISCUSSION

The results show that the new national high school physics syllabus is more explicit on inquiry skills than on levels of inquiry. The physics syllabus also has no suggested inquiry activities and detailed guidelines on how to implement inquiry-based science teaching. Although this arrangement give teachers opportunities to create their own inquiry lessons, it may not be helpful to those who have limited training in inquiry-based science teaching.

The findings also show unbalanced coverage of inquiry levels and inquiry skills in the national physics practical examinations. The inquiry levels in the physics practical examinations were restricted to structured and confirmation inquiry levels, with the former dominating. To a large extent the findings in this study are similar to

Table 3. Percentage distribution of inquiry tasks and skills in physics practical examination papers.

Inquiry task & skills	Year					
	2000 N=208	2001 N=200	2002 N=123	2003 N=190	2004 N=173	2005 N=184
1.0 PLANNING & DESIGN						
1.1 Formulates a question, defines a problem	0.0	0.0	0.0	0.0	0.0	0.0
1.2 Predicts experimental results	0.0	0.0	0.0	0.0	0.0	0.0
1.3 Formulates hypothesis to be tested	0.0	0.0	0.0	0.0	0.0	0.0
1.4 Designs observations/measurements protocols (Tables)	2.8	3.5	1.6	0.5	3.5	4.3
1.5 Designs experiment	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**2.8**	**3.5**	**1.6**	**0.5**	**3.5**	**4.3**
2.0 PERFORMANCE						
2.1 Manipulates apparatus	28.9	27.0	25.2	21.6	21.4	23.4
2.2 Measures/observes	33.2	35.5	35.0	55.3	31.8	35.3
2.3 Draws/labels diagrams	13.5	1.5	3.3	0.5	5.8	7.1
2.4 Records results	11.1	23.5	21.1	15.8	23.1	17.4
Subtotal	**86.7**	**87.5**	**84.6**	**93.2**	**82.1**	**83.2**
3.0 ANALYSIS & INTERPRETATION						
3.1(a) Transform results into standard form	1.0	0.5	0.8	0.0	0.6	1.1
3.1(b) Graphs data	0.5	0.5	0.8	0.5	0.0	0.5
3.2(a) Determines qualitative relationship	0.5	0.5	0.8	0.0	0.0	0.5
3.2(b) Calculates/determines quantitative relationship	3.9	5.5	7.3	4.7	11.6	7.1
3.3 Determines accuracy of experimental data	0.0	0	0.0	0.0	0.0	0.0
3.4 States limitations/assumptions/precautions	0.5	0.5	1.6	0.5	0.6	1.1
3.5 States conclusion/proposes a generalization	2.4	1.0	0.8	0.5	1.2	0.5
3.6 Explains relationships	1.0	0.0	0.8	0.0	0.0	0.5
Subtotal	**9.8**	**8.5**	**12.9**	**6.2**	**14.0**	**11.3**
4.0 APPLICATION						
4.1 Predicts on basis of obtained results	0.5	0.0	0.0	0.0	0.6	0.0
4.2 Predicts beyond the data/uses given data	0.5	0.5	0.8	0.0	0.0	1.1
4.3 Applies technique to new problem	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**1.0**	**0.5**	**0.8**	**0.0**	**0.0**	**1.1**

N= Number of codes identified in each examination paper for each year.

those reported in previous studies that examined science textbooks and laboratory manuals (Tamir & Luneta, 1981; Staver & Bay, 1987; Pizzin, Shepardson, & Abell, 1991) and laboratory manuals (Friedler & Tamir, 1986; Germann, Haskins & Auls, 1996; Staer, Goodrum & Hackling, 1998). However, there is some consistency in the coverage of inquiry skills in the syllabus and practical examinations. Both documents mostly emphasize lower inquiry levels and skills. A desirable situation would be where all the four levels of inquiry are covered in the practical examinations for students to demonstrate a wide range of investigative skills. However, some advantages of using activities at confirmation and structured inquiry levels are: students who have just started "doing science" gain procedural knowledge and manipulative skills (Woolnough & Allsop, 1985) which they can later apply in guided and open-ended activities; students can complete the investigations within the allowed time for the examination; it is much easier for the examiners to score students' reports, especially that standard marking keys (rubrics) are used. However, confirmation and structured inquiry levels mainly stimulate students' thinking about the procedure and results of the experiments. The analyses of the inquiry skills in the examinations provided further evidence that students were mainly asked to manipulate apparatus, carry out observations and measurements, record results, interpret results and draw conclusions. This finding implies that during the examinations students commonly worked as technicians following explicit instructions outlined in the examination papers. The lack of inquiry tasks on planning and designing in the practical examinations also suggests that students were not given many opportunities to identify or formulate problems or hypothesize and test them based upon their understanding of the concepts involved. Science instruction organized exclusively around confirmation and structured levels of inquiry emphasizes a teaching approach that portrays scientific knowledge as fact, which can only be found if one scientific method is followed (Eltinge & Roberts, 1993; Tamir, 1985). Such instructional approaches also portray an image of science as authoritarian, with correct answers coming only from an outside source (Staver & Bay, 1987).

These findings also show that the practical examinations were focused on the inquiry skills prescribed in the national physics syllabus, making it very easy for students and teachers to identify those that are frequently tested. As such, during the lessons some teachers are likely to restrict students to develop inquiry skills that are only tested in the practical examinations.

In order to provide opportunities to high school students to develop and demonstrate higher-order inquiry skills, the physics syllabus should be explicit on inquiry levels and the practical examinations should cover all four levels of inquiry. While the extent to which open inquiry experiments should be used in physics practical examinations may be questioned considering the limited time for the examinations, it should be an integral component of instruction during the course. On the other hand, when the various demands of open inquiry tasks are taken into consideration, it seems unrealistic to expect students to perform many open-ended activities in two hours of the physics practical examination. However, the responsibility to include guided and open inquiry activities in physics practical examinations rests with the high school physics curriculum planners, examiners, and teachers. One other implication of this study is that the findings provide information about some strengths and weaknesses of the physics syllabus and practical examinations that Zambian science educators or other science educators elsewhere can use in planning for teaching to compensate for deficiencies in their curriculum.

It is recommended that future research should focus on analyzing other Zambian high school physics curriculum materials such as textbooks, teacher made tests and laboratory activities for inquiry levels and inquiry skills and the compare them to those identified in this study. Physics classroom instruction observations should also be undertaken to find out the extent to which the levels of inquiry and inquiry skills are addressed during the lessons.

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Difficulties in Learning Inequalities in Students of the First Year of Pre-University Education in Spain

Lorenzo J. Blanco
Universidad de Extremadura, Badajoz, SPAIN

Manuel Garrote
Colegio "Ntra Sra del Carmen" Badajoz, SPAIN

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We present a summary of a study carried out with students of the first year of Bachillerato (the first of two pre-university non-obligatory secondary education courses in Spain) to determine and analyse some of their errors and difficulties in learning inequalities with the aim of improving the teaching-learning process of this topic. The study was based on work on the initiation to algebra, in particular on the observed difficulties and errors relative to algebraic skills.

Keywords: Inequalities, Students' Misteakes, Secondary, Algebra, Mathematics

INTRODUCTION

Our teaching experience has allowed us to observe the difficulties that Bachillerato students have, and the errors they make, when they are studying inequalities. Many of these problems re-occur year after year. This motivated us to look for what might be some of the causes so that they could be addressed directly or at least help us to rethink how we approach the topic.

The present work formed part of the doctoral program given by the Department of Didactics of the Experimental Sciences and of Mathematics of the University of Extremadura (two-year course 1999-2001), in the second year of which a research line was developed on "Errors and Difficulties in the Teaching/Learning of Mathematics".

In this framework we elaborated a project whose main objective was: "To describe and analyse certain errors and difficulties of first year Bachillerato (note 1) students studying the options of Nature and Health Sciences or Technology in learning inequalities with the goal of improving the process of teaching-learning of that topic". The goal of the present work is to describe and discuss some of the results without it being intended as a research report.

Correspondence to: Lorenzo J. Blanco, Assist. Prof. Dr. Mathematics Education, Dpto de Dtca. de las C. Experimentales y de las Matemáticas. Universidad de Extremadura. Badajoz. SPAIN
E-mail: lblanco@unex.es

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Theoretical Framework

We considered as referent the concept of epistemological obstacle (Brousseau, 1997). This is characterized as knowledge which has generally been satisfactory for the resolution of certain problems for some time, and which has thus become settled in the student's mind, but which subsequently is found to be inadequate when the student is confronted with new concepts and mathematical processes. According to Brousseau, its origin could be ontological or psychological, educational or epistemological (Brousseau, 1997).

We propose working on the mathematical concepts and processes that the students have studied but use inappropriately when they are dealing with inequalities. In this regard, we assume that knowing a mathematical object implies understanding and integrating definition, different systems of representation, properties, and applications (Gutiérrez & Jaime, 1996; Goldin & Shteingold, 2001; Blanco, 2001).

Likewise, we assume that "student errors are the result or the product of previous experience in the mathematics classroom" (Radatz, 1980, 16). Lochhead & Mestre (1988), citing Resnick (1983), note that "the research literature consistently indicates that misconceptions are deeply seated and not easily dislodged; in many instances, students appear to overcome a misconception only to have the same misconception resurface a short time later. This phenomenon is probably a result of the fact that when students construct learning, they become attached to the notions they have constructed" (Lochhead & Mestre, 1988, 132).

Other bases for the study were works on the initiation to algebra (Coxford & Shulte, 1988; Socas et al., 1989; Grupo Azarquiel, 1991; Kieran, 1992), specifically on the difficulties and errors that are observed with regard to the algebraic skills of Obligatory Secondary Education and Bachillerato students (Marquis, 1988; Gallego, 1995; Beltrán, 1997), as this is the field of the mathematical content of this investigation. The contributions that we have consulted point out different aspects of the teaching and learning of algebra that constitute difficulties and obstacles to learning. and which it is necessary to deal with in greater depth.

In this line, Socas (1997) and Palarea (1999) review students' difficulties and errors in learning mathematics in general, and algebra in particular. They group the difficulties into five categories: difficulties associated with:

1. the complexity of algebraic objects that operate semantically and syntactically;
2. thought processes, deriving from the logical nature of algebra;
3. teaching processes, deriving from the mathematics curriculum itself, from the educational institution, or from teaching methods;
4. the processes of the students' development; and
5. the students' affective and emotional attitudes towards algebra.

Socas (1997) classifies the main causes of error in learning algebra into two groups:

1. Errors that originate from some obstacle, such as the lack of closure, i.e., students see algebraic expressions as statements that are sometimes incomplete.

2. Errors that originate from an absence of meaning. These fall into two types:

2.1. Complexity of the objects and of the processes of algebraic thought. Examples are:

- Errors in algebra that have an arithmetic origin.
- Errors of procedure.
- Errors in algebra due to the characteristics of algebraic language.

2.2 Affective and emotional attitudes towards algebra.

Several workers have studied aspects of teaching/learning algebra that represent potential obstacles to learning. Thus Collis (1975) and Enfedaque (1990) describe the use that students make of algebraic letters and the meaning they attribute to them. Collis (1975), Behr et al. (1980), Kieran (1981), and Palarea & Socas (1999-2000) discuss the value that students attribute to the equals sign, finding that arithmetic has precedence over algebra, and Kieran (1979) discusses the use of parentheses.

Enfedaque (1990) studied students of year 8 of EGB (Basic General Education) and of years 1 and 2 of BUP (Obligatory Secondary Education) in Barcelona, putting forward some suggestions on how to introduce the use of letter symbols in algebra so as to decrease the incidence of errors, and also presenting some considerations on the teachers' attitudes to aid them in detecting those errors and, in sum, improve the students' algebraic skills.

Trigueros, Reyes, Ursini & Quintero (1996) give a design for a questionnaire to diagnose how the concept of variable is handled in algebra. They find the concept to be used with different meanings in different contexts, with the consequent differences in how it is dealt with. That this variability in how the concept is used makes it difficult to define could be the cause of many of the students' difficulties. They consider there are three forms in which a variable is usually employed in school algebra: as an unknown, as a generalized number, and in functional relationships.

MacGregor & Stacey (1997) present some difficulties in the use of algebraic notation as part of the results of a broader project denominated Concepts in Secondary Mathematics and Science – CSMS.

Kücheman (1978, 1981), within the CSMS project, notes that the considerations about understanding the algebra of numbers implies the development of skills in interpreting and handling letters and other symbols. A study of the diverse ways in which English secondary education students use letters established the following hierarchy:

“Letter evaluated: the letter is assigned a numerical value from the outset;

Letter not considered: the letter is ignored or its existence is acknowledged;

Letter considered as a concrete object: the letter is regarded as shorthand for a concrete object or as a concrete object in its own right;

Letter considered as a specific unknown: the letter is regarded as a specific but unknown number;

Letter considered as a generalized number: the letter is seen as representing, or at least as being able to take on, several values rather than just one;

Letter considered as a variable: the letter is seen as representing a range of unspecified values and a systematic relationship is seen to exist between two such sets of values" (Kieran, 1992, 396).

Usiskin (1988) points out the relationship that exists between the various conceptions of algebra and the different uses of letters in teaching, represented schematically in the following figure:

Conception of algebra	Use of variables
Generalized arithmetic	Pattern generalizers (translate, generalize)
Means to solve certain problems	Unknowns, constants (solve, simplify)
Study of relationships	Arguments, parameters (relate, graph)
Structure	Arbitrary marks on paper (manipulate, justify)

Figure 1. Relationships between conceptions of algebra and the uses of variables (Usiskin, 1988, p. 17).

Vega (1992) carried out a study whose objective was to elaborate profiles of the algebraic competence of pre-university students in Mexico City. Perhaps the most interesting finding of that study was the evidence that progress from one school year to the next was not reflected in any significant improvement in dealing with the problems that derive from algebraic manipulation.

All these contributions point to different aspects of teaching/learning algebra that constitute obstacles to its effective learning, and which require more detailed study.

METHODS

Since our intention in the present work was to make a first approach to the topic rather than an exhaustive study, we decided to use the questionnaire as the instrument for data gathering, including in it various recommendations appropriate for qualitative methods in general (Cohen & Manion, 1982; Woods, 1986) or specific aspects of the use of the questionnaire in similar studies (Enfedaque, 1990; Triguero, Reyes, Ursini & Quitero, 1996; Vega, 1995).

The questionnaire (Annex 1) was first suitably validated, and then given to 91 students from 4 different educational centres who were matriculated in the first year of Bachillerato, studying either the option Technology or the option Nature and Health Sciences (note 1). It was given after the students had received instruction in the topics that it covered. For most of the participants these were concepts that they studied for the first time in this school year: only some had prior ideas about the objects of study.

In the following section, we analyze the results for each item separately, noting the specific goals pursued with each. By way of a general picture, the following is an overall anticipation of those objectives:

- To examine the step from ordinary language to algebraic language in terms of an inequality that the students solve.
- To observe the meaning that the students attribute to inequalities.
- To analyze the use the students make of different systems of representation.
- To observe their operational abilities in solving a simple inequality.
- To observe their difficulties relative to the order relationship in the real numbers.
- To determine the difficulties the students have in assimilating different uses of letters in algebra.
- To observe their capacity to interpret the solution of an inequality.
- To check whether the students see inequalities as a tool that allows a certain type of problem to be tackled.
- To observe whether the students are able to connect the visual-geometric and algebraic languages.

RESULTS

In this section we shall show some of the errors and difficulties detected, and indicate their possible causes. The basis will be the analysis of the questionnaire and the subsequent confirmation in the interviews. At no time did we set out to make an exhaustive significant analysis of the data, although Annex 2 gives some overall results.

Items 1 and 2 dealt with the passage from everyday language to the language of algebra in terms of an inequality , and with the meaning that the students attribute to these expressions and the use that they make of different systems of representation.

Many students correctly gave the expressions asked for. Some aspects of their answers stand out, however. Despite their having worked with real numbers for several years, very few students took this set as the reference for their operations. Most limited themselves to the natural numbers, which would clearly represent an obstacle to their understanding the meaning of interval. This was a constant in their resolution of various items. Likewise, although use was made of the variable to give the requested expression, its meaning was not made sufficiently clear.

For item 2, there were students who understood the requested order relationship, even giving examples, but who, in passing to the algebraic expression, wrote the relationship backwards. This problem became even greater when they tried to give the double inequality in a single expression. They had difficulty in understanding the two inequalities together. Even when they were written together, they were comprehended separately, leading to such incoherent expressions as n < -2 > -11. (A similar situation appeared in the solutions to item 11.)

The aim of item 3 was to look at the level of skill in using operations to solve a simple inequality and the ability to interpret the solution. The problem was a first-order linear inequality [5-3(2-x) > 4-3(1-x)]. We found the answers to fall into three quite distinct groups: (i) the inequality was solved and interpreted correctly, i.e. an expression of the form 0 > 2 or -1 > 1 was arrived at and it was added that the inequality is not satisfied for any value of the unknown; (ii) the correct solution was given but the interpretation was not; and (iii) not even the correct solution was arrived at.

These results bring out the difficulties the students had in interpreting the result, since some of them who solved the inequality were incapable of drawing conclusions from it. This situation was also reflected in some of the students' uncompleted exercises. We also found operational mistakes: in the use of parentheses, of the signs < and >, and of the distributive property; in operations with whole numbers; and in passing from one inequality to another that should be equivalent.

With this exercise we began to realize that the students were not differentiating conceptually between equation and inequality, since they were using either term indistinctly to refer to the latter.

The students were thus clearly finding many problems and difficulties in trying to solve an inequality. Some of these problems were due to a lack of mastery of elementary algebra, and others were characteristic of inequalities themselves. Many students understood the greater than and less than signs to be a nexus between two algebraic expressions. They then carried this nexus through the various steps in solving an inequality without attaching any meaning to it, even to the point of simply substituting an equals sign. Few students endowed the inequality with any semantic content as was clear in the failures to interpret the result even after correctly applying the algorithm to reach the solution.

Items 4-6 brought out the difficulties in handling expressions involving the sign '-' in the inequalities and the order relationship in the real numbers. Few students both chose the correct answer and gave arguments. Most simply used the same techniques they would use for equations, again showing that little semantic meaning is attached to the sign and that the aim was simply to operate and solve for the unknown without taking any account of whatever meaning the result might have.

Item 6 also showed the students' difficulty in assimilating different uses of letters in algebra (also seen in items 7 and 10), in particular that they thought that 'a' represents a positive number and 'a' a negative number.

The aim of item 5 was to see to what degree the students were able to interpret the solution of the inequality. It again showed their difficulty in reading an inequality, as well as in understanding that the result of an inequality is not a value of the unknown but an interval. Let us illustrate this with some examples of the errors that were made:

- The inequality was solved correctly, but the question posed was not answered because the student did not know what to do with the values between 3 and 5.
- Having arrived at x > 3, the student crossed out x > 5 believing that the first expression should have appeared in the statement of the problem but not the second.
- After substituting 5 and 6 in the inequality, it was argued that "Yes, it is true because there are examples that demonstrate it".

This last solution confirmed that many students think that, in order to justify the statement they are presented with, it is enough to verify it for some value.

In item 7, we again use letters as generalized numbers in order to see whether and how the students use suitable tools to prove which of the two given algebraic expressions is greater. I.e., the aim is to see whether they consider inequalities to a tool that they can use to tackle certain types of problem.

Only 9.9% of the students correctly reasoned their answer. Some stated that it depended on the values, demonstrating the difficulty they have in using letters as generalized numbers, and others that the result of multiplying a number by a positive quantity is greater than adding that quantity to the number, which perhaps derives from their usually working with natural numbers.

The students have not sufficiently assimilated the concept of inequality, since only a few use this tool in order to justify the answer that they gave, even though this concept was the main object of most items on the questionnaire.

Item 8 showed the students' difficulty in connecting visual-geometrical language with algebraic language. Very few used the diagram to justify their answer, i.e., comparing the area of the square of side 'a + b' with those of the squares of sides 'a' and 'b', respectively. For many, the diagram was just a drawing that at no time were they able to relate to the question in hand, and they could not even understand why it was there. It was obvious they had become accustomed in their work in algebra to using other non-algebraic tools, and that this derived not from the students themselves but from the teachers and the methods used in the classroom. Most attempted to answer by expanding the binomial sum and comparing the resulting expressions.

In item 9 too, they could have used the diagram of the preceding question, but none did. The result for this item showed the difficulty the students find in this type of question. Only one succeeded in proving the statement, seven said the statement was true after checking its validity for various cases, while the rest failed to give any argument justifying the statement.

This exercise brought out some common errors such as considering that

"if a2 > b2, then one has that a > b with no more ado than taking the square root of both sides of the inequality".

In another sense, they had difficulties in considering thesis and hypothesis. I.e., they attempted to show that a2 > b2 when a > b.

Item 10 involves letters used differently, one as the unknown and the other representing a generalized number. The idea was not for the student to give the complete range of values for 'm', but simply to find some value for which the conditions are satisfied. The underlying objective, however, was to see how the students understand and interpret a solution of an inequality.

The answers given fell into the following categories:

a. a value of 'm' was found for the conditions of the statement, i.e., such that substituting it into the inequality, the statement was found to be true for x = 0 and false for x= 2;
b. the answer was incorrect; and
c. the response was left blank.

A large group of students did not differentiate between the uses of the two letters in the inequality. This led to a deficient understanding of the statement of the problem. Also, when they came to the actual calculation of the value of a letter, they simply relied on the techniques they knew for equations to get the result, even to the point of changing the sign of the expression without seeing the need for any justification.

This aspect also carried over to the interpretation of the solutions of an inequality. Even when they reached an expression of the form m < 1, they believed that this was not determining the unknown and that it was necessary to give an expression in terms of equality, i.e., 'm' has to be equal to a single value.

Items 11 and 12 were aimed at seeing to what degree the students could perceive a functional relationship between two letters so as to establish the range of variability of one in terms of the range of variability of the other.

In item 11, many students again had difficulty in attempting to give a single expression for a double inequality, even when they had assimilated the information contained in that inequality. Thus an expression obtained from the statement " 'm' is greater than 3 but less than 10" was 3 < m > 10.

The students presented substantial differences in giving meaning to the functional relationship between the two letters. While they found no great difficulty in determining the values of 'm' from those of 'n', this was not so for the contrary process which caused them certain conceptual difficulties deriving from their concepts of dependent and independent variable.

The intervals were calculated by substituting the smallest and the greatest values of one of the letters into

1, 2. In passing from ordinary language to algebraic language in terms of an inequality.
1, 2, 4, 6, 7, 10, 11. In the use and meaning that the students attribute to letters and to algebraic expressions.
1, 2, 7. They do not take the real numbers as their reference set for their operations, but limit themselves to the natural numbers.
1, 2, 5. To understand the meaning of interval.
1, 2, 11, 12. In the meaning of the variable.
2, 3, 5, 11. To understand the meaning of the greater than and less than signs.
7, 12. To use the greater than and less than signs, and, in general, inequalities to solve exercises.
3, 5, 10. To interpret the result of an inequality.
3, 4, 6. Operational errors (in the use of parentheses, the sign " – " y the signs "<", ">", "≤", o "≥"., the distributive property, operating with integers, and in going from one inequality to another that is equivalent).
3, 4, 6. They give no semantic content to the inequality. They find no conceptual differences between equation and inequality.
4, 6. On handling expressions that involve the order relation of the real numbers.
8, 9. Difficulty of connection between the visual-geometric and algebraic languages.

Figure 2. Summary of the difficulties the students were found to have about inequalities.

the given relationship and finding the respective values for the other letter. I.e. "if 3 < m < 10, since m = 3 + n, then 10 = 3 + n and 3 = 3 + n, whence one has that n = 0 and n = 7, and the result is (0,7)".

In item 12, the answers fell into one of four categories:

a. correct result, i.e. 'c' must take values less than 5;
b. the result given is just a single value for c;
c. incorrect result; and
d. a notably large number of students gave no response.

Again it was clear that the students generally do not see inequalities as a tool that can be used to solve certain types of problem, since only a few used the technique to respond to this item. Many of them tried all the ways they could think of to set the question in the field of systems of two equations with two unknowns. In particular, the relationship c + d = 0 was seen as an equation with two unknowns, and as they could find no other equation with two unknowns, they reasoned that the problem could not be solved because an equation was missing.

Finally, there is the aspect of checking the results. The fundamental goal of problem solving is to obtain a solution that is coherent with the conditions of the problem. For many of our students, however, the goal was to find a procedure to arrive at a solution, with at no time it being necessary to check the result since the procedure itself was the justification of its validity. In the figure 2 presents a summary of the principal results relative to the different items.

DISCUSSION

The analysis also shows the difficulties that the students have in assigning new meanings to concepts and mathematical processes related to inequalities. Thus, we find that the errors do not arise by chance, but rather that the students have a stable conceptual framework based on their previous knowledge – fundamentally that derived from their handling of arithmetic. We confirm that the basis of a part of the errors is in the students' prior experiences, in the sense noted by Radazt (1980).

We would like to highlight some aspects that seem to us to be significant.

Thus, a major fraction of our students have a deficient grasp of the concept of inequality. Many of them have not established any meaningful difference between this concept and that of an equation (items 3 and 12). I.e., the difference is merely in the symbol that is written between the two members of the relationship: the symbol '=' in an equation, and one of the symbols "<", ">", "≤", o "≥". The signs have no semantic value since they are used simply as a nexus between the two members of the inequality (item 3).

This absence of meaning was also manifest in the students' difficulties in reading from left to right or from right to left, i.e., difficulties in recognizing the equivalence of the expressions x>1 and 1<x, or to interpret expressions of the type 0>2 or –1>1 (item 3).

There were serious difficulties in passing from a statement given in words to an algebraic expression (items 1 and 2), especially if the expression involved a double inequality (item 2).

Many students had not established that there was a semantic difference between equation and inequality, and some of their conceptions of interval were as "a set of natural numbers, or at best a set of integers between some other two integers". Neither does their interpretation of the solution of an inequality seem to be the most appropriate if our intention is to endow the object of our study with semantic content (items 5 and 10). These results ratify the findings of Socas (1997) that the complexity of the objects and processes of algebra is a source of the students' difficulties.

For a good many of our students, algebra is "operating" with numbers and letters, with no other goal than obtaining their values by applying semantically empty algorithms. Thus, in dealing with an expression of the form -7x < 5, their objective is to leave just the unknown on one side of the relationship, and to this end they "pass the -7 to the other side of the inequality as a divisor" just as if the relationship was an equation. The goal of finding values of the unknown that make the inequality true is pushed into the background (items 4 and 6).

It was also evident that many students had still not mastered some of the difficulties of arithmetic. Thus, we found evidence of the students' difficulties in their handling of the distributive property, and in their use of parentheses, the sign rule, and the value attributed to the equals sign. These results corroborate those indicated in the second section by Collis (1975), Behr et al. (1980), Kieran (1979, 1981), Enfedaque (1990), and Palarea & Socas (1999-2000). This makes it even harder for them to acquire a new concept that requires the appropriate use of these skills (item 3). In this regard, we consider that the students' arithmetic knowledge acts as an epistemological obstacle, in the sense expressed by Brousseau (1997), to learning algebra.

The students can use algebraic letters without attributing any meaning whatsoever to them (items 5-7). We confirm that students have difficulties in the use and meaning that they attribute to letters, as was indicated by Collis (1975) and Enfedaque (1990). With respect to the different uses of letters, we consider that the students have a conception of algebra as generalized arithmetic, in the sense expressed by Usiskin (1988). We also consider that:

- A letter used as a generalized number is treated as belonging to the domain of natural numbers, or at best integers, with all the limitations that this implies, especially considering that one is working with inequalities whose solutions are intervals of real numbers (items 7 and 10).

- A letter used as an unknown is endowed with the greatest meaning and recognition by our students. Nonetheless, the need the students feel to find specific values for the letter deriving from its use in equations represents a major barrier to their interpretation of the solution of an inequality (item 10).
- Lastly, when a letter is used in a functional relationship, the way in which this relationship is presented becomes very important, since the students have deeply rooted ideas of dependent and independent variables with all that this implies for the reversibility of the relationship (item 11).

With respect to the use of variables, we note the difficulties that the students have relative to the three meanings described in Trigueros et al. (1996). They show greater facility in using a variable as an unknown, but greater difficulty with its use in functional relationships. In this regard, we consider it necessary to work on the three given uses of the variable, and on the possibility of flexibly passing from one to another according to the demands of the task that has been set. This last aspect presented many difficulties for the students that we studied.

With respect to the different systems of representation, ideally the use of more than one system would favour the understanding of algebra since different systems provide alternative and complementary strategies (Palarea and Socas, 1999-2000). Our students, however, use nothing but algebraic language to approach the different problems they had to answer (items 8 and 9). In most cases this was a consequence of the view that many of us as teachers have, and that we carry over to our classrooms, of the teaching-learning of algebra. In developing the content of algebra, we only use algebraic language and do not provide our students with other tools to represent concepts and thereby make them easier to learn.

The absence of meaning is one of the principal problems arising in working with inequalities. If our intention is for the students' learning of inequalities not to be reduced to mere mechanical tasks, it is important to give them a clear idea of the concept of equivalent inequality since it is this that endows the techniques of solution with semantic content.

Finally, the study induces us to assume that part of the difficulties presented by the students could be understood as corresponding principally to two points of the classification schemes given by Socas (1997) and Palarea (1999) – difficulties associated with the complexity of the objects and processes of algebra, and difficulties associated with the processes of teaching. In the former case, we see that the students have not managed to understand the mathematical objects involved in the inequalities with respect to integrating definition, different systems of representation, properties, and applications. In this regard, arithmetic proves to be an epistemological obstacle in a general sense, as well as in relation to certain specific concepts and processes. This situation is the consequence of traditional teaching methods that are based on developing algorithmic procedures, and which at times neglect to deal with the meaning of the objects that are being used.

CONCLUSIONS

The results of the work show that students find two types of difficulty in dealing with inequalities. On the one hand, arithmetic is still the fundamental referent for those students who make errors in the algebraic procedures, and, on the other, the absence of meaning is the underlying cause of the failure to understand the concepts and the algebraic process.

Given that the work is meant to be a first approximation to the topic, we wish to conclude by noting the need for a more detailed investigation of the difficulties in the teaching/learning of inequalities, with the problem being approached from different contexts, such as arithmetic, algebra, and geometry.

Educational Implications

The absence of meaning is one of the main problems that arise in working with inequalities. For that reason, greater attention will have to be paid to how the concept is introduced if one wants to avoid the learning of inequalities being reduced to merely mechanical tasks. Any mechanism of solution must allow students to understand the meaning of the process they follow to arrive at the correct solution of an inequality. Otherwise the mechanism they learn will be a source of error and one that they will not use unless the teacher or the textbook specifically tells them to.

Given the difficulties deriving from the complexity of the elements of the algebra, as teachers we should keep the following in mind when teaching inequalities:

- Not to introduce the concept of inequality or the techniques for their solution too rapidly.
- Ensure that the symbols used are clearly differentiated and that they have semantic value for the students.
- Establish with clarity the differences between the concepts of equation and inequality, with the clear implications that this entails especially when it comes to interpreting their solutions.

- Use different languages: 'everyday' language, visual-geometric language, and algebraic language. Translation from one to another favours a better understanding of the concept. The visual-geometric language in particular needs to be treated in some depth.
- The introduction of the formal notation can not be disconnected from the acquisition of the meaning of the concept and the processes needed to solve inequalities.
- The use of different strategies to approach questions related to inequalities both enriches the learning process and allows more students to acquire the concept.

The absence of meaning of mathematical objects is one of the main problems that we face in our classes. All our work must be oriented towards the search for educational alternatives, the more diverse the better, aimed at providing the meaning which will constitute the principal basis for learning mathematics

NOTES

Note 1. Spain's educational system is organized into three stages:
Primary from 6 to 12 years old.
Secondary from 12 to 16 years old.
Pre-university (Bachillerato) from 16 to 18 years old.
The student participants in the investigation were 16-17 years old.

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Evaluation Novelty in Modeling-Based and Interactive Engagement Instruction

Funda Örnek
Balıkesir Üniversitesi, Balıkesir, TURKEY

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A calculus-based introductory physics course, which is based on the Matter and Interactions curriculum of Chabay and Sherwood (2002), has been taught at Purdue University. Characteristic of this course is its emphasis on modeling. Therefore, I would like to investigate the effects of modeling-based instruction and interactive engagement on students' physics understanding. For this reason, The Force Concept Inventory (FCI) (Hake, 1992) as pre-and post-test was used to evaluate students learning and understanding following a newly developed approach to teaching mechanics in an introductory physics course. The results lead that it can be concluded that the modeling-based interactive teaching method helps students to improve their understanding and learning physics.

Keywords: Conceptual Understanding, FCI, Learning, Teaching, Physics Models.

INTRODUCTION

This paper provides an explanation of development of modeling-based interactive engagement teaching approach to teaching mechanics in calculus-based introductory physics course. Also, it demonstrates how the Force Concept Inventory (FCI) was used not only to evaluate this new teaching approach but also to analyze the student learning (Savinalnen, A. & Scott, P., 2002). The teaching was done by an instructor in department physics at Purdue University.

In USA and elsewhere, research results indicate that active-based teaching can lead to improvement of gains in student learning and understanding. I believe that this study can contribute to literature in physics education by "*demonstrating how insight into research on teaching and learning in physics have been drawn upon to revise instructional approaches and to thereby improve student learning*" (Savinalnen & Scott, 2002).

*Correspondence to: Funda Örnek, PhD., Teaching Assistant, Balıkesir Üniversitesi, Necatibey Eğitim Fakültesi, Fizik Eğitimi Bölümü,
Balıkesir, 10100 TURKEY.
E-mail: fundaornek@gmail.com*

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Structure of the Course

The Purdue physics course is a two-semester introductory physics sequence for physics majors. The course, PHYS 162, which treats Particles, Kinematics, and Conservation Laws, is taught in the Fall semester. PHYS 163, which treats Mechanics, Heat, and Kinetic Theory, is taught in the Spring semester.

Physics modeling takes place in each section of the course. Students used a few physics principles and approximations to construct their models to solve problems.

The structure of the course is different than many other physics courses. During the Fall semester, PHYS 162 consists of two lecture sessions, either small-group work or computer-laboratory sections, and workshops in a computer laboratory. Whether the small-group work or computer laboratory will be held is decided by the instructor.

Lectures meet on Mondays, and Wednesdays. During lectures, students are actively involved in their learning. Students interact with each other and with the instructor instead of sitting, listening, watching the instructor, and taking notes. In addition, the instructor performs hands-on experiments.

Small-group work, which is called "recitation" in all traditional physics courses, meets on Tuesdays, and

Thursdays. It has three sections which meet on the same day. Each section has about 24 students and is divided into 8 small groups. A traditional recitation is run by a teaching assistant solving problems in front of the class, whereas the small-group work sections in PHYS 162 are run by the instructor, a teaching assistant, and a student helper who has already taken these courses. Each small group has a small white board on which to solve physics problems. After they solve the physics problems, they share their solutions with the class by presenting their solutions. The purpose is to have students be actively involved. Teaching assistants, instructor, and student helpers are the facilitators.

The computer-laboratory session has three sections as does the small-group work session. All computer sections are scheduled at the same time that the small-group work sections meet. The instructor decides when they will have the computer laboratory or the small-group work. Students always stay in their section of the small-group section. Each student has a computer which he/she can use and write his/her own simulation program. They use a computer program which is called VPython. Again, the instructor, a teaching assistant, and a student helper are present in each computer-laboratory section.

Workshops are held in the same computer laboratory on Fridays to help students with their difficulties understanding the content covered during classes. These workshops are problem-solving and help sessions. Also, they are for students to catch up. There are three sections in a day as well. In each workshop section, the instructor, and a teaching assistant are present. Moreover, not only the instructor, but also the teaching assistants hold office hours for students.

During the Spring semester, everything is the same except for an additional lecture per week and student helpers (they are not available during the Spring semester). Lectures meet on Mondays, Wednesdays, and Fridays at the same time as in the Fall semester.

There are three 1-hour exams and a 2-hour final exam for each course. In addition, students are supposed to do homework, computer problems and daily quizzes. Daily quizzes, which happen all semesters, are given in lecture to identify whether students understand the concepts, and also for attendance, for which credit is given.

Since the course, PHYS 162, which treats Particles, Kinematics, and Conservation Laws, is taught in the Fall semester, covers force concepts, I only used the FCI results in the Fall semester.

Teaching method: Modeling-Based Interactive Engagement

Beginning the Fall Semester of 2001, the Physics Department at Purdue University started to teach a calculus-based introductory physics course by using a modeling-based interactive engagement method. To be precise, "modeling" as used here has a different meaning from "modeling" used in the notation of science education. In brief, modeling in physics is defined as "making a simplified, idealized physics model of a messy real-world situation by means of approximations" (Chabay & Sherwood, 1999). It is also called "physics modeling" in physics education community. In this course, physics modeling and computer simulations are used to promote conceptual understanding along with interactive engagement method. Hake (1998) defines "Interactive Engagement (IE) methods as those designed at least in part to promote conceptual understanding through engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors..." (p.65) In other words, it is a method that improves students' conceptual understanding by their interactions with each other using their thoughts and some hands-on activities. Then, they can have immediate feedback from their discussions with their peers, their teaching assistants, or their instructors.

Modeling-based interactive engagement instruction entails some features which focus on the development of conceptual understanding:

Physics Modeling

Modeling means something different to physicists. A physics model in the physics-education community is considered as a simplified and idealized physical system, phenomenon, or idealization. According to Greca & Moreira (2001), the physics models determine, for instance, the simplifications, the connections, and the necessary constraints. As an example one can think of a point particle model of a system in classical mechanics. A simple pendulum is another example of a physics model because it is idealized and consists of a mass particle on a massless string of invariant length moving in the homogenous gravitational field of the Earth in the absence of drag due to air (Czudkova & Musilova, 2000).

In Purdue's calculus-based introductory physics courses, students do not use models which are already created in this course. They apply the fundamental principles and create their own models. Modeling involves making a simplified, idealized physics model of a messy real-world situation by means of approximations. Then, the results or predictions of the model are compared with the actual system. The final stage is to refine the model to obtain better agreement, if needed. Sometimes it may not be needed to modify the model to get more exact agreement with the real-world phenomena. Even though the agreement may be excellent, it will never be exact since there are always some influences in the environment that we cannot consider while we are building the models. For instance, while a rock is falling, the gravitational pull of the earth and air resistance are the main influences. However, there are also other effects such as humidity, wind and weather, Earth's rotation, even other planets (Chabay & Sherwood, 1999).

In physics modeling (Chabay and Sherwood, 1999), the following process is followed:

- Start from fundamental principles which are the linear momentum principle, the energy principle, and the angular momentum principle
- Estimate quantities
- Make assumptions and approximations
- Decide how to model the system
- Explain / predict a real physical phenomenon in the system
- Evaluate the explanation or prediction

In summary, physics modeling is analysis of complex physical systems by means of making conscious approximations, simplifications, and idealizations. When students make approximations or simplifications, they should be able to explain why they make them. For instance, in modeling a falling ball, in general, air resistance is neglected. So, there is no force contribution from air resistance. While students do neglect it, they should be able to have reasons for this. As an example of modeling, consider the calculation of the acceleration of a block is pulled to the right with a force F as shown in Figure 1.

To analyze this system, we should start with the momentum principle,

$$\frac{d\vec{p}}{dt} = \vec{F}_{net}.$$

Because of friction between the table and the block, there is frictional force, *f* in addition to the force, F; pulling the block. So, the total force is

$$F_{net} = F - f.$$

From the momentum principle,

$$\frac{d\vec{p}}{dt} = \vec{F}_{net} = F - f.$$

So,

$$\frac{d\vec{p}}{dt} = \frac{d(mv)}{dt} = m\frac{dv}{dt} = ma = F - f$$

from this, it can be concluded that the block moves with a constant acceleration which is given as

$$a = \frac{F - f}{m}.$$

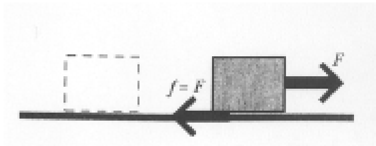

Figure 1. Pulling a Block (Chabay & Sherwood, 2002).

Computer Simulations

In this course, students write programs to simulate physical systems using VPython (Scherer et al., 2000). VPython makes students focus on the physics computations to obtain 3-D visualizations. Students can do true vector computations, which improves their understanding of the utility of vectors and vector notation. For example, students can study the motion of the earth in orbit around the sun by means of writing a program.

Creating simulations by writing computer program using VPython helps students understand physics because they can see how physics principles work.

The modeling-based interactive engagement method defined by Chabay & Sherwood (2002) can offer the potential to promote enhanced learning in conceptual understanding of physics.

RESEARCH METHOD

Research Context and Subjects

This study took place in the Physics Department at Purdue University throughout the Fall, 2004, semester. For this study, I focused on a calculus-based introductory-level physics course which includes lecture, small-group work, which is called "recitation" in a traditional physics course, and computer simulations. Only 16 students completed the pre-test and post-test administration of the FCI.

Theoretical Framework

There are several kinds of research designs which guide quantitative research in education. For the purpose of this study to answer my research questions I used a pre-experimental research design, the one-group pretest-posttest design. A single group is often studied, but no comparison between an equivalent non-treatment group is made. In this design, as shown in Figure 2, a single group of subjects is given a pretest, then the treatment, and then a posttest. The pretest and posttest are the same. The result that is examined is the change from pretest to posttest (McMillan & Schumacher, 2001). In my study, O (observation) meant that pretests and posttest were administered before and after treatment of the modeling-based interactive engagement instruction. X (treatment) was the modeling-based interactive engagement instruction.

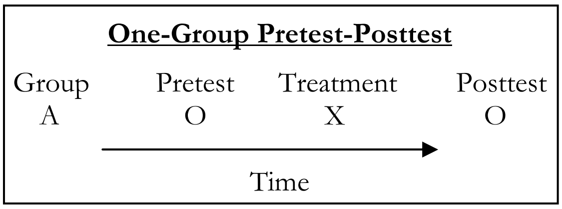

Figure 2. One-Group Pretest and Posttest (McMillan & Schumacher, 2001).

To use this design in my study, I compared pretest results prior to the modeling-based interactive engagement teaching method to the results after completing a semester of experience in this teaching method. I could at least state whether a change in the test results had taken place. What I cannot say is if this change would have occurred even without the application of the treatment. It is possible that any instructional method or mere maturation could have caused the change in grades and not the modeling-based and interactive engagement teaching method itself.

Data Collection

I used the Force Concept Inventory (FCI) which was administered as pre- and post-tests in the fall semester in Phys 162, to determine if the modeling-based interactive engagement teaching would have a significant effect on conceptual learning and understanding of physics. The Force Concept Inventory (Hestenes et al., 1992) is a 29-question multiple-choice test for measuring students' understanding of Newton's Laws. It probes the belief systems students hold concerning force, the primary concept of Newtonian mechanics (Churukian, 2002).

RESULTS

I used the Force Concept Inventory (FCI) which was administered as pre- and post-tests in the fall semester in Phys 162, to determine if the modeling-based interactive engagement teaching would have a significant effect on conceptual learning and understanding of physics. Only 16 students completed the pre-test and post-test administration of the FCI.

To compare students' pre-test scores and post-test scores, I used the Binomial sampling distribution (Blalock, 1960). Before going further, I would like to give some information about the null hypothesis because it is based on median difference instead of mean difference due to skewness (Blalock, 1960). In general:

H_0 (Null hypothesis): Population median difference is zero.

H_a (Alternative hypothesis): Population median difference is not zero.

The null and alternative hypotheses in my study are:

H_0: The modeling-based interactive engagement teaching method has no effect on students' pre-test and post-test FCI scores.

H_a: The modeling-based interactive engagement teaching method has an effect on students' pre-test and post-test FCI scores.

In order to test H_0 hypothesis, I utilized the Sign test which is the application of the Binomial sampling distribution and for a small number of cases (Blalock, 1960). For success, a + sign indicates cases where students' FCI score is increased, for failure, a - sign indicates cases where students' FCI score is decreased. If there are any students who show no change, these students are excluded from the analysis. Assuming that there are equal chances of pluses and minuses, the probability of getting a + sign in any given draw is 0.5 under the null hypothesis (Blalock, 1960).

As $\alpha = 0.05$ level of significance using a two-tailed test; I chose the critical region for which I can reject the null hypothesis. The calculated p-value which determines whether I can reject the null hypothesis or not is 0.022 using a two-tailed test. The probability value (p-value) of a statistical hypothesis test is the probability of getting a value of the test statistic by chance. The p-value is compared with the significance level and, if it is smaller, the result is significant. For example, if null hypothesis can be rejected at $\alpha = 0.05$, this can be reported as $p < 0.05$ (Lomax, 2001).

According to the result of the Binomial distribution obtained from the SPSS, the small p-value, which is 0.022, demonstrates the null hypothesis of "there is no effect on pre-test and post-test FCI scores" is not supported. Why is the null hypothesis rejected? If p-value is less than significance level (α) then H_0 can be rejected in favor of H_a. H_0 is rejected because the p-value = $0.022 < \alpha = 0.5$. Therefore, the result shows a significant change in students' FCI scores. In other words, the modeling-based interactive engagement teaching appears to have an affect on students' pre-test and post-test FCI scores.

Using the Sign test, I determined whether the effect on students' scores was positive or not. I looked at whether each student exhibited any increase or decrease in his/her FCI scores. The results as shown Table 4 are:

- 11 students exhibited increased their score on the post-test relative to the pre-test.
- 2 students showed a decrease in their scores.
- 3 students showed no change in scores.

I used the Wilcoxon Matched-Pairs Signed-Ranks Test (the T test) to compare pre-test and post-test scores and find out if there is significant difference or not. The Wilcoxon test includes the same null hypothesis as used in the t test for paired samples. Blalock (1960) explains how to use a T test:

> … The null hypothesis states that there are no differences between the scores of the two populations. After obtaining difference scores for each pair, these differences are ranked regardless of the sign. The sums of the ranks of both the positive and negative differences are obtained. If the null hypothesis is correct, then the sum of the ranks of the positive differences will be approximately the same as the sum of the ranks of the negative differences. If these sums are quite different in magnitude, the null hypothesis may be rejected. We form the statistics T which is the smaller of these two sums is used. T is obtained by adding the negative signs (negative differences). A T table for N ≤ 25 gives the critical values of T. T should be equal to or less than the values in the T table at the 0.05 level to reject the null hypothesis (p.266-267).

The procedure to calculate rank of difference in Table 1:

- Calculate the differences between pairs.
- Do not count zeros (if the difference is "zero").
- Rank the differences in increasing order according to magnitude of difference (without regard to sign); if multiple observed differences have the same value, "split" the ranks according to the number of observations (for example, the 9th and 11th observations have the same absolute value, 1, then each observation is ranked as 1.5).

Table 2 summarizes the differences between pre-test and post-test scores.

The sum of negative ranks, T, is 10.50. Blalock's T test table, the critical value of T for two-tailed test for N=16 at α = 0.05 is 30. Since T=10.50 is smaller than $T_{crit} = 30$, the null hypothesis – there are no differences between the scores of the two populations – can be rejected. The other way to show any significant difference is to use p-value, 0.014 from the Wilcoxon Signed Ranks test. Since $p = 0.014 < \alpha = 0.05$, there are statistically significant differences between the scores of pre-test and post-test with the post-test scores being higher. In other words, the modeling-based interactive teaching method appears to help students to improve their scores from pre-test to post-test.

In addition to determining whether the modeling-based interactive engagement teaching method has an affect on understanding and learning of physics as indicted by a difference between the scores of pre-test

Table 1.Computations for Wilcoxon Matched-Pairs Test and the Sign Test.

Pair Number	Pre-Test	Post-Test	Difference Between Post- and Pre-Tests	Rank of Difference	Positive Ranks	Negative Ranks
1	27	27	0	0		
2	29	27	-2	4		4
3	13	13	0	0		
4	13	23	+10	13	13	
5	27	27	0	0		
6	23	29	+6	9	9	
7	19	28	+9	11.5	11.5	
8	23	20	-3	6.5		
9	26	27	+1	1.5	1.5	6.5
10	21	29	+8	10	10	
11	24	25	+1	1.5	1.5	
12	18	27	+9	11.5	11.5	
13	21	25	+4	8	8	
14	27	29	+2	4	4	
15	17	20	+3	6.5	6.5	
16	18	20	+2	4	**4**	
Total					**80.50**	**10.50**

Table 2. Wilcoxon Signed Ranks.

		N	Mean Rank	Sum of Ranks
Posttest score-pretest score	Negative Ranks	2(a)	5.25	10.50
	Positive Ranks	11(b)	7.32	80.50
	Ties	3(c)		
	Total	16		

Note: a posttest < pretest
b posttest > pretest
c posttest = pretest

and post-test, I wanted to see if there was any correlation between the pre-test scores and the first exam grades, and the post-test scores and the final exam scores (there were three exams and one final exam). I used Kendall's Tau correlation coefficient r_b which measures the strength of the relationships between two variables (Blalock, 1960). Kendall's Tau r_b is calculated using the following equation:

$$r_b = \frac{S}{\sqrt{1/2N(N-1)-T}\ \sqrt{1/2N(N-1)-U}}$$

where S is equal to C-D. C is the number of concordant pairs (a given pair is ordered the same way).
D is the number of discordant pairs (a given pair is ordered oppositely)

$$T = 1/2\sum t_i(t_i - 1)\ ,\ t_i$$

is the number of ties in each set of ties in the first group.

$$U = 1/2\sum u_i(u_i - 1)\ ,\ u_i$$

is the number of ties in each set of ties in the second group.

In this study; let's say the first group is post-test scores and the second group is the final exam scores. Here is an example which explains that ties can be any number which is repetitive such as 27 repeats on pre-test scores or post-test scores. N is the number of cases (N=16).

In Table 3, if every time a given pair such as 1 and 2 is ordered the same way, then +1 is used for C. In other words, each pair increases or decreases. For example, pairs 2 and 3 both decrease. Post-test scores decreased 27 to 13 and the final exam scores decrease 73.53 to 56.69 in pairs 1 and 2. Therefore, we use +1 for this pair. Whenever pairs are ordered oppositely such as pairs 9 and 10, -1 is used for D. For instance, post-test scores increased from 27 to 29, but the final exam scores decreased 89.63 to 85.08. So, we use -1 for this pair. If pairs have ties (same scores), then there is no contribution from these pairs. For example, pairs 1 and 2 have ties in post-test grades which are 27. Therefore, there is no contribution. So, when we make calculations, the contribution from ties will be zero.

To calculate S = C-D, I will just show how to calculate it. I will not calculate completely because it takes too much space. Instead, I calculated using SPSS. Let me give an example from the above table. The contribution of pairs (1, 2), (1, 3), (1, 4), (1, 5), (1, 6)… (1, 10) ….is 0, +1, +1, 0, +1....-- -1…
C= +1+1+1…. ; D=-1….. ; S=C-D=1+1+1-1…..

I calculated the Kendall's Tau r_b using SPSS and tabulated in Table 4.

From Table 4, it is easy to see that there is low correlation between the pre-test scores and the first exam grades because 0.3 < r_b = 0.31 < 0.5. There is high correlation between post-test scores and the final exam grades since 0.7 < r_b = 0.75 < 0.9.

Table 3. An Example from the Study to Show How to Calculate S, and to Show Ties.

Pair Number	Post-test Scores (the First Group)	The Final Exam Scores (the Second Group)
1	27	89.73
2	27	73.53.
3	13	56.69
4	23	81.58
5	27	89.73
6	29	97.63
7	28	83.56
8	20	73.65
9	27	89.63
10	29	85.08
11	25	59.99
12	27	96.02
13	25	87.01
14	29	96.33
15	20	59.95
16	20	74.15

Table 4. Kendall's Tau correlations for the Force Concept Inventory (FCI).

	Pre-test vs. the First Exam Score	Post-test vs. the Final Exam Score
Kendall's Tau r_b	0.31	0.75

Some may suggest that the improvement in scores is due to using the same test as a pre-and post-test. The pre-test scores as an advanced organizer that focuses students' attention are ideas that follow during treatment. If there is carryover using the FCI at the beginning and end of semester it should be small. Other studies using the same pre-and post-test structure have shown only small gains. These studies show that any carryover would be small.

CONCLUSION

I wanted to find out whether an introductory physics course that uses modeling-based instruction and interactive engagement lead to better physics understanding.

The gains that students have made in increasing their learning and understanding of physics were determined by the Force Concept Inventory (FCI). The results obtained from the Binomial distribution test, the Sign test, and the Wilcoxon test indicated that there was a statistically significant improvement between students' FCI pre- and post- test scores. In other words, the modeling-based interactive engagement teaching method appears to have a positive effect on students' learning and understanding of physics. This Wilcoxon T-test also indicates that students in this course have made significant improvement compared to a traditional course. Since nonparametric statistics was used for this study due to lack of sample size, it is not possible to calculate and use the same notation for gain which are used in other studies. Therefore, I cannot compare students' gains in this course with students' gains in other universities.

In addition, the result obtained by using Kendall's Tau correlation indicated that conceptual understanding the students have when they begin the course is not related to their final exam grade. Instead, there is high correlation between post-test scores and course grades. That suggests the course grades are based primarily on conceptual understanding rather than other aspects of the course such as algorithmic problem solving skills. This indicates that the amount of conceptual gains students have made have bearing on their final grades. Given the improvement in conceptual understanding and the high correlation between their conceptual understanding and their success as measured by their course grades, one can conclude that the modeling-based interactive teaching method helps students to improve their understanding and learning physics.

Although the participant selection for this research limits the transferability of the findings to the broader population of all undergraduate physics students enrolled an introductory- physics course because it is more likely that selecting participants from an introductory course for non-physics majors or those whose physics and mathematics background are not strong could yield different results and small sample size, overall this study implies that the modeling-based interactive engagement teaching format used for calculus-based introductory physics instruction at Purdue University is successful at teaching physics.

A future research will explore that while including these populations mentioned above would be informative and add to the richness of the findings.

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Primary Pupils' Preconceptions About Child Prenatal Development

Kristina Zoldosova and Pavol Prokop
Trnava University, Trnava, SLOVAKIA

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The research deals a problem of primary pupils' preconceptions about a child prenatal development. Even the pupils cannot experience the phenomenon and can get only mediate information; their idea about the prenatal development is quite well constructed. The quality of the preconceptions depends mainly upon variety of informational sources kept at their disposal and on their own personality.

Keywords: Preconceptions, Child Prenatal Development

INTRODUCTION

Research into children's structure of biological knowledge has provided contradictory results. Carey (1985) claims that before the age 10, children's understanding of biological phenomena does not belong to any biological theory. Subsequently indicating that is conflated with the same theory by which they understand psychological phenomena. This indicates that they have undifferentiated psychology and biology theory. Carey (1985) further proposes that an intuitive biology emerges from an intuitive psychology between the ages of four and ten. Recently, Inagaki and Hatano (1997) argue that children's biology knowledge is gradually constructed through daily experience with living systems.

Although we can study children's concepts about birth as gradual construction of biological knowledge, the role of social experience is in this specific topic undoubtedly evident.

The process of acquiring biology knowledge involves children's concept of the human body. Numerous preconceptions about human bodily function have been reported (Nagy 1953a, Gellert 1962, Mintzes 1984). Most of the current research within this area was concerned with the human digestive system (Teixeira 2000, Rowlands 2004). It was discovered that the predominant idea of children aged four relating to food they ate, is that all the ingested food remains in the body entirely. This misunderstanding of the food consumption process almost totally disappears at the age of 10 (Teixeira 2000).

Correspondence to: Kristina Zoldosova, Assist. Prof. Dr. Science Education, Trnava University, Department of Preschool and Elementary Education, Faculty of Education, Priemyselna 4, 918 43 Trnava , Slovakia
E-mail: kzoldos@truni.sk

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The digestive processes can be largely explained by the children's first-hand experiences with food. For example, children can perceive intestinal sounds, feeling of being full or pain of the stomach. However, there exist other important biological phenomena with which no first-hand experiences might be expected.

Nagy (1953b) investigated children's concepts about birth. Using interview and essay writing, she found that children's knowledge about how they were born, (ages 4 to 10) rapidly increase. More specifically, she divided four "theories" of children's explanation of birth:

Theory (level) 1: There is no birth, as life has no beginning.
Theory (level) 2: A mammal's life begins, but without the mother.
Theory (level) 3: There is birth from the mother only.
Theory (level) 4: Mammalian birth also implies the father.

Theories 1 and 2 were found only before (age 8 years) and Theory 4 appeared only after eight years of age. The main theory was 3 in overall frequency.

Bernstein and Cowan (1975) continue their research and study the problem in connection with the Piagetian developmental theory. The results they obtained particularly correspond to Nagy's results. Equality can be found mainly in the upgrade of children's ideas in connection with the child's age that is evident and expected. Bernstein set 6 levels of idea understanding.

For comparison, here are short descriptions of the levels.

Level (theory) 1 – *preoperational*: The baby has always existed (in mother's belly or elsewhere).

Level (theory) 2 – *preoperational*: Assigning babies to some phenomena (usually persons, who function as manufacturers).

Level (theory) 3 – *transitional: preoperational – concrete operations*: To create a baby we need three major ingredients: relationship, mechanics of sexual intercourse and fusion of biological-genetic material. The ideas are mainly aimed at relationship (marriage, love and so on).

Level (theory) 4 – *concrete operations*: Ideas rely completely on physical causes of conception. We can find also sperm and ovule in these ideas.

Level (theory) 5 – *transitional: concrete operations – formal operations*: The embryo is preformed in one germ cell and sexual intercourse merely provides necessary and sufficient conditions for development to occur (warmth, food and so on).

Level (theory) 6 – *formal operations*: The Embryo begins its biological existence at the moment of conception and that it is a product of genetic materials from both parents.

In Kreitlers' (1966) research we can find only 3 theories (levels), but this study was aimed at children in the age range of 4-5½ years.

Theory (level) 1: The baby has always existed in the mother's belly.

Theory (level) 2: The baby is created in the mother's belly from the food she eats.

Theory (level) 3: The baby should be swallowed by the mother.

These 3 levels correspond to mentioned Nagy's and Bernstein's levels 1 and 2.

Considering the purpose of our research we would like to mention Bernstein and Cowan's finding, that children do not change their ideas only and mainly under the impression of (mis)information they can obtain. More important to this process is cognitive development. The progress in cognitive development is evident mainly in consecutive occurring of causality (not only in a material world, but also in its social sphere) in ideology.

Results of both the mentioned studies (Bernstein and Kreitler) corresponded with the Piagetian developmental theory. Alternatively, in Kreitlers' study disagreements with Freud's theory about the infantile belief in the universality of the penis were found. Piagetian insufficient causal thinking, alternatively Freudian infantile libidinal development do not hinder the adequate sexual enlightenment of children (Kreitler, 1966).

To know more about children's birth ideas Bernstein used the (analogous to Nagy) interview technique. She set out additional methods to discover the connection with cognitive development. We discovered that both studies were aimed at similar tasks, for instance: "How does the baby happen to be inside the mother's body?" These studies (and other's similar) did not investigate children's conceptions about prenatal development, thus the main idea of our research was to examine, what children aged 6 to 10 know about prenatal development. As we progressed deeper into qualitative research, we needed to support interview as a main research method with other method(s).

RESEARCH PURPOSES AND TASKS

The basic purpose of the research was a qualitative analysis of children's birth ideas and ideas about prenatal baby development. Twenty primary school pupils participated in this study; 5 at each of four primary school grades (6 – 10 years old, Table 1).

Table 1. Respondent group.

grade	age	boys	girls	Σ
1.	6-7	1	4	5
2.	7-8	1	4	5
3.	8-9	0	5	5
4.	9-10	2	3	5

We were trying to discover what a standard child idea is about and how deep differences can be found between the peers.

Partial purpose of the research was to find out the main source of information from which the pupils develop the data to create and modify their birth ideas.

The pupils age, is very specific. Primary pupils' age is known as the age of a concrete reality. Pupils adhere to their own experience in their local reality. Their level of cognitive development does not allow them to modify their own ideas with the help of visions, projections, abstract conceptions. As per norm pupils of this age don't possess much experience with the main amount of aspect typical for the researched situation. Their ideas are built mainly on mediate information. Therefore, we would like to know, who or what mediates/enables them this information?

Although the research topic is quite clearly defined; the research problem is still very wide for a particular qualitative investigation. We have set a few issues for further investigation:

Issue No1: How is the children's birth idea changed with age?

The purpose is to find out the differences between ideas of various age group pupils. We will explore ideas' details to be competent for expression of ideas plenitude and integrity valuation.

Issue No2: Are there differences between children's birth ideas of the same age?

As we expected, ideas about such a specific topic (in comparison to the pupils age and their ability to understand the reality hidden behind it) are not built on own experience and direct observation. Pupils use for the idea creation rather different information (often very vague and obscure). Also, pupils tend to manipulate the information into a very personal way, depending on many factors for example family background, age of the siblings, parent's extroversion, contra introversion, parents-fixation, including curiosity and accessibility to secondary information sources and much more. This is why the way of idea creation is very specific and individual and we can expect the differences.

Issue No 3: Have the children included in their ideas also aspects of prenatal baby development?

We can say that knowledge about prenatal baby development is in some way more biological than other aspects of the birth idea. Following the theory of Inagaki and Hatano (1997), children acquire knowledge mostly out of their own experience. The problem being is that the right observation of prenatal development is not accessible for the children. We suppose that they create the ideas only via indirect experience (pregnant mother or other woman) with use of imagination and acquired secondary information. Predominantly they do not think about phenomena they cannot experience.

Issue No 4: What kind of information influences the children's birth ideas the most?

There are many aspects of the birth idea. For example: conception, prenatal development (development of different apparatus, development of the apparatus function), the way of prenatal nutrition, childbirth, the role of a man at different stages of pregnancy and so on. We would like to discover, which part of the complex birth idea is the most developed. Of particular interest we would like to discover what type of information is the most accessible for the pupils, let us say the most receptive

Issue No 5: Have pupils access to more than one source of information for their preconception improvement?

On one side is a pupil's curiosity and on the other side his or her receptiveness to obtain information. We know that pupils can obtain certain informative information at school, however, we are trying to discover how strong a role of school is (for the preconceptions improvement) in comparison to the role of other information sources (encyclopaedias, TV programs, spontaneous learning and so on) and influences (fantasy, self interpretation etc).

RESEARCH INSTRUMENTS

There are several ways for gathering information about students' knowledge (more in: White and Gustone 1994). As a written word is not for our respondents the dominant expression form, we decided to use methods that are based on other forms of expression (more used in our respondent group). Two consistent methods were chosen: children's drawings and semi-structured interviewing. In contrary to mentioned research, we set children's drawing as the dominant method, interview only supported as a secondary method in this method.

Drawing is a one of the very first manifestation of human's mental life. The drawing speaks about a person's inner world, about favours, demands, living, thoughts, and attitudes, also about many other factors of the developing personality. Specifically the ability of a young child can communicate via drawings with his or her social environment by very specific way.

Usage of the children's drawings as a diagnostic method is not a novelty. More often it is used in diagnosis of different mental characteristics (as a tool of psycho-analysis; Backett – Milburn and McKie 1999). Specifically, the method looks very interesting and helpful, important is to realize that the method is not possible to apply in every respondent age.

Initially, the respondent has to be in a stage of so-called *spontaneous contextual drawing*. In this stage the respondent is unconscious of what is the purpose of the draw making (in our case: diagnosis of his or her idea).

Until the age of 2, children draw lines without real context. It is more about feelings and learning to express their own ideas. Later this stage of draw continuously enters the stage of spontaneous contextual drawing. This period of time is characterised by naive realism and constructive thinking. This period is also called a *golden age of children's drawing*. The drawing is a basic form of emotional life expression and can be considered as an important way of cognitive development and creativity manifestation.

This stage of drawing development holds over between the ages of 7 – 8 and is continuously replaced with stage of *real drawing*. The main target in this new stage is to draw down objects of reality in exact shapes (as they exist). In this stage we still can use the drawing method for the idea diagnosis. Children can be inhibited by the feeling that they are not able to reproduce the reality to an expected standard of reality. The result being that children probably will not draw every aspect of the idea we asked them to draw. They will draw just the aspects they are sure they are able to draw. The drawing interest trails off in age of 11 – 15. Written and spoken word becomes the main express tool.

In a stage of spontaneous contextual drawing, children drawings have few specifics, which relates from children's imperfect reality perception. A child usually draws objects in reverse perspective, as if he or she was a part of the drawing. Beside this, typical for these kind of drawings are big objects drawn in the background and small objects drawn in the front. In common we can find few different perspectives in one drawing (side view, top view, so on). We can also discover much usage of emotional expressions (for example, emotionally important objects and persons tended be drawn bigger or closer to him/herself; nearly always all what is perceived as important was seen to be drawn markedly or with details). Children tend to often have a problem in drawing movement.

Ability to represent the shape of the objects as they exist depends on many factors. For instance it depends on the amount of experience the respondent has with the drawn object. It also depends on the observational ability of the respondent and generally on a larger scale it depends also on an individual's personal talent. Considering that we investigate the idea (not the ability to draw it), we do not evaluate shape precision, but only endeavour to draw the object as it exists (not via applicated design as for instance "pillow-shaped clouds" or "smiling sun" are). By utilising this method we try to eliminate the level of talent. The main objective being to evaluate details of the drawings.

The number of drawn elements is a very significant indicator not only for drawing richness, but also for creativity, free thinking/liberalisation and the ability to express self-expression. To evaluate these aspects we need to determine the absolute frequency of the drawn elements per individual drawing. It is useful to set a few categories of drawn elements. Thereafter we counted frequencies for these categories. By using this method we were able to assign relevant elements of the drawing out of accessory elements (relevance considered in relation to the research problem).

In many cases, children used to draw elements that were not in a clear connection with the drawing content. Usually, the elements are related to some subjectively importance. Indications show that the researcher does not need to understand the connection to the content. The efficient way to deal with this deficiency is to use interview.

Procedure

Every pupil had a task to draw his or her own idea about a prenatal baby development and also (if known) baby conception and childbirth. The task was explained in detail in a clear way that the children understood. In the event of uncertainty the children had the possibility to ask the researcher for further explanation. The pupils had adequate time to draw in detail their ideas. They stopped drawing after 40 minutes. Thereafter, we individually interviewed every child.

The interview was recorded and lasted in average about 20 minutes. The main target of the interview was to gain a better understanding of the child's drawing. We were also asking for explanation of the absence of things we did not find on the drawing.

RESEARCH RESULTS AND INTERPRETATION

Drawing

As we reviewed the drawings, we discovered that it is possible to set 4 different categories of the drawings (Table 2).

Considering the results presented in Table 2 we assume that pupils from lower grades of primary school consider it very important to draw how the baby looks before birth. As the pupils become older, they put into their drawings also a mother. Significant difference can be found in drawings of the forth grade pupils, where we can find also development of the baby in a mother's womb. Indications look as if the older pupils have significant more information; and we cannot consider it via this simply way. It is mainly because pupils receive more information about the subject in third grade at school including the ability to record the development in drawings becoming clearly defied.

Further investigation of the drawing was targeted at detail. We have set categories of the drawn elements and count frequencies of appearance (Table 3).

Table 2. Categories of children's drawings.

Categories of the drawings	Drawings of pupils from grades				Σ	%
	1	2	3	4		
draw of foetus without development	5	2	0	0	7	35
draw of pregnant woman with foetus in her belly, but without development	0	2	5	0	7	35
draw of pregnant woman with developing foetus	0	1	0	0	1	5
draw of pregnancy development	0	0	0	5	5	25

Table 3. Categories of the drawn elements.

Category of the drawn elements	Frequency of appearance				Σ	%
	1st grade	2nd grade	3rd grade	4th grade		
foetus head, body and limbs	5	5	5	4	19	95
eyes	3	5	5	3	16	80
mouth	5	4	5	3	17	85
ears	0	1	0	0	1	5
hair	3	3	4	0	10	50
eyelashes	0	1	0	0	1	5
eyebrow	3	1	1	0	5	25
gender	0	1	0	0	1	5
umbilical cord	5	2	5	2	14	70
womb and foetal coverings	4	3	4	2	13	65
childbirth	0	0	0	1	1	5
fertilization: ovulum and sperm	1	0	1	5	7	35
foetus development	1	0	0	1	2	10
foetus growth without development	0	2	0	1	3	15
growth after birth	0	0	0	3	3	15
making love	0	0	0	3	3	15

Almost all pupils participating in our research (19/20) drew the foetus with a head, body and limbs. Not one respondent was able to draw any foetal inner apparatus. Although they were asked to draw also the apparatuses; they did not indicate nor include them in the drawings. It can probably be affected not only because of lack of knowledge, but also because of the difficulty to imagine such a projection. Pupils were asked to draw things they have never experienced. They saw it on pictures or photos and also they completed the idea using a combination of imagination and fantasy. Indicating that they are able to imagine what is inside of mother's belly, however, it is not easy for a young mind to imagine what is inside of a baby belly inside of the mother's belly. Even though the pupils did not have possibility to see pictures of how the inside of the foetus looks, we cannot say that this is the only reason that they did not draw the information. Perhaps it could be influenced by their ability of reality imagination.

Fourteen out of 20 respondents drew an umbilical cord. The result looks interesting; it seems that pupils know how the foetus gets the food. The connection to this knowledge is clearly indicated in some of the drawings. The Umbilical cord is directed to the foetus mouth, not to the umbilicus (30%), even in certain drawings it is drawn the right way (40%). We did not find any significant difference between knowledge of pupils from different grades.

The pupils did not draw placenta but they were clearly trying to draw at least the womb and some kind of foetal coverings. It can be assumed that to explain the function of the placenta is not as easy as the explanation of the umbilical cord function. We also still have to think and consider the fact that pupils draw their idea of presentation, things only they perceive as important.

The pupils drew also the foetus eyes and mouth (an interesting observation is, that pupils thought that the foetus before birth is not able to see). Only one pupil drew also the ears (it is also interesting, because in contrary to the subject of drawn eyes, pupils claimed, that the foetus before birth is not able to hear anything). Sometimes eyelashes and eyebrows occurred in the drawings. We feel these are details to which some pupils pay attention to, and others do not.

Only one respondent differed foetus gender. Even though we can perceive it also as a detail, after the interview we discovered that pupils mainly think that the foetus has the gender differed from the beginning. They also claimed that the doctor is able to identify the gender through mother's pregnancy.

The lack of drawings including gender differences as a result of the absence of drawn genitals was also noted by Reiss and Tunnicliffe (2001). They found, that drawings with reproductive organs among 4/5 – 11 year old children were scarce.

Concerning the drawings of older pupils (3rd and 4th grade, including one pupil from 1st grade) we can find an indication of fertilization. Pupils drew ovulum and sperm, sometimes also act of its fusion. A few of the older pupils drew their individual interpretation of the act physical love of man and woman (3 respondents out of 20, all from 4th class pupils) indicating an important part of prenatal development of baby. This is in compliance with Bernstein (1975) research results and particularly we can find it also in results of Nagy (as importance of father contribution; 1953b).

Interview

By obtaining and discovering further information, enabling a clearer understanding of the drawings, we decided to include an interview as additive research method. It often appears very difficult for pupils to speak about the subject freely, that is why we directed the dialog and leads the pupils by asking direct questions.

The pupils mainly experienced initial problems with direct questions relating to conception, the principal role of the father during conception, the duration of the pregnancy term, interpretation of different senses before birth and including an understanding of the environment in which a foetus lives before birth.

As we indicated at an earlier stage in this report, older pupils tended to include in their drawings thoughts about conception, (note: one exceptional pupil from the first class had a very clear idea about whole process of conception, surprisingly quite a scientific idea. This also included knowledge of descriptive words he used for the explanation). They draw especially sex cells. Their responses seem to be more schematic as it is common in children of that age (Nagy 1953b), they really did not understand how the baby can develop out of few cells.

In contrast, younger pupils have very interesting ideas about conception. The ideas differ and vary greatly, probably due to their initial lack of information. This is in comparison to that of older children who have gained and been exposed to advanced stages of information gathering. Strong indications show that pupils were probably influenced by various information and they significantly differ in their individual methods of expressing how they create and modify their own personal preconceptions.

A similar scenario is a clear interpretation and understanding of the father's role in conception and the whole pregnancy. Only 5 respondents indicated a clear understanding about this specific role. We are dealing here specifically about pupils having approximately the right idea. Pupils tended not to speak about physical love, sex or love making, but only about kissing and loving each other by an emotional way. Particularly they connect it with marriage status. These findings exactly correspond with Bernstein's (1975) findings.

All pupils were able to say, that the foetus develops in the mother's belly. By asserting further asking, it was quite clear that they were not able to exactly explain, what does foetus development mean? Also most of them said, that the foetus inner apparatus only grows (not develops). They further conceived that the foetus has some parts of the inner apparatus from the beginning and some occurs later, and more after birth. Mainly they indicated that the foetus has bones, a heart and a stomach from the beginning. Thereafter the brain develops (or occurs) later, after the birth. These preconceptions were more typical for younger children, but the preconceptions did not differ by any significant way. Surprisingly, most of the respondents were able to explain, how limbs develop, especially they were able to explain, that shape of the limbs, changes from the beginning of the pregnancy to the baby's birth.

As the pupils did not have a clear idea about the foetus inner apparatus and its development, it would be interesting to discover how they perceive the apparent function of the apparatus (breathing, eating, secretion, hearing, seeing etc.). When we asked pupils to explain how the foetus breaths and eats, we discover further imperfections in the pupil's conceptions. The partial problem of nutrient uptake was not so uncertain. Older pupils used to explain it by the existence of the umbilical cord. Some of them thought that it ends in the foetus mouth. The entire pupil research group had problems with the explanation of the foetus breathing. Only a few older respondents have had particularly the right idea. Most of the respondents experienced problems with the explanation and their ideas and responses were varied. For example, they thought that the foetus does not need to breath, nor that the foetus's nose is connected with the mother's lungs.

Most of pupils thought that the foetus does not have hair (younger pupils drew the foetus hair), and they are particularly convinced, that foetus has eyelashes and eyebrows.

Only one pupil from the first class thought that the foetus can see before birth. When we asked if the foetus can recognize darkness and light, some pupils said that it is not possible. Thereafter, we summarised the pupils think that the foetus is not able to use eyes despite the fact that the foetus already has the eyes (eyes are drawn in 19 out of 20 drawings). They argue: "If there is light in the mother's womb, foetus would not see anything". Some of the pupils think that foetus can hear. There are not any significant differences between opinions of younger and older respondents.

A very difficult task for the pupil's was to explain how the foetus environment in the mother's womb looks like. We saw on the drawings that most of the pupils used red colour for filling space inside the womb. We have discovered that they think the foetus floats in the mother's blood. A few pupils said that the foetus floats in water the mother drinks. Others thought that the foetus has a space filled with air in the womb. Only a few respondents (significantly older) defined the environment as amniotic fluid.

Respondents also know about foetus movements. Just two younger girls thought that the foetus cannot move.

Table 4. Information sources for the pupils' preconception construction.

Information source	Frequencies in the grades				Σ	%
	1.	2.	3.	4.		
parents	2	2	1	2	7	35
other relatives	1	1	1	0	3	15
schoolmates	0	0	0	1	1	5
books, encyclopaedias	2	4	3	1	10	50
documentaries on TV	2	0	0	2	4	20
kindergarten or school	1	0	0	0	1	5
only own idea	1	1	1	0	3	15

Older pupils had a quite clear idea about pregnancy duration (9 to 10 months). However, younger pupils differ in the explanation significantly. Some of them said that the pregnancy lasts about 5 weeks, few respondents claimed, that it lasts about 2 or 4 months. On the other hand, some of them said that it is about one or two years and one pupil claimed, that pregnancy can last one month, but sometimes also one or two years.

Pupils' Preconceptions and Information Sources

The construction of the preconception about prenatal development is a very individual process; children use various cognitive skills, feelings, imaginations, but also various sources of information. In our research we were trying to identify informational sources which influenced our respondents the most (Table 4).

Our respondents indicate books and family members (mainly parents) as the main informational sources for the construction of the preconceptions. In this aspect, there are no significant differences between older and younger respondents. It seems that even school offers some basic information about the prenatal baby development; pupils do not accept the information. Similar trends were found in UK research aimed at children's ideas about animals (Tunnicliffe and Reiss 1999). We suppose it could be caused by the fact that information they already have and they acquire at school are not coherent. Pupils rather stay with their preconceptions as they would change it under the influence of external information, especially if they do not understand the new information comprehensively.

Lack of information from school till age 10 is another explanation for the observed phenomenon. Although 8/9 year old children (grade 3) should acquire basic information about a human body, in Slovakia primary science curriculum is not focused on prenatal development. The possible role of school vs. other information sources cannot be clearly explained in Slovak conditions.

It is important to mention that the idea development continues regardless of information provided by mainstream education (similar finding was obtained also in the mentioned Bernstein's research, 1975). Stability of children preconceptions is high, that is why some of the infantile concepts are generally not corrected through knowledge acquired later, but are merely covered up by it (Kreitler and Kreitler, 1966).

The cognitive skills development plays the main role in the reconstruction of the preconception. Especially it is a way how the children manipulate with information and how important their own experience is (the same experience is accepted by a different way depending up the age). And like other aspects of Piagetian theory, the development seems to occur in a spiral line. In the children's ideas of different age we can find similar (or the same) issues, but the children deal with them in a more sophisticated way, where we can find much more integrated knowledge.

SUMMARY

Even at the beginning of the data analysis it seemed that older pupils dispose of more perfect and authentic idea about prenatal development; after a more detailed analysis we have found that the preconceptions differences (depending on a pupils' age) are not so significant as we expected they would be. We have discovered more significant differences between pupils of the same age.

Very specific information (like sperm and ovule) can be found in the ideas of the older respondents, the whole conception is not compact, and pupils do not understand the interconnection of the information acquired in mainstream education with their previously constructed idea.

In compliance with previously realised researches we have to accept the fact that the children preconceptions develop, but the topic is very specific. The preconception development depends on both the quality and quantity of informational sources the children keep at their disposal. The children's personality plays a very significant and meaningful role (curiosity, extroversion contra introversion, self-consciousness, etc.). We have also observed a development of ability to select relevant attributes of the idea for the expression. Younger pupils perceive quite different attributes of their preconception as the most important for understanding the phenomenon. Particularly it relates with intense development of ability to change their own preconception under the thumb of different information (disappearance of egocentrism typical for preschool age) and with intense development of the time perception ability.

Pupils' preconceptions about prenatal development vary, but not only in connection with age. The great role plays individualism and different access to various informational sources.

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Book Reviews

Mehmet Fatih TAŞAR, Section Editor
Gazi Üniversitesi, Ankara, TURKEY

AN IMAGINATIVE APPROACH TO TEACHING

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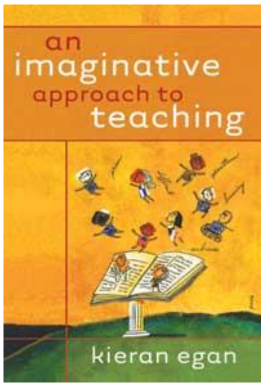

"All knowledge is human knowledge and all knowledge is a product of human hopes, fears, and passions. To bring knowledge to life in students' minds, we must introduce it to students in the context of the human hopes, fears and passions in which it finds its fullest meaning. The best tool for this is the imagination" (Egan, 2005, p. xii).

An Imaginative Approach to Teaching presented by Kieran Egan is all about how we can connect imagination to education's central tasks, and set students' imagination to learning on a routine basis, in every classroom, on everyday of the school year. The book provides educators a new and powerful understanding of how imagination works in learning as well as suggesting specific teaching techniques that activate students' emotions and imaginations in a variety of subject areas.

The book proposes that all children come into the classroom knowing how to use certain kinds of cognitive tools for learning, and an imaginative teacher should use these tools to provide engaging lessons in which students retain and use the knowledge they gain. In this aspect, the book identifies three types of cognitive tools that students can demonstrate, and then suggests a series of classroom practices incorporating these cognitive tools into specific lessons.

The book consists of three main chapters. Each chapter describes one type of cognitive tools that students utilize as they go through stages of cognitive development: oral language, literacy, and theoretical or abstract thinking. The first chapter explains the tools that come along with the oral language stage, such as story, metaphor, binary opposites, rhyme, rhythm, and pattern, jokes and humor, mental imagery, gossip, play, mystery, and embryonic tools of literacy. It is stated that most commonly the tools introduced in the first chapter will be found in young children, roughly before seven years, before literacy begins to significantly influence their thinking. Moreover, these tools are indicated to be highly effective in organizing and categorizing knowledge, as well as keeping in memorable form.

The second chapter explains the tools that mature with the literacy stage, such as sense of reality, extremes of experience and limits of reality, association with heroes, sense of wonder, collections and hobbies, knowledge and human meaning, narrative understanding, revolt and idealism, changing the context, literate eye, and embryonic tools of theoretic thinking. It is proposed that the tools mentioned in the second chapter are most commonly found in children, roughly between seven and nine years, after literacy become more fluent and thinking more realistic, and they are pointed out to be building upon the way

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children understand their experiences. However, it is noted that they are "not to be seen as some kinds of hooks or motivators", but as "clues to help solve the problem of how to make knowledge about the world meaningful to students" (p.36).

The third chapter explains the tools that develop with the theoretical thinking stage, such as sense of abstract reality, sense of agency, grasp of general ideas and their anomalies, search for authority and truth, and meta-narrative understanding. It is noted that the tools described in the third chapter will be found in young adults who have picked up the previous sets of tools, and they are regarded to be highly effective at enhancing students' thinking ability, generating flexibility, and encouraging students to search out patterns, look for essences, and construct their theories.

After each chapter, a half chapter is provided showing practical relevance of these cognitive tools in preparing lesson plans on different subject matters. Examples of the first chapter include how to prepare lessons such as Place Value, Butterfly Transformations, Properties of Air, Homophones, and Heat. Similarly, examples of the second chapter include lessons such as Parallel Lines, Life Cycle of a Cold-Blooded Vertebrate, and Tree. Lastly, examples of the third chapter include lessons such as Revolutions, Calculus, Hamlet, and Simple Harmonic Motion. All these examples are written in a way that draw students into the content, drive their intellectual inquiry, and create a sense of wonder as they pursue their learning.

In general, the book offers an understanding of how students' imaginations work in learning and demonstrates how the acquisition of certain kind of cognitive tools can drive students' educational development gradually. It underlines the fact that the essence of teaching is not simply to teach facts and skills that can be reproduced when required but to relate the facts and skills to their deeper meaning in human experience through the use of imaginative approach to teaching.

The book values imaginative education as it aims much more knowledgeable students who are able to think flexibly, creatively, and with energy. In this aspect, the book suggests teachers to regard the classroom as a place from which one takes off into other environments, so that they can easily engage students' imaginations in learning. Lastly, it underlines the fact that in order for the imaginative thinking "to develop adequately and to work effectively, students need to know a lot" (p.169) about the related subject matters.

Overall, *An Imaginative Approach to Teaching* can be useful for teachers, teacher educators, staff development professionals in a great extend. No matter whatever style of teaching suits one best, the suggested teaching techniques can help teachers all age groups and all subjects, to plan their lessons in a more creative and imaginative way.

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Fatma Kayan
ODTÜ, Eğitim Fakültesi,
İlköğretim Bölümü,
06531 / Ankara
TURKEY
E-mail: fatmakayan@yahoo.com

The reviewer is a PhD student in the Elementary Education. She is involved in studies relating to elementary mathematics education, mathematical problem solving, and teacher professional development.

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