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M. Fatih Taşar, Associate Editor
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In Memoriam

David Ausubel (1918 ~ 2008)

Professor Ausebel passed away in the morning of July 9, 2008 at the age of 90. Among his most notable scholarly work were *The Subsumption Theory* and *Advance Organizers*.

Ausubel was an assistant surgeon and psychiatric resident with the U.S. Public Health Service and worked in Germany in the medical treatment of displaced persons after W.W. II. He worked at the University of Illinois between 1950-1966. He served as a professor of educational psychology and medical education at the University of Toronto between 1966-68. Then he moved to the City University of New York, where he chaired the doctoral program in educational psychology. He retired in 1975. During his entire carrier he has been a very influential figure in the field of educational psychology.

He was most cited with the following quotes:

"If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach … accordingly." (1978, p.v)

"These organizers are introduced in advance of learning itself, and are also presented at a higher level of abstraction, generality, and inclusiveness; and since the substantive content of a given organizer or series of organizers is selected on the basis of its suitability for explaining, integrating, and interrelating the material they precede, this strategy simultaneously satisfies the substantive as well as the programming criteria for enhancing the organization strength of cognitive structure."(1963, p. 81).

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Scientists and Scientific Thinking: Understanding Scientific Thinking Through an Investigation of Scientists Views About Superstitions and Religious Beliefs

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Scientific literacy is explored in this paper which describes two studies that seek to understand a particular feature of the nature of science; namely scientists' habits of mind. The research investigated scientists' views of scientific evidence and how scientists judge evidence claims. The first study is concerned with scientists' views of what constitutes superstitious beliefs. The second concerned potential conflicts between scientific theories and evidence, and religious beliefs. The research findings suggest that these scientists, unlike their stereotype, hold idiosyncratic views of what constitutes good scientific evidence and sound, credible testimony. The interviews provide a window into scientific thinking as practiced by modern scientists, and suggest that the scientists are rather more open to alternative thinking than might be supposed. The implications of these findings are discussed in the context of their implications for scientific literacy.

Keywords: Literacy, Religion, Science, Sociocultural, Superstition

SCIENCE AND SCIENTIFIC LITERACY

Science has been spectacularly successful, with things like international air travel, space flight, and curing of medical illness now routine. The impact of enabling technologies like micro-computers which now dominate much of everyday life, have become available to the general population only as recently as the 1980s. High speed computing and huge increases in cheap, small, memory storage devices is likely to further increase scientific and technological advances.

One feature of the incredible and seemingly ever increasing advance of science and technology is a sense of unease amongst some of the general population about sciences potential to change our lives, in sometimes unpredictable and alarming ways. Public understanding of science and ability to engage in debates about science is part of what is referred to as 'scientific literacy', which according to much recent literature, is of increasing concern worldwide (Carson, 1998; Laugksch, 2000). The term 'scientific literacy' actually represents a diversity of views, but a common theme in the literature is that of being 'learned' or knowledgeable about some science content, and being able to critique scientific debates. According to Laugksch (2000) a scientifically literate person does not accept opinion about a contentious scientific matter uncritically. Rather, he or she wants to see logic or evidence for any stance taken on the issue (Miller, 2000). Some authors argue that the success or otherwise of a

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science education system can be evaluated by reference to the literacy of the citizens (Preece & Baxter, 2000; Yates & Chandler, 2000).

It is interesting that many societal scientific debates are characterised by suspicion of scientists themselves, and their purported motives (Durie, 1997). Reiss (2003) suggests "the topics on which scientists work – and so the subject matter of science itself – to some extent reflect the interest, motivations and aspirations both of the scientists that carry out such work and of those who fund them" (p. 154). In other words, technological change is seen to be driven by the motives, interests, and values of the science and technology community, rather than society as a whole (Dalgety, Zegwaard & McCurdy, 2003; Durie, 1997). This may be one reason that scientists are now seen somewhat as 'tainted witnesses' with a vested interest, or captured by personal interests, unduly influenced by funding providers, such as central government or multinational corporations.

That the science and technology community has such a large impact on technological change would likely be less problematic if the values and culture, and the demographics, of the science community were reasonably representative of society as whole (Reiss, 2003). However, in general this is not the case. Women, for example, are reported to be underrepresented in science and technology higher education faculty posts and other science-related occupations. In a specific example, in the United Kingdom only 12% of science professors are women (Greenfield, 2000), and a similar lack of representativeness apparently applies to many ethnic minorities. For example, indigenous peoples are reported to be underrepresented in post-compulsory science education and science professions, possibly as a result of perceived conflicts between indigenous worldviews and the worldviews of so-called 'Western science' (Jegede & Okebukola, 1989, 1991; Paku & Coll, 2005)

It is hard to overestimate the importance of scientific literacy in the modern era. Carson (1998) says we need to "equip students to be good, informed citizens capable of participating in public discourse concerning matters of science" (p. 1007). Important and topical issues relate to matters such as the appropriate use of cloning technologies or genetic modification or engineering (Brunton & Coll, 2005). Oftentimes the 'right answer' is not obvious for such scientific debates, and the public are faced with trying to decide who is credible in scientific debates. Such debates are hampered by a litany of 'scientific' disasters such as the over-use of pesticides like DDT (Nestle, 2003), and medical mishaps such as thalidomide (Center for Drug Evaluation & Research, 2002). A dramatic recent example of public debate in which scientists were discredited is that of the UK governments 'scientifically-based' claims that the so-called 'mad cow disease' could not cross the food chain from animals to humans (see Nestle, 2003). This plainly proved incorrect, and helped make the British pubic highly sceptical about scientifically-backed claims for other issues such as GM crops and the like. A strong case for the importance of scientific literacy as a focus for science education is provided by Carson (1998). He comments that "science has become far more than an esoteric body of facts about the natural word" (p. 1011). Scientific literacy also is important in the management of schools and school curricula. With devolution of school management in some countries debates about what should be included in school science curriculum can become quite heated (characterized by creationism vs. evolution debates, see e.g., Dagher & BouJaoude, 1997; Gould, 1983, 1991a, 1991b; Kass, 1988).

Nature of Science and the 'Scientific Mind'

An important aspect of scientific literacy is familiarity with the nature of science and scientists. To engage in debate about scientific issues we suggest necessitates some understanding of the nature of science. Much of the success of science has been attributed to the so-called scientific method (Chalmers, 1999), and high standards of evidence for scientific claims and theories. But how does science 'work'? How do scientists obtain data? What data is good data? What are the 'rules of the game' in science? Much has been written about the nature of science, and research into students' understanding of the nature of science. It seems students often see science as a codified body of knowledge that is essentially unable to be challenged (e.g., Pfundt & Duit, 2000). Much constructivist writings and constructivist-based pedagogies have sought to overcome such notions. Constructivists see scientific knowledge as personally mentally-constructed, based on personal experiences, and influenced to a greater or lesser degree by the social context in which knowledge construction occurs (Good, Wandersee & St. Julein, 1993; Tobin & Tippins, 1993).

It seems from the literature that students ascribe scientists fairly stereotypical images and beliefs, as do the general public, seeing them as objective seekers of truth and inevitably ascribing to experimentalist methods of inquiry in their scientific research (Dalgety, Coll & Jones, 2002). Scientists are, however, humans and like all humans hold views and biases, for example, seeing some things worthy of inquiry and others not (Laugksch, 2000). However, like technology (Sade & Coll, 2002), science is increasingly presented in the science education literature as contextualized and value-laden, and to possess a 'sociological agenda' (Allchin, 1998). Carson (1998) argues that science education should not "leave students vulnerable to the occasional dogmatism of the scientists, but able to appreciate and yet criticise the enterprise of science" (p. 1012). Guisasola, Almudí and Furió (2005) point out that students are likely to see science as codified knowledge (in physics at least) for which textbooks present a very simplified version of the nature of science, one in which science knowledge is seen to be accumulated in "non-problematic, non-historical, 'linear' accumulation" (p. 333). In contrast, recent work by Dagher and Ford (2005) suggests that science biographies written for children provide insights about scientific experiments and procedures used by scientists, but speak little of how scientists make connections between theory and evidence.

Gauld (2005) in a landmark paper summarizes much research into the 'scientific mind' and scientists' views of the nature of science. This is presented in terms of the 'scientific attitude' (attributed to Gauld & Hukins, 1980), and 'habits of mind'. According to Guald's (2005) analysis, habits of mind for scientists can include: open-mindedness, scepticism, rationality, objectivity, mistrust of arguments from authority, suspension of belief, and curiosity. A number of these habits of mind at first sight seem incompatible (e.g., open-mindedness and scepticism). However, it is the interplay of these habits of mind that results in 'the scientific attitude', in which "no idea, conclusion, decision or solution is accepted just because a particular person makes a claim but is treated sceptically and critically until its soundness can be judged according to the weight of evidence which is relevant to it" (Gauld, 1982, p. 110). A key feature of evidence claims, according to Zinman (1968), is that scientists have "very high internal critical standards" (p. 79).

Herron (1969) suggests that with respect to the understanding of the nature of science presented in the literature "we 'talk' a much more impressive procedure than we actually do" (p. 105). This resonates nicely with Reif's (1995) view that to understand science involves more than gaining content knowledge; it also involves understanding of the "requisite thought process" of science (p. 281).

The literature is replete with commentary and rhetoric about what scientists are purported to think: their epistemological beliefs (Matthews, 1996), their views about the nature of science (Matthews, 1998), conflicts between science and religion (e.g., Gauld, 2005; Mahner & Bunge, 1996a, 1996b), and superstitious/pseudoscientific beliefs (Preece & Baxter, 2000; Yates & Chandler, 2000). But according to Coll and Taylor (2004) there are little data reported from contextualized and detailed research studies about scientists' views of the nature of science, and conflicts between scientific and everyday thinking.

Theoretical Basis to the Inquiry: Science as Sociocultural Practice

The construction of science as a culture, where belonging is characterised by the enculturation or assimilation of cultural norms, is consistent with sociocultural learning theories (Lave & Wenger, 1991). Sociocultural learning theories see cognition as 'constructed jointly', and learning being strongly influenced by social, cultural and historical factors. According to (Wertsch, 1991, p. 86) "the basic tenet of a sociocultural approach to mind is that human mental functioning is inherently situated in social, interactional, cultural, institutional, and historical context". Thus, the science community of practice cannot be divorced from the social, cultural and historical elements of their own identity and the workplace itself. To understand these norms and practices of the scientific community requires some form of enculturation into the community of practice; something that is not open to the public. Enculturation into a community of practice involves the learning of skills, knowledge and understandings (e.g., in science, the scientific method, accuracy, repetition, etc.) all within a particular sociological framework (Evans & Heidegger, 1999). The general public may not see any great need to become 'enculturated into science'. However, it is our contention here that a facet of scientific literacy involves just this. In other words, here we argue that to become scientifically literate, people need to have at least some understanding of what science is and how scientists go about their business (for a counter to this position see Ben-Ari, 2005). Specifically, here we are concerned with what scientists consider to be 'scientific evidence' for a proposition or propositions. Understanding how scientist work, we suggest would enable students and the public to engage in more informed scientific debates.

Research Aim and Questions

Our overview of the literature here suggests that scientific literacy is an important and current educational issue. It also suggests that, with a few exceptions, scientists are seen by the public and in science education writings in stereotypical images. Research and writings about scientists' views of the nature of science tend to focus on 'hard science' concepts with, for example, Franklin (2002) exploring this notion in physics by examination of rationalisation about relativistic quantum mechanics, concepts beyond the vast bulk of the general public (or indeed most physicists!). Here we sought to explore the issue of scientific literacy and scientist habits of mind, by drawing on current issues that the general public encounter and is familiar with: namely, pseudoscientific beliefs and superstitions, and religious beliefs.

Gauld (2005) points out that scientists may hold two positions: a rationalist stance which is that presented in the public domain (the public domain of their community of practice), and the private idiosyncratic views more accessible by interpretivist, ethnographic educational research approaches. The issue of scientific literacy in this work is thus explored by a qualitative, in-depth, investigation of scientists' views of scientific evidence. The overarching aim is: How do scientists judge evidence claims? The research reported here comprises two intensive interpretivist-based studies. The first study is concerned with scientists' superstitious beliefs (some details of which have been presented elsewhere, Coll & Taylor, 2004). The second concerned potential conflicts between scientific theories and evidence, and scientists' religious beliefs.

METHODOLOGY AND METHODS

The methodology derived from the sociocultural-based theoretical framework described above comprised two methods: surveys and interviews. The details of these are now described in turn.

The Surveys

We made use of two instruments in which participants are asked to respond to a four-point scale ranging from 'I believe that this is almost certainly true' to 'I believe that this is almost certainly untrue' with two in-between responses qualified by replacing 'almost certainly' with 'quite likely'.

Table 1. Items from Exeter instrument (Preece & Baxter, 2000)

The positions of the stars and planets when you are born affect what will happen to you during your life
Some houses are haunted by ghosts
It is possible to tell what is going to happen to you in the future by studying the lines on the palms of your hands
Wearing jewelry made out of certain crystals can help to keep you healthy
Some men and women can find missing persons by swinging a pendulum over a map
In the past aliens from some other planet have landed on Earth
Breaking a mirror is likely to bring you some bad luck in the future
The 13th of July 2001 is a Friday and people should be careful on that day as 'Friday the 13th is unlucky'

The first instrument was based on previous work by Preece and Baxter (2000), the Exeter superstitions instrument, in which respondents are presented with a series of item statements, which these authors considered to be superstitions (e.g., Some houses are haunted by ghosts; Some men and women can find missing persons by swinging a pendulum over a map; and In the past aliens from some other planet have landed on Earth) (Table 1).

The second instrument, developed by the authors, contains 18 assertions or propositions that were deemed by a panel of experts to consist of potential conflicts between religious beliefs and scientific theories (Table 2). Sample items included: People can be cured of serious ill health by petition to a higher spiritual power; The age of the earth is no more than 10,000 years old; After death the soul/spirit of a person returns in a subsequent life form; and, Human conception can occur by spiritual not physical means.

Table 2. Items from religion and science instrument (Preece & Baxter, 2000)

The age of the earth is no more than 10,000 years old
After death the soul/spirit of a person continues to exist
After death the soul/spirit of a person returns in a subsequent life form
What happens in a person's life is set at the beginning of their life
A person can affect what happens in their life by petition to a higher spiritual power
Human conception can occur by spiritual and not physical means
People can be cured of serious ill health by petition to a higher spiritual power
Order in the universe exists as a result of the influence of a higher spiritual power
Evil behavior in the world occurs as a result of powerful evil spiritual forces
Inspiration for arts, sciences and crafts is a consequence of spiritual forces
The lives and activities of all living things are influenced by spiritual forces
There are benevolent spiritual forces that assist or protect people in their daily lives
Some particular animals have special spiritual status
All living and inanimate things have a soul/spirit associated with them
Disasters that occur in the world are a result of powerful evil spiritual forces
Disasters that occur in the world are a result of people's evil behavior
People who behave well are rewarded in an afterlife
Humans are distinguished from other animals as a result of having a soul/spirit

Instrument Validation

Validation of terms like superstition, and of what constituted current science views and conflicts with those views, was achieved by the use of a panel of experts. The panel of experts consisted of scientists across a range of disciplines that examined each item statement in the instruments and asserted that it was in conflict with current scientific thinking in that discipline. These individuals had no contractual interest in the study (Guba & Lincoln, 1989), and were not participants in the inquiry (other than in this advisory capacity). Propositions about religious beliefs were chosen to access beliefs purported to come from several religious faiths and denominations: Catholic, Fundamentalist Christian (viz., Christians who believe in the literal interpretation of the Bible); Sunni Islam, Judaism, Buddhism, Hinduism, and Bahá'í (based on religious writings and unstructured interviews with religious ministers and faith adherents for each of the above named religions).

Survey Administration

The term superstition did not appear on our version of Exeter instrument used in the present work, nor was it used in the interviews (except when introduced by participants). In the first study, as a first step, the researchers administered the Exeter instrument to a number of scientists working in industry and in tertiary education (n=40). The purpose of this was not to replicate earlier quantitative work as such, but was to ascertain if scientists agreed with any of the beliefs presented on the Exeter instrument (i.e., provided any response other than 'I believe that this is almost certainly untrue'). The reason for this was that the reported development of the Exeter instrument appears to assume that all scientists would automatically disbelieve all the propositions presented to them (Preece & Baxter, 2000). Clearly there would be little point in the present research if this was in fact the case. A similar thing was done with the religious beliefs instrument. Our initial survey of scientists suggested that a cohort of scientist did not dismiss all propositions

Table 3. Demographics of research participants: Superstitions study

Pseudonym	Discipline	Academic Status/Experience	Comments
Brian	Chemistry	Associate Professor/experienced researcher experienced in administration & management	
Miles	Chemistry	Senior Lecturer/established researcher with emerging international reputation	
Charlie	Biology	Lecturer/new appointee with modest research reputation, although emerging in his field	
Richard	Earth sciences	Associate Professor/experienced researcher; experienced in administration & management	
Peter	Physics	Lecturer/emerging researcher	
Terry	Chemistry	Senior Lecturer/emerging researcher with, but considerable administrative experience	
Nikki	Chemistry	Lecturer/emerging researcher	
Mack	Physics	Senior Lecturer/emerging researcher	
Anne	Biology	Lecturer/emerging researcher	Strongly identified as atheist
Mary	Physics/Biology	Senior lecturer	
Sue	Biology	Teacher/emerging researcher with limited reputation & administrative experience	
Jane	Biology	Lecturer/emerging researcher with some administrative experience	
Teresa	Environmental science	Senior Lecturer/experienced researcher with experience in administration & management	
Fiona	Chemistry	Lecturer/emerging researcher with considerable administrative experience	
Judy	Mathematics/Psychology	Lecturer/emerging researcher with considerable administrative experience	
Josie	Human biology	Lecturer/experienced researcher with experience in administration & management	
Theo	Biochemistry	Senior lecturer/experienced researcher with experience in administration & management	
Nigel	Mathematics	Lecturer/emerging researcher with some administrative experience	Strongly identified as 'born-again' Christian

Table 4. Demographics of research participants: Religion and Science study

Pseudonym	Religion	Occupation/Discipline	Qualification
Gerrad	Church of England	Lecturer in biology	PhD
William	Presbyterian	Lecturer in biology	PhD
Bob	Hindu	Lecturer in physics	PhD
Mary	Catholic	Lecturer in biology	PhD
Arnie	Methodist	Lecturer in agroscience	PhD
Susan	Agnostic	Lecturer in agroscience	PhD
Phil	Agnostic	Lecturer in agroscience	PhD
Iman	Sunni Muslim	Completing PhD in agroscience	MSc
Ahmad	Sunni Muslim	Completing PhD in materials & process engineering	MSc
Mahmoud	Sunni Muslim	Food and meat researcher	PhD
Jack	Catholic	Lecturer in biology	PhD
Allan	Bahá'í	Resource consent manager	MSc Environmental Science
Celia	Hindu	Earth Science	MPhil
Anne	Hindu	Completing PhD in materials & process engineering	MSc
Brian	Bahá'í	Pharmacist	BPharm
Lyle	Bahá'í	Marine biologist	PhD
Liam	Christian	Completing PhD in chemistry	MSc
Kevin	Christian	Completing PhD in the Earth sciences	MSc
Patty	Buddhist	Chemist	MSc
John	Buddhist	Chemist	MSc
Rachel	Buddhist	Physicist	MSc
James	Buddhist	Physicist	MSc

in the instruments. Hence, we subsequently interviewed two cohorts of science faculty in two separate studies. For the superstitions work, there were 18 participants interviewed, with none of the original 40 scientists surveyed. For the religion and science study, we administered the instrument to a cohort of 20 New Zealand and Australian scientists in advance of interviews (see below).

Interviews

The second phase of the work involved intensive one-on-one semi-structured interviews based on the responses made to the administered instruments. This involved an approach in which individual constructions were elicited by interactive dialogue between the researchers and the participants (Good, Wandersee & St. Julien, 1994). This dialogue was conducted on 'neutral ground' in order to reduce the influence of investigator bias (Johnson & Gott, 1996). In practical terms this consisted of the interviewers constantly working to ensure undistorted communication took place: words and beliefs that hold an 'established' meaning (e.g., a 'superstition', a specific religious belief or an 'established' scientific theory) were only ascribed the meaning imparted to them within the conversation of the interviews (see also below, terms like 'higher power', 'spirit' and 'soul').

In the interview protocol, the participants were first asked to complete the instrument (in advance of interviews) and the responses formed the basis for a series of probing, in-depth interviews, that addressed their responses and other topics not presented in the instrument that arose during discourse (such as water divining, acupuncture, etc.). It is important to note at this point that the researchers did not seek to exclude beliefs introduced by the participant (religious beliefs, medical-related beliefs, etc.), whether they were on either of the instruments or not. In these interviews the researchers' focus was not on a particular belief, or belief type (as identified in the literature, or held by the researchers); rather we strived to ascertain the basis on which the scientists had arrived at their beliefs about the propositions contained in the instruments, and any other beliefs respondents introduced in the conduct of the interviews.

Sample

The samples were convenience samples, but interview participants were chosen purposively to provide a reasonably even gender balance, and a range of scientific disciplines (chemistry, the Earth and biological sciences, physics, etc.). For the superstitions work there were two cohorts from two 'conventional' tertiary or higher education institutions (i.e., institutions which were founded as universities rather than originating as polytechnics and/or universities of technology): one from New Zealand the other from the UK. For the religion and science study all participants were from conventional tertiary institutions based in New Zealand and Australia (Tables 3 & 4).

The participants were typically highly educated with about half holding a master's degree and half a doctoral degree. Half of the master's graduates are currently studying towards doctorate. Those employed, were working as faculty or research scientists in their disciplines. This group ranged from relatively new staff appointments with two or three years experience, to experienced people with senior-level research and management responsibilities. About half of the participants had an international reputation for research in their disciplines, possessing substantial research publications in international journals and other peer recognition such as long term service on editorial boards for journals. Participants were recruited by means of a letter of invitation that confirmed the use of pseudonyms and assured them of confidentiality.

For the religion and science study, we sought participants with a variety of faith commitments. First were those who were raised in a faith, practiced that faith as children and young persons, and who now described themselves as 'non-practicing'. The intention here was to see if these individuals had 'drifted away' from their beliefs and religious convictions for no particular reason, or if this occurred because they encountered conflict between religious beliefs as they became enculturated into their particular scientific community. Second, we sought participants who were strong faith-adherents and currently strongly practicing in their faith (as identified by the participants – i.e., they reported that they were currently practicing their faith in terms of religious observance and rituals). The intention here was to see if, for example, a strong Christian was more inclined to 'accept' Christian beliefs that were in conflict with scientific theories than they were about say Hinduism or Bahá'í beliefs that were in similar conflict, and vice versa.

Researchers' Viewpoints and Background

The researchers in this work come from different educational and religious backgrounds. Given the nature of the present work (i.e., dealing with an emotive and complex topic), it is appropriate for the authors to describe their background in order for the reader to aware of any potential biases and to aid in interpretation of our research findings.

One researcher was brought up in a relatively strict Catholic background. He was and still is a 'practicing Catholic' in that he attends Sunday observances and other Catholic obligations regularly. He is a scientist with a doctorate in chemistry and record of publishing on organomentallic chemistry. He also is a science education researcher with a second doctorate, and publishing record in science education. Metaphysically he ascribes to constructivist views and acknowledges social influences on scientific and educational research. A second researcher is from a church-going Protestant Christian background. He is still a tentative believer but no longer attends church on a regular basis. He has a doctorate in science education and came from a science background, having completed undergraduate and postgraduate degrees in the biological sciences. Like the above researcher, he ascribes to constructivist views and acknowledges the social component of research. A third researcher was raised as an atheist and was converted to the Bahá'í Faith at high school as a result of extensive intellectual discussions with a strong Bahá'í adherent. He is an engineer with a doctorate in materials and process engineering and has an undergraduate degree in the biological sciences. He is a social-constructivist in epistemology, but subscribes to a scientific objectivist methodology for his scientific/engineering research. He is broad in agreement with an interpretive-based research approaches to science education research in that he recognizes the importance of subjective views in both learning and research in education.

Data Analysis

Data analysis for the instruments employed simple summaries of frequency distribution. In the case of the interviews, these were audiotaped and transcribed verbatim. Interview transcripts were examined for statements about the scientists' views in an iterative process based on a phenomenographic approach allowing pools of meaning, and subsequent categories of description, to arise from the data (Marton & Booth, 1997) (Tables 5,6 & 7). Portions of transcripts are used to illustrate the process of analysis and interpretation, and pseudonyms are used throughout this report of the research. These have undergone light and minor editing (e.g., removal of repeated words, changes of tense) in a few cases, purely to make them more readable – consistent with an interpretive approach to educational research. In accord with an interpretive, sociocultural-based approach, the research findings reported here are not directly generalizable to other settings. An alternative, and that applicable here, is the notion of transferability (Guba & Lincoln, 1989) in which the reader evaluates the significance of the findings in his or her own educational context. The provision of descriptive findings (see below), using the so-called 'thick description' is intended to facilitate this process (Merrian, 1988; Peshkin, 1993).

Table 5. Rationale for scientists' beliefs for Exeter instrument

Belief	[1] Agreement	Reason(s) For	Reason(s) Against	Example(s) For/Example(s) Against
Astrology	Sceptical	Theoretical basis	Testimony; Theoretical basis; Experiments	Physical nature of planetary position/Used to make money; no physical link; no evidence for link; minimal effects because of distance; No correlations
Ghosts	Not sceptical	Personal experience	Testimony	Related to Ouija board experiences
Palmistry	Sceptical			
Crystals	Not sceptical	Testimony & Theoretical basis	Testimony; Theoretical basis; Alternative explanations	Crystals exert electrical & field effects/Friends beliefs seen as uncritical; No chemical reasons for effects by quartz ; Happened because of some other factor
Missing persons & pendulum	Totally sceptical	None	Theoretical basis	None/No connection between map and pendulum
Aliens	Open	Don't know enough	Testimony	Possible aliens landed in past; Nature of alien life; Roswell incident; paradigm shifts/Unreliable witness 'elderly' or 'children'
Mirror	Totally sceptical	None	Theoretical basis	None/Seen as socially grounded
Friday 13	Totally sceptical	None	Theoretical basis	None/Seen as socially grounded

Table 6. Rationale for scientists' beliefs for superstitions interviews

Belief	[1] Agreement	Reason(s) For	Reason(s) Against	Example(s) For/Example(s) Against
Water divining	Not sceptical	Theoretical basis	None	Physical interaction between objects/None
Ouija board	Open	Personal experience	Theoretical basis	Dramatic personal event - lights fusing/No possible credible explanation
Acupuncture	Not sceptical	Testimony	None	Doctors seen as credible/None
Identification of gender	Not sceptical	Personal experience	None	Own pregnancy/None
Destiny/Predetermination	Sceptical	Theoretical basis; Personal beliefs	Personal beliefs	Quantum effects, probability; genetics/Peoples' choices effect own destiny
Birth rates	Sceptical	None	Testimony	None/Birth rates in study
Numeracy	Sceptical	None	Theoretical basis	None/Seen as socially grounded
Clairvoyance	Sceptical	Experiments	Experiments	Nostradamus/Police inquiry failure
Psychic/Paranormal	Sceptical	None	Experiments	None/Police inquiry failure
Interplanetary life	Open	Don't know enough	None	Statistical probability of life elsewhere; Lack of knowledge of brain and its functions/None
UFOs	Open	Testimony/Don't know enough	None	Pilots seen as credible/None
Archaeological events	Open	Don't't' know enough	None	Nasca Lines in Peru; Stonehenge/None

RESEARCH FINDINGS

The research findings are summarized in Table 8, and here we provide a brief overview of the findings before presenting them in more detail. Some of these themes were reasons given by the scientist for supporting the instrument propositions, others were reasons for disbelieving them – these differences are detailed under individual headings. The themes discerned included: Personal experience/Personal beliefs; Testimony from other scientists; Potential theoretical basis/Related evidence; and that We don't know enough.

Personal Experiences

The scientists recognised the influence of personal experience in the formation of their own beliefs. Some personal experiences were seen to influence the scientists thinking about beliefs, making them at least potentially believable. Josie, for example, felt there was some prospect that one could tell the sex of a baby based on her own personal experiences during childbirth: "I had twins and I was attached to blood pressure monitors, two monitors, one for each twin, picking up blood pressures and their heart rates towards the end of the pregnancy and there were differences."

Table 7. Rationale for scientists' beliefs for religion and science interviews

Belief	[1] Agreement	Reason(s) For	Reason(s) Against	Example(s) For/Example(s) Against
Age of the Earth Less 10,000 Years	Sceptical	Theoretical Basis	Testimony	Changes to speed of light influences dating experiments & metaphorical age/Scientific evidence of fossils, dating experiments, etc.
Soul/Sprit Exists after Death	Not Sceptical	Testimony/Don't Know Enough	Theoretical Basis	Near death experiences/Indoctrination
Soul/Spirit Returns in Subsequent Life Form	Not Sceptical	Testimony/Don't Know Enough	Theoretical Basis	Affinity with things Russian & Revolution/
What Happens in Life Set at Beginning of Life	Sceptical	Personal Experience/ Don't Know Enough	Theoretical Basis	Marriage & wealth prediction came true and /
Petition of Higher Spiritual Power	Open	Personal Experience/Testimony	Theoretical Basis	Successful personal petition/Failed personal petition & mere act of petition
Human Conception Can Occur by Spiritual Means	Sceptical	Theoretical Basis	Theoretical Basis	Sexual reproduction necessary & social factors e.g. of purity/Amictic cells
Ill Health Cured by Petition to Higher Spiritual Power	Open	Testimony	Theoretical Basis	Successful personal petition/Failed personal petition & mere act of petition
Order in Universe Exists Because of Higher Spiritual Power	Sceptical	Don't Know Enough	Theoretical Basis	Order & structure of animals/
Evil Behavior Exists Because of Evil Spiritual Forces	Sceptical	Personal Experience	Theoretical Basis	Grandfathers death/Schizophrenia
Inspiration for Arts, Science, Craft Consequence of Spiritual Forces	Totally Sceptical	None	Theoretical Basis	None/No potential link
Lives/Activities of Living Things Influenced by Spiritual Forces	Totally Sceptical	None	Theoretical Basis	None/No potential link
Benevolent Spiritual Forces Assist/Protect People	Not Sceptical	Personal Experience/Testimony	Theoretical Basis	
Particular Animals Have Special Spiritual Status	Sceptical	Personal Experience	Theoretical Basis	Encounter with native birds/Lack of logic-punishment coming back as animal
Living & Inanimate Things Have Soul/Spirit	Sceptical	None	Theoretical Basis	
Disasters Due to Evil Spiritual Forces	Sceptical	None	Theoretical Basis	Auto suggestion - 'pointing the bone'/
Disasters Due to Peoples Evil Behavior	Sceptical	None	Theoretical Basis	None/Disasters due to bad behaviour & natural disaster no-ones fault
People Who Behave well Rewarded in Afterlife	Not Sceptical	Personal Beliefs	Theoretical Basis	
Humans But Not Animals Have Soul/Spirit	Sceptical	None	Theoretical Basis	

[1] *Key:*
Exeter Responses (all participants): Totally Sceptical, only response was 'I believe this was almost certainly untrue'; Sceptical, most common response was 'I believe this was almost certainly untrue'; Not sceptical, at least some respondents indicated 'I believe this was almost certainly true' or 'I believe this is quite likely to be true; Open, most respondents indicated 'I believe this was almost certainly true' or 'I believe this is quite likely to be true'.
Interview Responses (participants who identified this belief spontaneously during interviews for both superstitions and religion & science studies): Totally Sceptical, respondent was dismissive of all propositions/beliefs discussed during interviews; Sceptical, respondent that raised this issue was dismissive of this belief; Not sceptical, respondent that raised this issue was fairly dismissive of this belief, but did not totally discount the belief; Open, respondent that raised this issue indicated that they agreed with this belief.

Table 8. Classification of scientists' views for evidence claims for superstitions and religion and science studies

Classification	Basis	Comment
Personal experience/ Personal Beliefs	The scientist had undergone personal experience of the type discussed/The scientists held strong personal beliefs about the topic	Some dramatic personal experiences were strongly influential
Testimony	The scientists rated personal testimony of others, typically media-based, either as credible or non-credible; Credible witnesses were educated people or experts (e.g., medical people or airline pilots) non-credible witnesses were either 'gullible', 'charlatans', 'children or the 'elderly'	Most widely held basis for believing or dismissing belief
Theoretical basis	The scientists perceived a possible theoretical basis to the belief	Commonly related to scientists' own discipline or area of expertise
Experimental evidence	Controlled, quantitative experiments, actual or hypothetical, seen to be able to provide evidence for/against the belief	The scientists were highly sceptical about 'apparent' evidence claims of this nature, but were willing to consider such propositions
Simple alternative	The scientists were convinced that even with strong empirical evidence supporting the belief, there would be a simple, underlying alternative explanation	The scientists were highly sceptical about 'apparent' evidence claims of this nature
Don't know enough	The scientists felt current knowledge about the belief was inadequate to either support or dismiss the belief	Commonly related to probability arguments, e.g., with respect to space/aliens

Some reported personal experiences were highly dramatic and unsettling, clearly exerting a significant impact on the scientists. The most compelling example was that provided by Theo when he talked of his experiences with an Ouija board (a movable 'board' that is thought by some to provide a means of communicating with dead people or 'spirits'). His response to the proposition that some houses are haunted by ghosts was that he thought this was almost certainly true. He explains his reasoning, based on a personal experience: "Threats were made against a particular woman in the group and the timing of that and in the lead up to that potential action we were corresponding with whatever was going on saying that we forbade it etc, etc. But whatever was happening was getting more and more excited and the climax of the exercise was the lights fusing in the house."

Personal experience likewise emerged as a reason for believing some religious propositions with, for example, some scientists reporting friends and colleagues being cured of significant illness (e.g., cancer) by 'petition to a higher power'. This was in some cases seen as resulting from what Bob called "the mere act of petition," and in other cases from the actual intervention of a higher power as seen in Phil's comment that "I know that in the intervention of God, there is clear evidence in healing." Those who opposed such interventions generally felt that the notion of 'mind over matter' was the overriding influence as seen in Steve's comment that " 'pointing the bone' [an Australian aboriginal indigenous custom of placing a curse on a person, by literally pointing a bone at them], that sort of thing in [Australian] Aboriginal or African culture, if you believe you've done something wrong, it could be because a higher power intervened, or it could be because of a belief that was self-fulfilling." Personal experiences reported included Bob's experience of physical encounter with a native bird species [the native bird showed affinity for his presence] which he considered as potential support for a proposition that "some animals have a special spiritual status" and Jim's personal links and affinity with things Russian which he appeared to consider as potential evidence for having lived a past life. 'One of the other things is that my birthday is on the day of the Russian Revolution.'

As was seen in our study of scientist views about superstitions some personal religious experiences reported in the present work were dramatic, and strongly influential on participants' beliefs. This is illustrated in the case of a strongly-practising Hindu participant, who talked of a dramatic personal experience involving 'spirits'. Celia said: "When my grandfather died I was a little girl at the time my mother was looking after him at the hospital and he said wanted to see me…my mum took holidays for me from the school and I went with my mother to visit him in hospital and he died at the hospital – but the second it really happened that his spirit got into me and maybe three or four months later everyday at 12 O'clock afternoon midday I used to get fits."

Similar reasoning was used by Celia to explain the common Hindu support for pre-destination (as probed in an item, 'what happens in a persons life is set at the beginning of their life') which she interpreted as being astrologically-related: "Even now everyone [i.e., in India] decides when you get married, or where you go. We were seven students and he [a pundit-astrologer] said you should be married at 29 and you'll be very rich and be owning a car at that time. I never believed it at that time, but definitely next time. I brought a car here [i.e., in NZ]."

The converse also was true in that lack of, or non-fulfilling personal experiences were deemed to be evidence against some propositions. To illustrate, Celia apparently did not accept that 'a person can be affected in their personal life by petition to a higher spiritual power' (item 5, appendix) as the result of failed petition: "I was once thinking that if I pray to God I would get good marks, it never happens, I have to study to get good marks. So I slowly understand that it doesn't happen."

Personal Beliefs

Likewise personal beliefs based in religion, with no supporting 'evidence', or indeed any perceived need for evidence, was used as a basis for acceptance of some of the propositions in the item statements used in the interviews. Alan was rather dismissive of Hindu-based beliefs in reincarnation and the special status of some animals: "I guess the evidence for reincarnation is flawed in that there's not much point to the exercise…why come back as a cow as a punishment?"

As might be expected, although most participants were more accepting of their own religious beliefs, when they conflicted with science this was not universally accepted. For example, Annie was brought up and remained a practicing Hindu. However, when probed about reincarnation she commented: "In Hinduism there is a thing called reincarnation…when people ask if I believe in reincarnation, not I don't, but I believe the soul lives on," a statement more in accord with Christian religious belief, than Hindu.

Witnesses Testimony

The bulk of the 'evidence' in favour of, or against, pseudoscientific and superstitious beliefs was judged to come from witnesses and their testimony. Such witnesses were typically seen as lacking in credibility. These non-credible witnesses fell into two categories; honest individuals who were genuinely misguided, and those with more dubious motives – the latter typically people associated with the entertainment industry, or the mass media.

Some of the non-credible witnesses were seen to be influenced by social mores such as the popularity of reporting alien sightings. Much of this was thought to arrive from television and other mass-media sources such as popular magazines: 'I think it's used as an industry to make money. It's a populist thing." Some of the scientists were highly cynical, distrusting motives and credibility of certain witnesses: "I think it's generally looney toon people generally promoted this, women who look like soothsayers, and that sort of image I've associated with it. So I don't have any belief in it whatsoever" [emphasis added]. The honest but misguided were deemed not credible for other reasons; some were dismissed because they were "elderly people" or "small children" others were seen as being "too emotional" and thus subject to "placebo" type effects or autosuggestion. Mitch, for example, said: "I think strange things happen in this world and people tend to come up with the explanations that it was in their beliefs or their religious views, or their worldview, and that are consistent with it." Going on to illustrate with an example, he said: "I remember the case that physics department at Canterbury [University], they had a little study on the hospital maternity ward, where it was claimed that they had more babies during full moons. The matron there was absolutely convinced of it. So one of the students studied the records for the last 10 years and there were no data, couldn't find anything."

Likewise, an overactive imagination (with respect to, for example, ghosts haunting houses) was seen to be likely, with Nikki saying" "Ok he's heard some noise … and he goes, I have certainly heard a ghost." Another reason for disbelieving personal testimony was that "people believe what they wish to believe," particularly in relation to religious matters (as evidenced in the haunted house proposition). Anne comments: "I think it has the potential to be tainted by the nature of the prior expectation of what they are going to see." Others saw friends and associates as less discerning about such experiences: "I had a couple of friends who used them [crystals to improve health] and they buy into that sort of stuff. But I have to say they tend to be very uncritical. They are not from a scientific background. I would take it with a grain of salt because they tend not to question."

In some cases the scientists dismissed other people's reported claims based on their own personal real-life experiences, feeling that many of their own personal experiences would have been interpreted by other – perhaps more gullible – individuals as evidence for the propositions put before them in these studies. Hence, the testimony of others, when it conflicted with scientists' own more "logical" interpretations, resulted in the former being deemed unreliable by Charlie: "I personally would have experienced situations in a house where you think, oh that's a pretty scary noise and your imagination immediately starts to sort of think about those things. Yet when you sit down and rationalize it, you think, no, no. It's probably something like you know whatever happened here, the wind was banging on the door or whatever."

Credible witnesses were, perhaps not surprisingly, seen to be other scientists or "people educated with a science degree" according to Sue, and people whose "credibility is based on their record of having done some systematic research in a particular area" as identified by Miles. Others deemed credible included someone who was "doing a doctorate in engineering." Interestingly, the participants dismissed some claims on the basis of the evidence being anecdotal. However, anecdotal evidence from credible witnesses was deemed adequate – at least enough to question the likelihood of phenomena – or as adequate grounds for keeping an open mind. Mary comments: "Acupuncture has been practiced for thousands of years in China, so as I said it seems to be credible because it works in some individuals… But it's been used for thousands of years and in some people it has a dramatic effect."

Similarly, anecdotal evidence from "fairly stable sorts of people" was seen as a basis for thinking that some houses might be haunted, but was not seen as adequate for astrology-based claims because such anecdotes were likely tainted by reports from "charlatans" and "crackpots." Credible witnesses were thus seen to be level-headed people with no obvious ulterior motives, Brian pointing to "airline pilots have reported incidents of being followed by craft or things like that, I mean I would guess the majority of airline pilots are fairly sort of level headed people - we hope!"

Similar themes were seen for the religion and science study. A number of the scientists felt that whilst they themselves were not sure of the details of the evidence against some of the propositions, negative testimony from other scientists meant such propositions could not be taken seriously. This was most typically the case for the age of the Earth proposition with, for example, Keith a biologist commenting that "the scientific evidence of fossils and dinosaurs and all that sort of stuff, the age of the stars," and Jane another biologist saying "you would have to throw out so many theories to believe that one." This occurred irrespective of religious faiths with, for example, Annie, a Hindu, commenting "I know a little bit about carbon dating and I know it is definitely older than 10,000 years because I believe in the carbon dating technique and the research that has been done in terms of prehistoric creatures, and the evolution of man." When asked why she believed in carbon dating she replied, "because the half life of carbon-13 decays and produces isotopes of carbon, it has been scientifically proven, that decay kills off [sic] carbon."

Other participants pointed to things such as near death experiences for which in their minds, there were now sufficient reports to support the religious propositions presented in items about spirits/souls existing after death or returning in a subsequent life (Table 7). Alan comments: "Our consciousness is not affected by sleep or injury to the person's brain or whatever, there have been far too many cases of people remembering to dismiss…there are studies currently being conducted into near death experiences to the point where enough scientist are taking them seriously to warrant belief."

One scientist, an Earth scientist and fundamentalist Christian, ostensibly did think that the Earth was less than 10,000 years old. This he reasoned was a matter of data interpretation: "There is fossil and dating evidence, facts that suggests the Earth is millions of years old, these are facts…but you can interpret this in other ways." When questioned, he talked about a theory to do with changes in the speed of light which ostensibly meant that radio-chemical dating experiments were unreliable: "The speed of light is constant, but it may not always have been constant … this would affect the reliability of the carbon-dating data."

Theoretical Basis to Beliefs

A strong theme to emerge was that the scientists though there might be some theoretical basis for the belief. This is not to say they knew of any such theoretical basis, but the scientists felt that some theoretical basis might be uncovered in the future. This differs markedly from notions of experiments or empirical testing (see below); rather it was seen as necessary for there to be "a possible mechanism of action." Teresa pointed out that "I could have a minimal number of observations, but if I could work out a possible explanation ok. It's like an Ouija board, if I could work out a possible explanation, then ok." Fiona shared this sentiment: "I think I would want to be convinced, I would want to know what people thought was actually happening, what they thought might be causing it." This she saw as essential for believing in propositions like those raised in the interviews: "I would find it a believable proposition in that it had an effect, but I would want to know why it had an effect, and I think because I don't know why, because I can't come up with an explanation why it may have an effect, then I suppose at the end of the day I would tend to think it's a psychological effect."

In the case of the proposition that crystals improve some people's health, some of the scientists could see a potential mechanism, based on their knowledge of crystals generally, and the fact that according to modern scientific theory, crystals can exert electrical or field effects. So Josie felt "there could possibly be some link between the chemical composition of the jewellery [and] absorbing something." Charlie expanded on this idea: "In my own mind there is a possibility that fields of whatever you like to call them, electricity or whatever there is associated with particular minerals, can potentially influence a force in the body." Likewise, the few that were less sceptical about astrology like Judy, thought that there were, potentially, underlying theoretical reasons not inconsistent with current scientific thinking: "There are physical aspects to the planets, the positions of the planets, so taking the physical and taking actual events that have happened to me, I just have to reserve judgement on that."

The scientists discriminated between fairly similar phenomena, with, for example, water divining seen as potentially credible, Terry saying "water diviners do work because the water in the pipe or whatever somehow works. There is an interaction between all objects," Teresa open to the idea "there appears to be something in it," and Josie suggesting that "You could rationalise that couldn't you? In terms of humidity differences in the desert or wherever." In contrast, finding a missing individual by swinging a pendulum over a map was not deemed credible: "I just can't see a connection between a map and a pendulum." So, because there was a potential theoretical reason in the former, namely "an interaction between all objects," water divining might work.

In some cases lack of belief was grounded in the individual's own scientific knowledge of a particular discipline. This, the scientist's felt, made them well qualified to judge the veracity of claims. So the physicists and Earth scientists were generally dismissive of astrological propositions confidently one asserting that "there is no evidence that the planets could affect you," and another saying "I think they are too far away to have any magnetic or electrical impact," and going on to relate this to their own scientific knowledge. Richard comments: "Knowing the affects, they are pretty minimal and I expect they would cancel out anyway … Just because there's no scientific evidence, doesn't necessarily mean something is not true. But I would say that we understand pretty well the interaction between the planets and what's going on here, that we can almost completely rule out any possibility of an interaction." Others were equally dismissive of astrology on these grounds: "You are talking such vast distances and I really can't see that there could be any physical link." Similar expressions were made by chemists, within their area of expertise, for example, about the use of crystals to improve health: Brian comments: "I don't see you know the power of crystals so I don't see why something that's crystalline should have any magic effects just because it is crystalline … I don't see what's special about quartz."

The lack of a theoretical basis to some beliefs was attributed to the socially-grounded nature of many of the beliefs discussed in interviews. This was particularly true in the case of numbers-based beliefs. Brian again: "If you go to somewhere like Japan, I think the number five, or the number seven, is unlucky and not the number 13." Nikki, likewise commented: "Unlucky? But in Russia it is the opposite." Similarly, beliefs about bad luck were seen to have social origins with Peter commenting: "This to me is one of those superstitions generated to control behaviour. Like a long time ago mirrors were extremely expensive to make."

Again similar themes emerged from the religion and science study. To illustrate, for most of these scientists human conception by spiritual rather than physical means was deemed impossible. Celia a Hindu, said: "It's ridiculous, it will never happen, I totally believe it is due to physical means, because I am not a Christian I have never tried too understand that." Similar views were expressed by Annie another Hindu: "Conception was like a gift that was handed to virgin mums, they were born into a normal family." However, some strong Christian adherents used their discipline-specific scientific knowledge to propose reasons as to why this might be possible. For example, human conception was seen as at least technically feasible since non-sexual reproduction in other species was well established as seen in Bill's comment: "It's a possibility that if we have an all loving God who constructed these processes in the first place using the natural things anyway, why can't you have as amictic cell [i.e., which can give rise to offspring without fertilization] in the ovary in the womb of a woman turn itself into an embryo? It happens in plants all the time." Those that discounted this proposition attributed the belief to something deemed to socially-acceptable at the time with, for example, Keith commenting "that way she [i.e., the mother of Christ] can't have been soiled in any way, something that has a basis in belief and trying to fit into a particular framework."

It was noteworthy that some scientist 're-worked' some of the items presented in the surveys, thinking on their feet and seeking alternative explanations. Alan, for example, as noted above was rather dismissive of Hindu beliefs in reincarnation, but upon probing he looked for alternative explanations that might be seen or interpreted as "evidence" at least consistent with such beliefs. He said of reincarnation""the fact that genetic material is passed form one person to another as generations proceed, one after another, that is 'reincarnation' so to speak."

Controlled Experiments and Appropriate Quantitative Evidence

For some of the scientists controlled empirical experiments were seen to be able to – in principle at least – establish credibility of some of the propositions. Charlie, for instance, felt that "What I would look for would be some sort of correlation between when people were born and the positions of the stars and planets and what had actually happened to those people," in order to believe in astrology. Mary likewise felt that "some statistical analysis of how it all matched, horoscopes of people that have now died, look at what has happened and see if it matches," might convince her.

Simple Alternative Explanations

Even reliable empirical evidence, or highly credible testimonies, were seen to be unconvincing in some cases. As mentioned above, the scientists felt that there would need to be a reasonable explanation even in the light of overwhelming empirical support. The participants felt that for such 'evidence' there would likely be other more credible – or equally credible – explanations. Fiona, for example, said that reports of crystals improving health "may have happened because of some other factor." Explanations must be "complete," they must explain regularity of events, and be able to offer explanations for those circumstances in which the event differs. In other words, anecdotal or other evidence in support of beliefs (superstitious or otherwise) could also be dismissed on the basis of coincidence. Terry comments: "I have a lot of trouble believing that it was anything to do with the breaking of a mirror. There would be a second order of explanation that could be used, and even with evidence I don't believe it could be true."

Countering coincidence is seen thus to be important, this was raised in a number of interviews when the scientists commented about the use of clairvoyants in police investigations and soothsayers like Nostradamus. Anne comments about a local police investigation in which the police (unsuccessfully) employed a psychic to try to find the body of a murdered child. "You don't have the prediction in the discovery, you have discovery in the prediction … you hear that sort of thing it will be like you know Nostradamus predicted the state of the World. Some of the psychic cases I've been involved with like Mona Blades [a famous New Zealand murder victim], it was sort of like make the prediction. I mean some cases where they've claimed to have had a positive hit it tends to have been that they claimed to make predictions but no one's recorded, before the event took place."

We Don't Know Enough

For a number of propositions the scientists felt that they could not completely discount a given proposition because the knowledge of science in this area is tenuous or incomplete (in the minds of these participants at least). As a consequence, alternative explanations must be considered, or at least cannot be totally discounted. These scientists were thus surprisingly open-minded about some beliefs. Nigel, for instance, said "I think in time we will find life somewhere else out there," and cosmic and religious related beliefs (e.g. ghosts and aliens) were those most widely believed. Peter, for example, stated: "I can't absolutely say that there is no possible effect of the way the cosmos works at particular times – we don't know enough about physics at the moment to say that that it has effects." This, it seems, came from a belief that we don't know enough about such events – in the minds of these scientists – suggesting we need to keep our options open. Charlie, for example, said: "I think it is possible that aliens in whatever form might have landed on Earth in the past and left no evidence of their arrival … In my mind we have detected nothing, and we as a society have not been able to travel far in space to try and go further than our ability to communicate." Other arguments related to the nature of aliens, as Josie pointed out "it depends on what you mean by alien doesn't it? Whether or not they are viral particles or bacterial particles – whatever they might be."

Probability arguments based on the sheer numbers of space objects seemed to sway some of the scientists. Jane for example, felt "If you are defining all the conditions of planets you need to sustain life in terms of what a planet can have, not being too cold, right sort of atmosphere, a sun that lives long enough for life to actually happen, then there's millions and millions of planets out there and the laws of probability at least one of them is going to have life."

Others also related their ideas to the "Roswell incident" and other cosmic matters and seemed influenced by the astronomical space-time context, with, for example, Mitch saying, "there could be life forms out there in the universe, possibility that there is life on a number of those planets. [There is] the possibility that intelligent life has evolved quicker than it did on Earth and therefore may have visited the Earth."

The comparative paucity of knowledge about astronomical and historical phenomena and events was also seen as grounds for keeping one's options open. It thus seems that the scientists were aware of historical paradigm shifts in scientific thinking and this influenced them to keep an open mind. Mitch comments: "I think you've got to think outside the box when it comes to anything … you still can't let yourself be too closed in by their interpretations that if someone's offered an alternative one and it's credible from a scientific point of view then you should let your mind open a little bit."

Such thinking also applied to the scientists' perceptions of our understanding of the brain, with many of the scientists thinking that there remains much unexplained about the brain – thus they were open to alternative explanations including paranormal phenomena. Brian comments: "We're only getting to grips with sort of the medical side of our bodies and how you fix tonsillitis and appendicitis and things like that and we don't really know how the brain works and whether, some people have other abilities and that kind of thing."

Other geographical and physically anomalous phenomena were seen as difficult to explain; such as lines in South American deserts. Mary's comments:

'The Nasca Lines in Peru. Where the symbols can only be seen from the air yet from the dating of them they were made far before anybody had a sort of means of flying as far as we know … Obviously that may not be the only explanation, but I think it is one possible explanation." Historical matters commonly surfaced as seen in, for example, Thomas's comments on Stonehenge and the like: "I guess I read about these things where certain inventions are turned up in Egyptian times like batteries and things and it makes you wonder. Stonehenge, how could they have conceived that, being the primitive peoples they were back then? It makes you wonder'."

The notion that we simply don't know enough about many "spiritual things" meant that some of the participants in the religion and science study likewise felt that "we need to keep an open mind." This particularly occurred in relation to ephemeral things such as spirits and souls living on after physical death and cosmological notions of pre-determinism and order in the universe or its creatures. Mary indicated that she thought that order in the universe was almost certainly due to a higher spiritual power: "You're looking at some structure, let's say a fly or a spider, now what are the chances the probability that something like that can construct itself?" This was universal across the religious denominations with Annie a Hindu commenting that the reason she was prepared to believe the notion that after death a spirit could continue to exist was because "I think that there is a lot yet to be discovered, there's a lot yet unknown that we don't know about and it could be proven…even if science has not proved it now, who know what might happen in the next 1000 years?" She held similar views about people being cured by petition to a higher power: "People diagnosed with cancer found other ways and means not in terms of cures like alterative medicines, but in terms of believing, having faith and praying or taking up religion that they have been healed," although she went on to comment that this was likely due to "a belief that they can destroy it if people believe in something it gives them the ability to fight something better."

Scientist Habits of Mind

Our argument here is that developing an understanding of actual scientists' views about evidence and rationale of evidence claims provides insights into their habits of mind (as defined by Gauld, 2005). These habits of mind appeared to be a consequence of both personal beliefs arising from a variety of experiences, including their scientific training. It is likely that the formation of these habits of mind also was influenced by a variety of factors such as upbringing and environmental-cultural influences. However, the data here suggest personal beliefs and scientific training together exert a potent influence in the formation of scientists' habits of mind. The most significant outcome for this interesting mixture of scientists is variation in habits of mind: for example, for some participants personal beliefs (including religious beliefs) appear to override their scientific training and the norms of their profession; for others personal beliefs are paramount; and, for some personal beliefs and scientific thinking are compartmentalized. Here we seek to identify what we see as the main habits of mind that are evident from our findings.

First, is a combination of the habits of mind, rationality and skepticism. Evidence for this comes from beliefs of the capacity of petition to a higher power to cure illness - or not - depending on the dominance of science or religion; to make life or career choices based on religious beliefs; and, to modify our physical environment or environmental management practices because both science and religion encourage this. These scientists thus appear to engage in a toss up between rationality and skepticism when dealing with the issues mentioned above.

Second, is a combination of the habits of mind open-mindedness, rationality and mistrust of arguments from authority. Evidence here comes from the view that scientists need to be open to alternative interpretations even if these are outside mainstream science, including major theoretical paradigms like evolution, or seemingly unchallengeable things like human conception. So here the scientists are open-minded, do not automatically accept the prevailing view, but seek to rationalize the evidence in front of them.

Third, and related to that mentioned above, is the habit of mind open-mindedness. Evidence here comes from a view that because of a consciousness of alternative interpretations for say religious and scientific ideas, teachers of tertiary level science need to be aware of the potential religious diversity in their classes, and teach in a manner that is respectful of personal religious views, whilst maintaining scientific integrity. This necessitates an open-minded outlook to science than many may instinctively think was absent in science learning environments.

IMPLICATIONS FOR SCIENCE TEACHING AND LEARNING

Some authors have argued that an outcome of good science education is improvement in scientific and technological literacy (Laugksch, 2000; Mahner & Bunge, 1996a, 1996b) and argue that religion and superstition are 'antiscience (see, Matthews, 1996, & references therein). Modern citizens constantly confront scientific and technological issues and science/religious conflicts. Given that scientists are generally seen as (sometimes 'tainted') authority figures with respect to science claims, it is of interest for science educators to understand what beliefs scientists hold, and on what basis, they hold such beliefs. A more liberal approach to science teaching might, as Matthews (1996) posits, "maintain that science instruction should be more than merely the conveyance of factual knowledge" (p. 91). Quite so. In other words, science is value-laden as many authors working in the area of the nature of science have long maintained (see, e.g., Sutching, 1995). Others like Ogawa (2002) argue that science needs to move beyond the Western view of science and take cognisance of "indigenous science."

One feature of scientific literacy is the ability to make credibility judgements of peoples' and scientists' testimony. Scientific literacy is important in modern society as people encounter debates and issues of a scientific and technological nature, including science curriculum matters. This study provides a window into some scientists' thinking, in this case with respect to potential conflicts between science and religion. The research findings provide evidence for dissonance for many of these participants, but others have in contrast rationalized such dissonance in variety of ways. It is our view that these data point to a more open-minded attitude than is commonly ascribed to scientists. This suggests that scientists are not automatically dismissive of non-scientific beliefs (including religious beliefs) and points to a human dimension of scientific thinking.

A second issue is the impact if any of scientists' beliefs on their teaching of scientific content, especially in the case of religious beliefs that conflict with science theories. A scientist's research is screened in that if he or she wishes to publish research in scientific journals peer-review likely 'screens out' views that are widely disparate from those held consensually by the particular community, such as chemists, Earth scientists, and so on (insofar as there is consensual agreement). The fact that many of the scientists in the present work held beliefs that were in direct conflict with 'normal science' is not necessarily of concern in this context. Tertiary level teachers arguably have more autonomy over specific course content (in that, for example, they are not constrained by external curricula) although course offerings may be subject to some peer review and scrutiny (e.g., accreditation programs exist for many professions, and course structure and content in tertiary level science are often externally moderated, especially at advanced levels). But what of say an Earth scientist or biologist that is required to teach current scientific theories that conflict with their personal religious beliefs? Several such individuals were identified in this work. There are several possible explanations or responses to such an issue. First, many religious beliefs (spirits, destiny, special status of animals, etc.) are topics unlikely to arise during teaching (McGeorge, 1992, points out that in the school system sometimes this also is avoided when the topic evolution is not expressing presented in curriculum documents). Second, such individuals might seek to avoid occupations, including tertiary level teaching, that result in such encounters.

Mahner and Bunge (1996a) assert that "consistency in one's belief system is hard to come by" (p. 112). This seems to be borne out in the present work. However, their addendum that this is "particularly [so] in the midst of a society where religion wields a formidable cultural and political power," seems to us to be somewhat overstating the case.

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Animals in the lives of young Maltese Children

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Young Maltese children have experience and knowledge of animals. We explored the range of animal with which they are familiar and the origin of this knowledge. The children interviewed were in Pre School, aged 4 years, and in the first year of compulsory education, aged 5 years Verb l questions and photographs were used as the probe to access understanding and the sources of their learning. Different questions explored different concepts – effectively three groupings, animal knowledge, habitats, and source of knowledge. The animals photographed were from three areas that were established as popular with children, namely: pets usually found in homes, familiar animals such as farm animals and wild animals. Reduced sized colored photographs of the animals were used as a cue to encourage children to talk Children recounted instances where they have met animal pictures printed on books, charts and posters. The majority of children were familiar with the selected animals. Apart from the animals shown on the photo cards the children were able to mention a range of other animals the animals mentioned include a range of animals that are not found locally. The most two popular animals children mentioned were the tiger and the lion. Results show that these children possess a high sense of observing detail and interpreting visual material. They mentioned other materials where they have encountered animals, including toys, clothes, blankets, pillows and school stationery and often mentioned their favorite animal characters from the media

Keywords: Young Children, Malta, Animals, Knowledge Source

INTRODUCTION

Inquiring into children's ideas is an important step towards teaching them. Our work aims to identify the ideas that young Maltese children develop about animals, the range of common and less common animals with which these children are familiar and any difference across ages and gender. The amount of knowledge held about animals together with the influences on the child affect the knowledge they acquire. The sources of knowledge also contribute to their understanding.

Children are natural observers and inquirers of the world around them. They learn from their first hand experiences (Boulter et al, 2004). Children learn to identify an organism using a basic or everyday name of the culture in which they are living (Rosch & Mervis, 1975; Brown, 1958). Ryman (1974) showed that the inability of eleven year-old children to classify the biological exemplars they were given as members or non-members of a taxonomic group suggests that the children had no grasp of the defining attributes required to perform such a task. Moreover, Braund (1998) showed that children's thinking about animals in science lessons changes as they develop with the youngest children simply being concerned with shape, form and size. Prokop et al (2007) explored children's understanding of birds in their area whilst Prokop et al (2008) found that if children looked after pets, vertebrates or invertebrates, children had a better understanding of these animals. Tunnicliffe (1995) showed that when children look at animals as exhibits, they mention anatomical features such as the

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Table 1. Number of children taking part in the study

	Kinder 2	Year 1	Total
BOYS			25
State School 1	2	3	
State School 2	1	1	
State School 3	6	7	
Independent School	2	3	
GIRLS			25
State School 1	3	2	
State School 2	2	1	
State School 3	6	6	
Independent School	3	2	
TOTAL	25	25	50

Table 2. Classification used to categorise children

Gender	5	Age Year 1
Boys	4-5	5-6
Girls	4-5	5-6

dimensions of the animal, its shape and its colour. Shepardson (2002) investigated primary aged children's ideas about insects and found that their ideas reflected understandings based on physical characteristics of size and shape, both arthropod and insect characteristics that they had learnt, human-insect interactions, their life story, feeding and type of locomotion. Tunnicliffe (1995) found that children of the same aged remarked most often about salient features of live and preserved animals in zoos and natural history museums. Whilst Tunnicliffe and Reiss (1999) found that, when grouping animals, the youngest pupils relied mainly on anatomical reasons. Older pupils still used anatomical reasons but were more likely also to use other reasons, such as those based on taxonomy, habitat and behaviour.

Moreover, children also acquire understanding and knowledge from the society in which they live, from carers and from various artefacts as well as from the technological media (Russell, 1993). The sources of information that provide children with information also often involve adult influences. Lucas (1981) drew attention to the informal construction of ideas by children through information gleaned from the media. Out of school experiences have a large contribution to children's understanding and knowledge (Tunnicliffe and Reiss, 1999). Moreover, keeping pets influences children's understandings of animals (Prokop et al 2007) and focused study on invertebrates in the primary classroom motivates pupils to being enthusiastic about learning about and being more caring towards invertebrates (Watson 2006). Thus, we, as educators, must be cognisant of these findings. However, once in formal education children are taught scientific concepts but they bring their ideas which they have built from the earliest age (Driver 1985) and they show coherence towards their ideas (Osborne and Freyberg, 1985).

However, compared with adults, young children almost certainly possess a different set of concepts, which they map onto the word 'animal'. Furthermore, young children employ anthropomorphic terms in their explanations of both the form and behaviour of other animals (Carey 1985). Keil (reported by Carey 1985) found that five year olds used its appearance to define the category to which an object belonged, but by nine years of age they understood that the name represented a natural kind and thus the named object possessed certain properties that could be inferred from knowledge of the name of the object. Similar ideas about aspects of biology have been found amongst children of similar ages but from different cultures (Reiss, Tunnicliffe et al, 2001).

Children construct their own knowledge in trying to make sense of things around them (Gatt et al, 2003). They try to interpret new situations and guide their actions using mental models that they would have developed. Such mental models are in turn revised in the light of their encounter with a new experience (Von Glasersfield, 1995). Cultural influences also have an impact and language forms an important part in cultural issues and everyday knowledge attached to experiences (Dawson, 1992). Moreover, personal and social influences cannot be separated as they occur one and at the same time, a fact we must accept (Solomon, 1987).

The research reported here probes the understanding of young children about animals, from what sources of information do children in Malta obtain this knowledge and are similar ideas acquired across ages and genders?

METHOD

This research focused on children either side of the transition from informal (pre school) to formal schooling in the first year of compulsory education.

Children in the preschool level (age 4) and in the first year of compulsory education (age 5) were included in the study.

The methods employed were are interview about instances (Osborne and Freyberg 1985), using questions and using photographs, drawings and words as the probe to access understanding (Boulter, et al. 2004).

The children were asked several questions as well as shown a series of photos of animals. The animals were chosen from three areas that the researchers knew from observation and discussion with parents and teachers were popular with children, namely: pets usually found in homes, familiar animals such as farm animals and wild animals. Reduced sized coloured photographs of the animals were used as a cue to encourage children to talk since it has been shown that when presented with pictures, even though images reduced in size from

Table 3. The whole range of animals and the percentage number of children mentioning them other than the selected ones

Percentage	Animals Mentioned by Children
34%	Tiger
30%	Lion
26%	Bird
18%	Crocodile, fish, cow
16%	Giraffe
12%	Snake, chicken, tortoise, rabbit, lizard
10%	Duck, frog, shark,
6%	Leopard, hamster, bee, turtle,
4%	Bear, pigeon , deer, cock, hippopotamus,
2%	Rhinoceros, hedgehog, lioness, penguin, butterfly, bull, chick, goat, mosquito, kangaroo, grasshopper, angel fish, clown fish, mammal, amphibian, dragonfly, calf, wolf, gorilla, dinosaur, mole

reality and two dimensional, children initially describe the picture as a means of orientation for themselves (Boulter et al. 2004). In this case, eleven photo cards were used- produced from photographs in included the animals: horse, sheep, dog, cat, elephant, dolphin, zebra, ladybird, spider and mouse.

Different questions explored different concepts. Effectively there were three groupings. Firstly animal knowledge secondly places where animals lived, and lastly source of the children's knowledge. The first three questions explored ideas about animals. One targeted children's knowledge on the range of animals they know about while question two introduced the set of animals used as the focus of the study. In the third question the children were requested to state whether or not they think that the image in the photographs were an animal or not and if they responded affirmatively explored the reasons behind this. Questions four and five were about places where animals live. Questions four, five and six probed the source of knowledge followed by a question seeking to elicit the salient features of the animal which caused the children to make the categorisation. A pilot study with four children was carried out. The questions were presented in Maltese to facilitate understanding and then translated into English. In the main study the conversations from 50 children from 4 schools were audio-taped and transcribed. The transcripts were read and re read and the main ideas of the children identified.

RESULTS

Apart from the animals shown on the photocards the children were able to mention a range of other animals. Table 3 illustrates the percentage number of instances (from the range of animals other than the selected ones) that each animal was named by the children coming from both samples. The animals mentoned include a range of animals that are not found locally. The most two popular animals children mentioned were the tiger and the lion.

The percentage of children able to classify the animal correctly increased with age (Table 4). Kindergarten children had difficulties in classifying spider, dolphin and ladybird with more than half of the children stating that they are not animals. Otherwise, there was no significant difference between the gender of the children and their ages in the content of their responses. The horse was the only example identified as an animal by all of the younger children. When asked to mention other animals, the examples cited most often were not endemic to Malta. In fact 34 % of responses mentioned a tiger, 30% a lion and 18% crocodile. The bird was mentioned as a super ordinate category but no species identified. Table 4 represents the selected animals as classified by the two samples as being recognised as an animal or not an animal.

The majority of children were familiar with the selected animals. All children coming from Kindergarten 2 and Year 1 recognised the horse as being an animal and the horse was the most popular animal to be recognised as being an animal by all interviewed students. Question 3 tackled directly the animal concept fostered by the interviewed children. When the children were shown each photograph they were asked to name the illustration and this was followed by a further probing phase where the child had to classify into an animal or not an animal.

The animal that was least recognised as being an animal by Kindergarten 2 children was the dolphin, since 64% of the group classified the dolphin as being a fish and not an animal. When asked to mention some animals at the beginning of the interview the same girl included the fish as being part of her list of animals. Similar thinking was found amongst other chdilren questioned.

Most pupils, particularly the younger ones saw animals as mainly the large terrestrial animals such as those found at home as pets, on a farm or in the jungle. These would be the first animals that they have come across and therefore their concept of 'animal' has remained restricted and influenced only by their first experiences that they encountered at home from stories told and other instances such as viewing animals on television. The animal that was least recognised as being an animal by Kindergarten 2 children was the dolphin.

Table 4. Is it an Animal?

Selected Animals (Photo Cards)	Yes				No			
	Kindergarten 2		Year 1		Kindergarten 2		Year 1	
	Number	%	Number	%	Number	%	Number	%
Cat	22	88	25	100	4	16	0	0
Dog	24	96	25	100	1	4	0	0
Dolphin	9	36	16	64	16	64	9	36
Elephant	23	92	25	100	2	8	0	0
Horse	25	100	25	100	0	0	0	0
Ladybird	11	44	12	48	14	56	13	52
Mouse	18	72	18	72	7	28	7	28
Pig	21	84	24	96	4	16	1	4
Sheep	22	88	25	100	3	12	0	0
Spider	10	40	16	64	15	60	9	36
Zebra	21	84	25	100	4	16	0	0

Children used different characteristics as indicators of animals. The children's criteria used for justifying their allocating the image presented as a member of " animals" or not are grouped into the following: appearance, noise production, size, habitat, any other personal experience the child might have had with a particular animal and further ambiguous responses. Sixteen percent used the number of legs possessed, especially when the animal had 4 legs. *Eight percent of the children referred to the tail while 4% looked at the fur by 4 %.* Six per cent percent of children stated that if something made a noise it were an animal and 16% categorised on size. One fifth or 20% of the children also referred to the habitat of the animal in deciding on how to classify the example in the photograph.

Sixty four percent of the group classified the dolphin as being a fish and not an animal. When asked to mention some animals at the beginning of the interview the same girl included the fish as being part of her list of animals. Similar thinking was found amongst other children. The least recognised as an animal by Year 1 children was the ladybird since only 48% stated that this is an animal b ut most children recognised the ladybird.

Two children from the whole sample gave responses that have been classified as ambiguous because of their unclear nature. When interviewed about how they knew that particular objects mentioned were animals these children gave explanations, which were not clear even though these children were probed further to, clarify their responses.

Children's personal experience and their encounters with animals were explored in Questions 4 and 5. The responses obtained from children included various instances from their personal life where they have met animals and also any other experiences they might have or have had directly with particular animals.

The sources from where children have obtained their ideas and information were retrieved from the responses given to question 6 and 7. The sources of information and the percentage of children citing each are shown in Table 5 and the representative percentage number of children.

The children mentioned a range of sources from which they learnt about animals but family were mentioned as the main source of knowledge One third of the children said they found out about animals from their mother, father siblings or other adults like uncle and aunt, grandparents. Television, videos, DVDs, CD roms, internet, books, pictures on posters, charts, toys, print on stationery or clothes and travel were also mentioned in lesser numbers. Table 6 shows the different types of sources mentioned by the children from the whole sample in more detail and the percentage number of children representing each mentioned source.

The children's sources of obtaining information pinpoint the adults' influence on the process of obtaining knowledge. As the results of the study show, family peaks high in statistic in being the most popular source of obtaining information for children. Along with different members of the family that children have referred to, one finds other significant adults in the child's life for example the teachers, uncles, grandparents etc in class and from the teacher. However, the number of children who referred to this context of science learning is very low and therefore insignificant when compared to other sources widely mentioned.

Table 5. The source of information cited by children

Source Type	%
Family	32.9
Media	26
Other significant adults	15
Printed Material	14.4
Others	6.2
Travel	5.5

Table 6. Source Types

Source Type	Number of children	%
Mum	27	54
Dad	16	32
Siblings	5	10
Teacher	10	20
Other Adults	12	24
Television	19	38
Videos/DVDs, CDs	16	32
Internet	3	6
Books	14	28
Pictures/Posters/Charts	7	14
Toys	6	12
Print on stationery/clothes	3	6
Travel	8	16

Twenty-six percent of the interviewed children referred directly to media sources as being ways of obtaining information about animals. The most popular medium was television followed by other encounters of animal characters on video, DVD and CD rom. This highlights the importance of media influence that present children are receiving continuously in the technological evolutionary world. Children made various references from contemporary cartoon animal characters and cinema films.

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Even though the percentage of the internet cited as being one of the sources mentioned is still significantly low when compared to other sources, the chances might be that future trends will encompass the internet as being a more popular source amongst future generations.

Children recounted instances where they have met animal pictures printed on books, charts and posters. Considering the young age of the children, this shows that they possess a high sense of observing detail and interpreting visual material. The children also mentioned other material where they have encountered animals. These include toys, clothes, blankets, pillows and school stationery. On many instances the children mentioned their favourite animal characters emerging from cinema as the animals being printed onto their belongings. Once again here the media influence re-emerges.

Six percent of the children interviewed mentioned their experiences abroad as being part of obtaining their knowledge on animals. These children gave a wider variety when asked to name the animals they knew. In their list they included exotic animals such as kangaroo, mole, hippopotamus, penguin and gorilla. When taking a deeper look into the nature of their responses, these children seem to give specific details about particular animals.

DISCUSSION

Different age groups were sampled in similar studies carried out by Bell (1981). The study carried out in New Zealand investigated 39 average ability pupils, ranging from 9 to 15 years and inquired the scientific concept of the word 'animal'. Results from this small study show that most children did have some conception of what an animal is. However, they overall possessed a limited scientific understanding of the concept 'animal' which they had acquired from various sources, which they encountered as well as from observations they made themselves in the natural world. We found that children had a personal set of criteria consistent with his/her process of classifying instances. The recognition of a horse by all the children is not surprising for it is big in size and represents the four-legged terrestrial animal widely used in children's stories, nursery rhymes and books It is the typical animal on Maltese farms, and one of the largest animals on the island Moreover, curricular experiences in Year 1 where the curriculum requires that children tackle the topic of animals formally in class as they learn more information about farm animals and their pets. Even if children recognised the ladybird, they did not classify it as an animal, indicating restricted use of the term in general public understanding (Bell, 1981). A number of children recognised the dolphin as an animal, but many responded 'no' to classifying it as an animal as they thought that it was a fish. As Carey (1985) found, marine life is isolated and distinguished from the other animals because of their natural habitat in the sea.. The dolphin, being the animal least recognised by Kindergarten 2 students, is indicative of a common misconception of it being a member in the fish family but not an animal. In research conducted by Kubiatko and Prokop(2007) 30% of the pupils studied knew that dolphins brethae by lungs which also supports the view of the Maltese chidlren that a dolphin is a fish. This misconception repeated itself in the various responses given out by children. This conception may have arisen from the teaching about fish in a separate context rather than being members of the animal kingdom.

Such misclassification may also be indicative of the narrow use of the term 'animal' by the majority of people to describe mammals (Bell 1981) although Villabi and Lucas (1991) showed that such misclassification could be the result of semantics in a particular language. None the less, children's understanding of the concept animal is narrower than that used in science. According to Bell's study (1981), the criteria used by children to describe the characteristics of some animals are not characteristics owned by all animals. Bell (1981) argues that when used as criteria these characteristics limit the range of concept examplars and result in the restriction of the scientifically accepted concept. These arguments apply for this study as the interviewed children mentioned similar characteristics to that of Bell's study. None of the interviewed children used scientific characteristics of living things (for example: respiration, growth, reproduction) as being the characteristics of animals. This finding may be due to the fact that the primary curriculum lacks scientific concepts related to animals. Another reason might be that the messages that children obtain throughout their personal life experience has a very limited scientific orientation.

Contributing to misconceptions held by children as to the meaning of animal may be the confusion between the scientific meaning of the word 'animal' and its common meaning. According to Bell's (1981) summary of interviews' findings, the common meaning appears to refer to the restricted category of four-legged terrestrial mammals. This implies that pupils might find difficulties when challenging their common concept attributed to the word animal with scientific meanings. Barnes (1969) refers to this difficulty while emphasising the barrier that exists between teachers' language and children's meanings. The most common influence was coming from thier home environment when they recalled that they had animals kept as pets. As Solomon (1987) points out a greater amount of information is culled from the media in an incidental, unintentional casual fashion where there is exposure to information through watching television programmes. Moreover, Lucas (1986) distinguishes informal instruction, which is intentional from that which is to be found in fiction and advertisements, children in today's world are exposed to informal science, which unlike formal taught science the vast majority of this information is highly attractive.

Furthermore Russell (1993) indicates, children interpret the world and physical phenomena and hold various representations that might have varying degrees of 'goodness of fit' and serve as long as their predictive and explanatory utility is still useful to the child. The responses given by the interviewed children portray their ideas that they have recalled from their everyday life encounters with animals. This implies that each individual constructs personal meanings of experiences and the understandings held by each individual vary. Gunstone (1990) identifies that, children's science is made up of a type of reasoning linked with the individuals' already existing knowledge and beliefs.

Tunnicliffe and Reiss (1999) found home to be one of the most important sources of information about animals for primary aged children. Children interpret the world and physical phenomena for themselves and hold various representations that might have varying degrees of 'goodness of fit' which and serve as long as their predictive and explanatory utility of such ideas is still useful to the child Russell (1993). The children's sources of obtaining information pinpoint the adults' influence on the process of obtaining knowledge. As the results of the study show, family peaks high in statistic in being the most popular source of obtaining information for children. Along with different members of the family that children have referred to, one finds other significant adults in the child's life for example the teachers, uncles, grandparents etc. Solomon (1987) argues children construct meaning about different scientific concepts that are influenced by agents present in their socialisation process. Indeed, some of the interviewed children mentioned that they obtain information about animals directly from schools, in class and from the teacher. However, the number of children who referred to this context of science learning is very low and therefore insignificant when compared to other sources widely mentioned.

The responses given by the interviewed children reveal their ideas that they have recalled from their everyday life encounters with animals. This is turn implies that each individual constructs personal meanings of experiences and the understandings held by each individual vary. In line with Gunstone's findings Gunstone (1990)

The children, even at as young an age as 4 and 5, were found to hold personal alternative frameworks about the meaning of the concept 'animal'. They will bring these ideas with them to school and may interfere with learning about simple science concepts. Teaching young children about animals requires that their already existing ideas be taken into consideration. In particular, teachers need to be sensitive to the potential ambiguity of the term 'animal' and the features that children consider as indicators of animals. . In many cases, teaching about animals often involves displaying a variety of examples. Learning about animals, however, is more complex. Teachers need to help children to explore their reasoning about what features they consider in deciding whether a specimen is an animal or not. Even from a very young age, it is necessary to allow children to explore and compare their understanding if one is to promote similar practices of reflection and construction of knowledge at an older age. In this increasingly environmentally poor society (Louv, 2006) teachers need to b e aware of what ideas and encounters children entering school have experienced and hold before their formal education in biology and the environment begins.

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Teaching Species Identification – A Prerequisite for Learning Biodiversity and Understanding Ecology

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Animal and plant species identification is often emphasized as a basic prerequisite for an understanding of ecology and training identification skills seems a worthwhile task in biology education. Such identification tasks could be embedded into hands-on, group-based and self-determined learning: a) Teaching and learning should make use of a small selection of species (6-8) and b) these species should be embedded into learning about their natural and life history; c) different materials could be used for identification, i.e. stuffed taxidermies, plastic models or pictures. However, pictures seem only a second choice; d) ideally, pupils use identification books or dichotomous keys for their identification task to foster their methodological skills and to promote lifelong learning by enabling them to make use of such books and keys; e) if the preference is on identification keys rather than on illustrated material, pupils should be trained previously to cope better with the extrinsic load put on them by the difficult material; f) outdoor field trips and excursions should be employed only after a proper preparation in the classroom.

Keywords: Books, Ecology Teaching, Identification Materials, Methods, Species Identification

INTRODUCTION

Why species identification?

Children have serious problems with classifying animals (e.g. Bell, 1981) and they often incorrectly classify vertebrates as invertebrates (e.g. Braund, 1998) or birds as non-bird species (Trowbridge and Mintzes, 1988, Prokop et al., 2007). Although these facts are well-known there is a limited source of research that investigates children's abilities to identify living organisms. Albeit there are a few reports from plant species identification (Bebbington, 2005), reports from vertebrate species identification are scarce.

Species identification may be viewed as an antique way of teaching and learning in biology education. Modern times have turned to syllabi stuffed with general biology, aspects of genetics, ecology and evolution. However, for a clearer understanding of these aspects of the living world mostly, if not always, examples from species were used, e.g. when illustrating allopatric divergence of populations (speciation processes) during the glaciation of the Pleistocene, very often the European Crow species (Carrion Crow Corvus corone and Hooded Crow Corvus cornix) were invoked. Also, to illustrate material flow and functioning of ecosystems, this approach needs discrete species to make the facts more understandable.

Biodiversity has become a challenging educational topic, enforced by the conference of Rio in 1992 (van Weelie and Wals 2002; Gaston and Spicer 2004). Today, the value – even in currency – and the general importance of biodiversity is unquestioned (Gaston and Spicer 2004). Most people throughout the world value and appreciate biodiversity. However, biodiversity is a rather 'ill-defined' and complex construct at least in

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terms of educational circumstances (van Weelie and Wals 2002). Such complex and abstract constructs usually have to be transformed into smaller entities to aid learning and understanding especially in school students, and of course, also in the general public. The most common entity used by conservation groups are species (van Weelie and Wals 2002). Especially spectacular species, such as the Ivory-billed Woodpecker (Campephilus principalis, Dalton 2005) or dolphins (Barney et al. 2005) were used as a venue in environmental education and conservation.

Therefore, basic knowledge about animal or plant species, their identification and life history has been targeted as a fundamental aspect for learning and understanding in biodiversity (Lindemann-Mathies 2002; Randler and Bogner 2002; Gaston and Spicer 2004; Randler et al. 2005) as well as in the framework of ecological questions (Leather & Helden 2005). Such a fundamental view of biodiversity is shared by both, educational instructors and practitioners as well as by conservation biologists. Many conservation agencies and NGOs make use of flagship species to raise money, again, emphasising the value of species (Czeck et al. 1998; Dalton 2005).

Animals are fascinating for children and adolescents, e.g. in Norway animal-related activities received high scores, such as bird feeding (74%), or watching hare, fox and moose (63%). Watching TV programmes received an almost similar proportion compared to learning about animals in schools (Bjerke et al. 2001), suggesting that schooling might not be the main source of animal knowledge. Further, engagement in animal-related activities decreased parallel to age (Bjerke et al. 2001) suggesting that species knowledge may also decrease. There are few studies aiming at assessing knowledge about vertebrates and identification skills in pupils (overview: Randler and Bogner 2002), mostly complaining about the low species knowledge in general. Further, many educational practitioners and conservationists claim – often without sustain – a significant decrease of species knowledge in today's children and adolescents. As there are not many studies in this respect, such a claim may belong to the 'folklore' of environmental education (Hendee 1972).

Here, I will focus on different methods in teaching and learning about species. The primary focus is on vertebrate species, although insects, spiders and other invertebrates should receive a similar treatment at school.

What are the basic concepts of pupils in species identity?

Generally, many pupils have concepts and ideas about animal species and they are able to identify them on a higher taxonomic level such as genus, family or order. For example, nearly 100% of all pupils are able to identify a Mallard (Anas platyrhynchos) as a member of the family ducks (Anatidae), but only a small number of pupils can label the species correctly as Mallard (Randler, 2003, 2006). Teaching and learning, therefore, should make use of such prior concepts and embed them into the lessons, hence, a refinement of the concept duck into a more detailed description (diving ducks versus dabbling ducks), and two examples (Mallard and Tufted Duck Aythya fuligula) would result in a better learning because it focuses on the refinement itself and makes use of the prior concept. Figure 1 depicts some examples of prior concepts.

Why is species identification so difficult?

Some practitioners and teachers compare identification of species with the learning of new words of a new language. However, it seems that learning species names is much more difficult and complex than acquiring new words for a given language. Names of species can be grouped into different clusters:

Some names contain information about the visual appearance of the species; assume, for example, a Black-Headed Gull (Larus ridibundus). Even if you have never seen one, you will have a vivid impression how the bird might look like.

Other names may contain information about the song or behaviour of the species which will not usually aid the identification, e.g. the Chiffchaff's (Phylloscopus

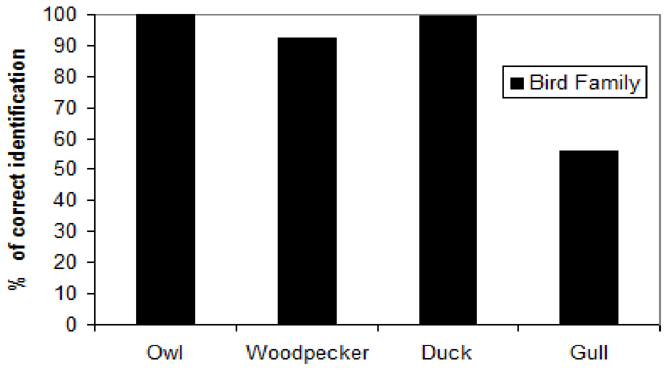

Figure 1. Percentage of pupils that are able to identify the respective bird family correctly as owl, woodpecker, duck and gull.

collybita) song sounds "chiff-chaff" and its name contains information about vocal characteristics but could not be used to learn species by its appearance.

A third cluster contains names that refer to an association, such as the Monk Vulture (Aegypius monachus), a vulture with an appearance as a monk.

The last group of species names contains names that are not motivated with regard to appearance or do not provide any association. Such names are often names that refer to a person, e.g. Naumann's Thrush (Turdus naumannii) and it is difficult to imagine mentally the appearance of it.

To test these different clusters of species names and their influence on learning and retention, Randler & Metz (2005) applied a research design with University students. A total of 15 species were selected, and the selection consisted of five triplets. Each triplet contained three species that shared the genus or family name and differed in the species name. One of the species contained a name that referred to its appearance, e.g. the Blue Tit (Parus caeruleus) has a blue head, the Coal Tit (Parus ater) has a black face (similar to coal, an association), and the Willow Tit (Parus montanus) prefers willow/birch habitats. The name of the latter species does not aid its identification. Five such groups were presented to the students.

Randler & Metz (2005) presented these species (as a photo and a capital containing the name of each species) in a computer-aided presentation to 100 students, in different orders of randomisation, and the students were asked trying to remember as much species as possible. After 80 minutes, the procedure was repeated in a different order and the students had to write down the names. In between were two lessons **of** German grammar or of educational psychology. Results are depicted in Figure 2.

As expected, names without any visual aid were retained less often than names with visual aid. Interestingly, names that evoked an association were retained better than names with a reference to its appearance. This means that during teaching species identification, the names of the species should be explained to aid learning and understanding. It further shows that retention of species names is difficult itself which again emphasise that pupils (and even students) should not be treated with too large lists.

How many species should be taught?

A first survey based on an expert rating organized as delphi-study (Mayer 1991) found a large amount of species that should be taught during secondary schools: nearly 250 species were identified. Of course, this is far too much for teaching even when this list was based on a covering of the complete secondary level. Teaching and learning should make use of a small selection of species and should emphasize methodological aspects, such as hands-on, group based learning using original objects. Randler & Bogner (2002) chose 14 different bird species centering on the ecosystem lake and found low retention rates after six to eight weeks. These authors further tested different methods of teaching (see below). As one result, these authors concluded that six to eight species are considered sufficient for an identification task (Randler & Bogner 2006). These species should be embedded into learning about their natural history and their key life history traits. This seems crucial to learning and understanding since teaching species names in a way that simply appears as some kind of labeling is detrimental.

Which educational methods should be used?

In their study mentioned above, Randler & Bogner (2002) used 14 bird species and applied two different educational methods. First, one group received a hands-on, learner-centered environment and pupils could look

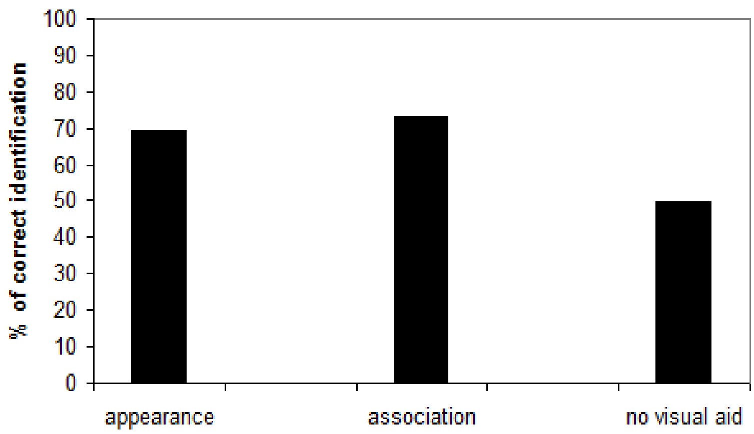

Figure 2. Percentage of correct identification (retention) of bird species names according to three different groups of names. A) Name with regard to the visual appearance, B) name with an association, and C) name with no visual aid for identification.

at stuffed taxidermic specimens. The other group served as a control and received a teacher-centered demonstration using a slide presentation dealing with exactly the same species. Knowledge was tested previous to teaching, immediately thereafter and with a delay of 6-8 weeks. Approx. 250 pupils participated in this treatment-control-study (see Figure 3).

Interestingly, both treatments did not differ in their effectiveness and overall retention was not very high. Therefore, Randler & Bogner (2002) concluded that the number of species in these two lessons might have been to high, and, as consequence reduced the number of species from 14 down to six (albeit for one educational lesson).

Then, they repeated their treatment in other biology classes with approx. 500 pupils. The treatments were carried out in two different school stratifications. [The German school system separates pupils at the end of the 4th grade into three stratifications, according to their cognitive abilities: lowest stratification = Hauptschule, medium stratification = Realschule and highest stratification = Gymnasium]. The results are presented in Figure 4.

In both stratifications, pupils in the taxidermic treatment received significantly higher achievement scores in the retention test. This suggest that hands-on group based work is significantly better than a teacher-centered presentation. However, retention as measured in percent (Figure 4) was high in both treatments, again suggesting that a reduction in the number of species to be learnt improves retention.

Educational implications from these studies emphasize: i) a reduction in species number is a useful way to improve learning, and ii) "modern" instructional approaches lead to a higher retention rate.

Materials used for identification tasks

Having demonstrated that such hands-on, group-based and learner-centered work retains a sufficient amount of knowledge in the retention test, we now turn towards some more details, namely materials used for identification. Many syllabi emphasize (or even request) the use of a dichotomous identification for species identification as a scientific method. At the University (tertiary) level, these identification keys are usually used during courses in botany and zoology. Dichotomous keys are usually based on a decision between two alternatives, followed by another pair of alternatives unless the final species name (or other taxonomic level, such as genus or family) is reached. These keys have been developed for different topics, e.g. human biology (Bavis et al. 2000), plant identification (Ohkawa 2000), fruits, nuts and cones of trees (Collins 1991), timber (Thomas 1991) and amphibians (Randler 2006). If coloured keys or books were used for identification,

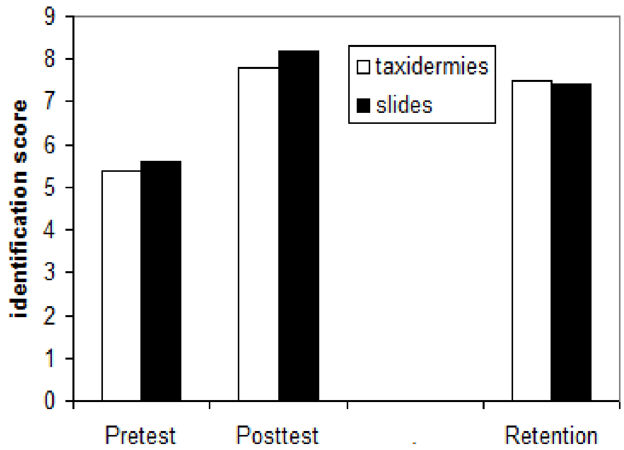

Figure 3. Changes in knowledge about bird species using two different treatments.

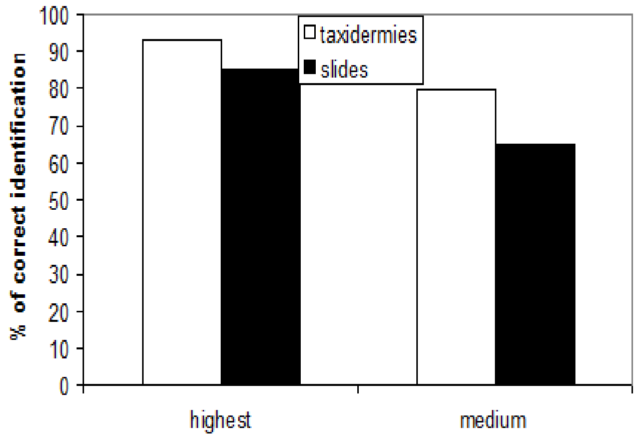

Figure 4. Retention rates (in percent) of two different treatments (taxidermies vs. slides) and in two different school stratifications.

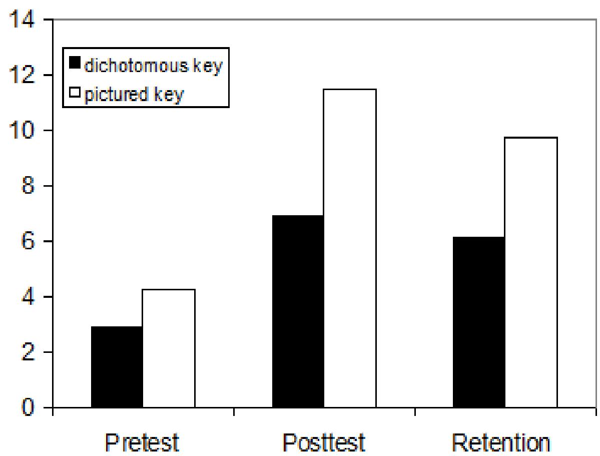

Figure 5. Differences between two identification materials over time (Mean scores are presented).

pupils often focus on the pictures alone. The benefit of dichotomous keys is a closer and more detailed look at the objects or models. Further, in comparison to books, such keys are scientifically more precise and foster the understanding of scientific terms.

To examine this question, a research design was applied to contrast both methods. The educational program was based on signs and tracks of animals. These signs were presented in the **class as** original materials. The tracks contained objects such as owl pellet, insect galls from different trees, feathers, tracks, feeding passageways of insects in the bark of trees, or feeding remains at spruce cones. The identification keys were similar in structure and in the number of solutions they offer, but they differed in the presentation of the way which leads to a correct identification: The illustrated key contained pictures of the respective tracks and signs, while the dichotomous key started with a decision between two alternatives. All other variables were kept constant (e.g. we used the same original objects and the same teacher and the same number of alternatives).

Achievement scores of both groups are depicted in Figure 5. As prior knowledge differed, we applied a multivariate general linear model (GLM) using pre-test as covariate, and gender and treatment as fixed factors. As expected, pre-test showed a significant influence. Further, treatment, received significance. In detail, pupils performed better in both posttest and retention when using a picture-based identification key and boys scored better than girls in the posttest.

Further, some emotional questions were used to gain insight into other dimensions than cognitive ones. Emotional variables derived from the inventory proposed by Laukenmann et al. (2003) and Gläser-Zikuda et al. (2005) were used. We measured these constructs based on four different dimensions: interest, well-being, boredom and difficulty of the questions based on a five-point Likert-scale (1 = lowest expression, 5 = highest). Each dimension was tested with one question immediately after the lesson.

There were significant differences with regard to the emotional variables: Pupils of the illustrated key perceived a significant higher well-being and tended to be less bored (Figure 6). No differences existed between both identification keys in interest and both groups experienced similar difficulty in their task, suggesting that cognitive results are not based on differences in the difficulties of the instructional materials.

The results presented here are interesting because they support the use of illustrated identification materials for teaching and learning biodiversity. In contrast to the views of many practitioners, language based keys indeed seem inferior compared to picture-based keys.

Therefore, to cope with these results, we used another line of research to improve the usage of dichotomous keys. Now, we used a language-based dichotomous key that was supported by a few black-and-white illustrations which aid the final identification of the respective species. The benefit of this key is that it can be copied and pupils can take them home for their personal use.

Two different identification materials were compared with each other. The identification key was obtained from Schroedel-Verlag (Schrodel, Braunschweig, Germany) and was explicitly made for the use in a school setting (biology lessons, 5th and 6th graders). It contains a DIN A 3 page in black-and-white that can be easily copied and given to the pupils. The key has a dichotomous structure where there is always a decision between two alternatives, e.g. whether the pupil of the eye is vertical or horizontal. When you have gone through all alternatives the final species' name is reached and there is a black-and-white illustration to further support the identification.

The identification book (Amphibien und Reptilien erkennen und schützen, amphibians and reptiles; total pages: 159; Blab & Vogel 1996) was also obtained from a commercial producer. This book depicts a total of 19 reptile species on 37 pages. The book provides various photographs and sketches in colour and verbal information about identification, behaviour, natural history and ecology.

Pupils worked together in groups of 2 - 4 pupils and each group received either an identification book or the dichotomous key. The plastic models were presented in a kind of workstations (Schaal & Bogner 2005). Pupils then moved from one desk to another, looked at the models and identified them. After pupils had finished their work, results were discussed and corrected in the classroom.

Pupils did not differ in their prior knowledge (Figure 7). Immediately after the educational treatment there were no significant differences between both treatment groups, and also after a delay of four weeks. This suggests that both educational materials are equivalent in their effectiveness and that both may be used to achieve a sustained learning and retention (Figure 7).

Model specimens, identification tools (either books or keys), hands-on instruction and group-based learning approaches provide successful learning environments for secondary school pupils. This was proved in some earlier studies (Randler & Bogner 2006, Randler & Knape 2007).

In this study, we used these previous results and focused on the identification material itself. Both treatment groups significantly improved their species identification knowledge about reptiles and we further suggest that such methodological teaching sequences should be embedded into everyday school practice. Further, we emphasize that the number of species that should be taught during such lessons should not be exceedingly high – approximately six different species seem sufficient for 5th and 6th graders.

With regard to our identification materials, we found no significant difference between both approaches, suggesting that either the identification book as well as the black-and-white key were equally suitable for this identification task. The advantages of the key are clearly its low costs, i.e. it can be copied and each pupil may retain the key and may use it further in out-of-school settings. Further, this key trains pupils to look critically at verbally explicated differences and to scrutinise the models in detail. However, the identification book also has its advantages. The book consists of many pages and, therefore, pupils must thoroughly go through it to find the correct identification. Further, such books also provide a wealth of information about the respective species' ecology and behaviour.

Addressing the age-old question about outdoor ecology

Outdoor ecology and field trips have been acknowledged in many publications (see Rickinson et al. 2004). When teaching biodiversity, many practitioners prefer settings with an outdoor ecological education over classroom instructions (Barker et al., 2002, Killermann 1998, Lock 1998, Tilling 2004). However, such educational lessons often deal with rather immobile taxonomic groups such as plants or invertebrates (Killermann 1998) because amphibians (or mammals, birds) are sometimes difficult to observe under natural conditions. Conservation actions, such as preserving migrating frogs or toads should be useful settings for teaching and learning about species.

Further, outdoor education could be enhanced by previous learning within the classroom to properly prepare the students for forthcoming issues and task in nature and to prevent students from a cognitive load and from novelty effects (Falk 1983, Sweller et al. 1998). Such a cognitive load (or novelty) may arise when students are confronted simultaneously with different environmental conditions. In terms of amphibian conservation actions this might mean i) species that are new to students and previously unknown, ii) different settings compared to the rather familiar classroom setting (weather conditions; night time), and iii) different learning environments, such as working in groups and doing hands-on activities or encountering living animals.

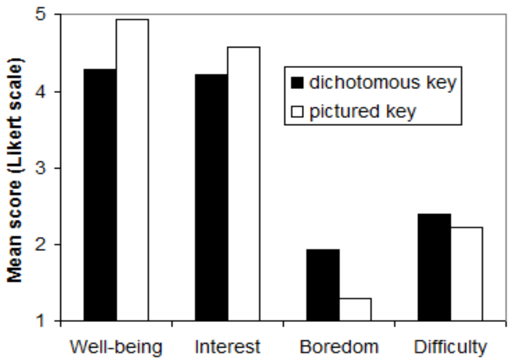

Figure 6. Differences in emotional measures between concerning identification materials (Mean scores of the variables are presented).

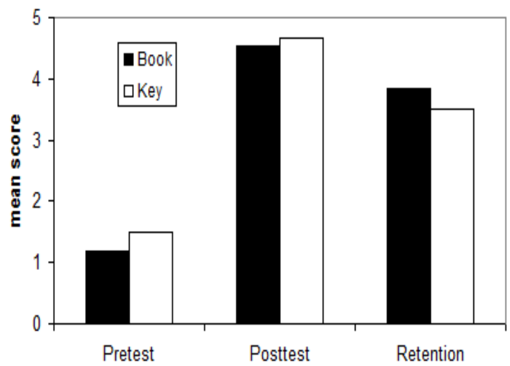

Figure 7. Comparison of different treatments and its cognitive achievement over time

Therefore, students that are not prepared by any prior teaching in a familiar setting, such as the classroom, might benefit less from outdoor education (see Falk 1983, Orion & Hofstein 1994).

To investigate the effectiveness of outdoor ecology teaching, an educational program was developed in amphibian conservation. The program was divided into two parts and was embedded into teaching activities prior to and after a specific conservation action. The indoor program was followed by all students, while the additional outdoor program was attended by half of them. After the additional outdoor program students that had participated at the conservation action told other pupils about their experience ('peer-tutoring'; Neber 1995). The additional outdoor program took place when toad and newt migration peaked. In order to minimize novelty effects of the environment (Falk 1983) a conservation action was visited located in the students' residential town. Students could participate in the outdoor work voluntarily. During this action, school students were guided by students from the University of Education which collected, determined and counted all amphibians on their annual way to the breeding pond.

The additional outdoor group (hereafter: treatment) did not significantly differ from the indoor group

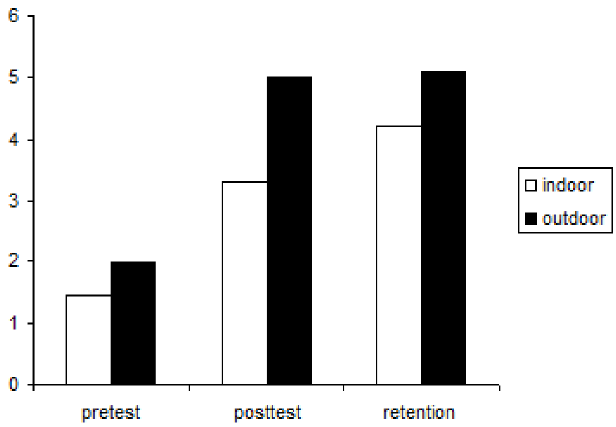

Figure 8. Cognitive effects of an additional outdoor teaching program on pupil's achievement.

(hereafter: control) prior to teaching (Figure 8), but immediately thereafter. In the delayed retention test significant differences remained. Nevertheless, students from both groups significantly improved their knowledge.

The treatment group scored significantly higher during both the post-test and the retention test (maximum of six items). This is an interesting fact because other studies failed to show such marked and significant differences regarding cognitive abilities between treatments, especially when different treatments were compared (e.g. Armstrong & Impara 1991; Bowler et al. 1999). However, there is also evidence that outdoor ecology education increases both cognitive and affective dimension among pupils that participated on field trips (Orion & Hofstein 1994, Prokop et al. 2007, Žoldošová & Prokop 2006).

Interestingly, pupils from the control group showed a significant positive shift in their knowledge from posttest to retention test while the scores of the treatment group remained similar. The posttest was applied before any further teaching took place. We suppose that the clearly visible learning effect from posttest to retention in the control group is a result of the following lessons where students were encouraged to report their experience gathered during the conservation actions to their classmates. This provides some kind of 'peer-tutoring' which was found to have a significant positive effect on learning and retention (Neber 1995). These results are encouraging since they show that students that could not participate in a specific (outdoor) activity might benefit when the participating individuals were encouraged to report their experiences, ideally in small groups of 3 - 4 (Lou et al. 1996). This could be organized in a rotating system where student groups move from one tutor to another.

Another major conclusion is that outdoor ecological settings should also take place during school life and students should visit habitats in their vicinity to reduce novelty. Although many studies showed a highly significant improvement in either cognitive learning or in environmental perception (with a focus on enhancing preservation attitudes), one should keep in mind that residential outdoor programs are rather expensive and often linked with traveling. This might lead to a lower acceptance of such programs. Schools should provide their students with such local outdoor ecological programs.

Further, outdoor activities should be properly prepared by a preceding educational unit in the classroom. Some studies found that their modern teaching approaches (e.g. outdoor ecology) scored significantly worse or did not reach any significant effect when compared with a rather traditionally taught control group (see, e.g. Killermann 1996, Randler & Bogner 2004). This was found in such different educational settings such as experiments, modern media or in different teaching strategies (learner-centered vs. teacher-centered). Falk (1983) suggested that children's perception of the novelty of the environmental setting affects their learning outcome. Extremely great novelty will inhibit learning. Therefore, such outdoor experience in elementary school students should make use of more familiar outdoor settings in the vicinity of the student's residential town, rather than making use of any farther travel if cognitive aspects are in the main focus.

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The Effect of Using Concept Maps as Study Tools on Achievement in Chemistry

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The purposes of this study were to: (1) examine whether or not the construction of concept maps by students improves their achievement and ability to solve higher order questions in chemistry, (2) investigate the differential effect of the treatment by gender and achievement level, and (3) explore the relationships between performance on concept maps and chemistry achievement. Participants were 60 tenth-grade students randomly divided into two groups. The study spanned six weeks in a class that met five times a week. The material covered was acid-base titration and equilibrium in weak acids. The students were pre- and post-tested using a teacher-constructed chemistry test. Results showed that while there were no significant differences on the achievement total score, there were significant differences favoring the experimental group for scores on the knowledge level questions. Moreover, there were sex-achievement interactions at the knowledge and comprehension level questions favoring females and achievement level – achievement interactions favoring low achievers. Finally, there were significant correlations between students' scores on high level questions and the convergence and total concept map scores.

Keywords: Concept maps, Meaningful learning, Chemistry, Achievement.

INTRODUCTION

Research has shown that many students lack the necessary knowledge and skills in science and technology to function in the modern world (American Association for the Advancement of Science [AAAS], 1989; Ogawa, 1998) at a time when there is increasing demand for scientifically literate individuals who can analyze and anticipate novel problems, rather than memorize disparate facts, and with the potential to change and adapt (AAAS, 1989). However, what is happening in schools is not promising. Students' performance and interest in science are declining (Markow & Lonning, 1998). Secondary school and college students' knowledge of science is often characterized by lack of coherence and the majority of students engage in essentially rote learning (BouJaoude & Barakat, 2000, Brandt et al., 2001; Nakhleh, 1992). The problem is twofold: The abstract and highly conceptual nature of science seems to be particularly difficult for students and teaching methods and techniques do not seem to make the learning process sufficiently easy for students (Gabel, 1999; Schmid & Telaro, 1990).

These problems are quite serious in chemistry, which is widely perceived as a difficult subject because of its specialized language, mathematical and abstract conceptual nature, and the amount of content to be learned (Gabel, 1999; Moore, 1989). The prevailing teaching practices do not actively involve students in the learning process and seem to deprive them from taking charge of their learning (Francisco, Nicoll, & Trautmann, 1998). Novak (1998) accentuated the need for educators to take advantage of the available knowledge base of learning, learners, knowledge construction, and instructional tools to improve

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educational quality, a knowledge base that has not been tapped sufficiently.

Improving educational quality requires, at the least, placing learners in active rather than passive roles (Moore, 1989). People learn by being engaged actively, and a person is not an empty vessel to be filled with information. Knowledge that empowers and increases the learner's self-confidence is that which results from the coming together of individual actions, feelings, and conscious thoughts (Novak, 1998). Rote memorization disempowers learners and promotes fear of learning because it is irrelevant to their own experiences. In addition, information learned by rote in the absence of connections with previously acquired frameworks is largely forgotten (Novak, 1998). Thus, the goal of education should be to develop educational experiences that facilitate meaningful learning and reduce the need for rote learning. Ausubel (1968) describes meaningful learning as the establishment of non-arbitrary relations among concepts and sees that meaningful learning is achieved if learners choose to relate new information to ideas they already know. Meaningful learning occurs if learners have relevant prior knowledge and meaningful learning material and are willing to understand and apply the effort needed to attain meaningful understanding (Novak, 1998).

Concept Mapping

As the problem of improving the teaching/learning process preoccupies educators, concept mapping promises to be useful in enhancing meaningful learning. Concept maps help learners to make evident the key concepts or propositions to be learned and suggest connections between new and previous knowledge. Concept maps have been used in a variety of educational contexts. Each context reflects an alternative theory of knowledge acquisition. On the one hand, the rationalist theory of learning suggests that disciplines have inherent structures that should be conveyed to learners. Therefore, concept maps should be evaluated by relating them to ideal maps, teacher-constructed maps, or expert concept maps. On the other hand, constructivists highlight the uniqueness of each individual's representation of concepts (Beyerebach & Smith, 1990) leading them to devise various mechanisms to evaluate students' concept maps. Nevertheless, both theories concur that meaningful learning occurs when concepts are organized in an individual's cognitive structure.

Concept maps are flexible tools that can be used in a variety of educational settings (Stewart, Van-Kirk, & Rowell, 1979). For example, they can play a significant role in curriculum development, learning, and teaching (Novak, 1984). Concept maps are useful in science curriculum planning for separating significant from trivial content (Starr & Krajcik, 1990) and in focusing the attention of curriculum designers on teaching concepts and distinguishing the intended curriculum from instructional techniques that serve as vehicles for learning (Stewart et al., 1979). Furthermore, concept maps have been used as assessment tools to measure learning outcomes different from those revealed in commonly used psychometric instruments (Markham, Mintzes, & Jones, 1994). However, Johnstone and Otis, (2006) suggested that "maps should be treated as very personal learning tools" and consequently, are not appropriate for assessment purposes. Finally, more recent studies have used concept mapping to engender relational conceptual change in college level chemistry (Liu, 2004).

In an attempt to identify more conceptually based teaching and learning methods, research has investigated the use of concept maps in many content areas such as biology, physics, and chemistry. Stensvold and Wilson (1992) investigated the effect of students' construction of concept mapping in high school chemistry laboratories on their comprehension of chemical concepts. No differences were found between the experimental and control groups. In their turn, Nicoll, Francisco, and Nakhleh (2001) investigated the effect of construction of concept maps on freshman chemistry students' achievement and ability to link concepts. Positive results were achieved for both variables. Horton et al. (1993) conducted a meta-analysis study in which they found that there were many more studies using concept mapping in biology than in physical sciences and that, although results showed positive effects on attitude and achievement, these effects were more obvious in the biological than the physical sciences. In addition, Horton et al. found that concept maps were constructed mostly by students in class and that there were no differences between males and females, even though previous research (e.g. Novak & Musonda, 1991) suggested otherwise.

As seen above, research addressing the use of concept maps in chemistry has been limited and has produced inconclusive results. Moreover, there are disagreements between researchers on the effectiveness of concept mapping in chemistry teaching. Zoller (1990), for example, questions the effectiveness of concept mapping in chemistry because many chemistry concepts are abstract, nonintuitive, and not directly interrelated. In contrast, Novak (1994) argues that the problems are not due to the nature of chemistry; problems rather arise from the fact that students learn chemistry by rote and do not recognize key concepts and their relationships. Moreover, Novak contends that instruction fails to stress chemical concepts and relationships. Differing results could arise also from the fact that studies have focused on the use of concept maps an instructional, curriculum development, and assessment tools but not as study tools, especially in homework assignments.

Many students struggle to learn chemistry, but are often unsuccessful. It seems that many of them do not construct appropriate understandings of fundamental chemical concepts throughout their educational experiences (Nakhleh, 1992). Instead of having well structured and integrated domain-specific knowledge structures, students consider the different chemical concepts as isolated elements of knowledge. This lack of integration may be the main reason for difficulties in concept formation and application of acquired knowledge (Brandt et al., 2001). Thus, concept mapping as a method to build explicit links and relations between concepts, as a study tool that I used as personal learning tool (Johnstone & Otis, 2006), and as an opportunity for students to construct maps using their own terms (Horton, et al., 1993), is expected to stimulate the construction of integrated knowledge structures leading students to achieve higher in tests that measure high cognitive levels.

Research has demonstrated that concept mapping is a skill that requires time for mastery. However, a metal-analysis conducted by Horton et al. (1993) has shown that positive effects were achieved in studies than ranged in length from 2 to 22 weeks, with an average duration of six weeks. As a study tool, concept mapping is most effective if it is used on an on-going basis over the course of instruction. Thus, when students build concept maps in homework assignments recurrently, they will get the chance to revise their understanding by modifying their maps leading to better understanding. Furthermore, because of personal involvement and the ability to revise offered by homework assignments, concept mapping is expected to help students overcome difficulties with abstract and complex science concepts by integrating them into well-structured cognitive frameworks.

Purpose

The purpose of this study was to answer the following questions:

1. Will Grade 10 students who construct concept maps as homework have significantly higher grades on chemistry achievement school tests than Grade 10 students who do not construct such maps as homework?
2. Will the use of concept maps as homework with Grade 10 students have significantly different effects on students with different achievement levels?
3. Will the use of concept maps as homework with Grade 10 students have significantly different effects on males and females?
4. Will there be a significant correlation between students' mastery of concept mapping skill and their achievement in chemistry?

METHOD

Participants

Participants in this study were sixty Grade 10 chemistry students from a co-educational private high school in Lebanon. They were randomly divided into two sections based on achievement, which is the school policy. For the purposes of the study, the sections were randomly assigned to the experimental and control groups.

Instruments

Chemistry Achievement Tests. The dependent variable in this study is the students' chemistry achievement. Two tests were used to measure achievement. One of the tests measured students' pre-requisite knowledge in topics related to the ones covered during the study (Appendix A presents examples of the questions used in the pretest). The second test measured student achievement at the conclusion of the study (Appendix B presents examples of the questions used in the posttest).

According to Lehman, Carter, and Kahle (1985) and Willerman and MacHarg (1991), a test must be at the comprehension level and above in order to measure meaningful learning. Consequently, many items on the achievement tests used in this study were at the comprehension level or above. The pre-test assessed students' achievement in solubility equilibrium. The post-test assessed students' achievement in acid/base titration and weak acids equilibrium. A table of specifications was used guarantee that the items on the two tests represented the content. Moreover, a detailed description of the six levels of Blooms' taxonomy (Bloom, 1969) was used to make sure that the items were at the different levels of Blooms taxonomy. Two science education faculty members, a science teacher, and a chemistry education doctoral student were provided with the objectives based on which the lesson plans and tests were designed along with a detailed description and examples of Bloom's taxonomy and were asked to classify the test items and match them with the objectives. Differences in classification were discussed among the faculty members, teacher, and doctoral student and the researcher in order to reach consensus. The reliability (α) of the pretest was .83 while that of the posttest was .84. The two researchers and the chemistry teacher of the control group corrected the achievement tests based on a detailed, agreed upon, common key.

Concept Map Scoring Rubric. The researchers developed an expert concept map (Appendix C) and a scoring rubric (Appendix D) to monitor students when constructing concept maps. The scoring rubric used in this study combined the qualitative analysis of gross structure and the quantitative analysis of links, in order to provide a valuable tool to highlight the key characteristics of concept maps. The qualitative "spoke-chain-net" classification put forward by Kinchin, Hay, and Adams (2000) is able to describe the gross changes in a concept map which is indicative of radical restructuring. In addition, the degree of valid cross-linkage, the amount of branching, and the hierarchical structure are included in the analysis because they reflect associative and superordinate-subordinate categorical relationships among concepts.

The quantitative analysis of the concept maps consisted of three dimensions: The links' validity, convergence, and salience. McClure, Sonak and Suen (1999) showed that the most reliable scoring procedures are those that focus on the links in the map, the element which is most problematic to students but which reveals a good deal about their depth of understanding. In the scoring rubric, each proposition is scored from zero to three in accordance with the following scoring protocol: Zero is assigned to invalid links, the links that were constructed based on incorrect scientific information. One is assigned to the link that connects interrelated concepts but that misses the label. Two is given to the link that is scientifically correct and has a possible label indicated, but does not specify the direction. Three is given to the correctly labeled links with the directions specified by an arrow.

Convergence measures the extent to which the possible links are actualized in the students' maps. The convergence score is computed as the number of the valid links in a map divided by the number of all possible links as derived from the expert map. Finally, salience measures the abundance of valid links. Salience is computed as the number of valid links divided by the number of all links in a student's map.

Procedure

The treatment took place during the third term of the school year. The students were pre-tested using a teacher-constructed chemistry achievement pretest (Appendix A). The study extended over six weeks. The class met five times per week for fifty minutes daily. The material covered was acid base titration and weak acid equilibrium. At the end of the treatment period, the students were post-tested (Appendix B). Study participants were randomly assigned to two sections based on overall achievement. A different teacher taught each section. One teacher taught the experimental group in which students were trained to construct concept maps as homework while a different teacher taught the control group in which students covered the same chemistry content with regular exercises assigned as homework. It is important to note that the school is which the study was conducted belongs to a worldwide network of schools that has adopted standardized curricula, teaching and assessment methods, and pacing charts on which all teachers are trained extensively before joining any of the schools in the network. Consequently, both teachers followed a teaching pacing chart which contained a detailed description of the content and teaching methods to use in each period. These charts are established at the beginning of the semester to insure that teachers cover the same material and use the same teaching and assessment methodologies. Moreover, the average achievement of the two sections was equivalent during the first semester of the academic year during which the study was conducted. Finally, the tests used before the start of the study consisted of high-order thinking skill questions as per school policy.

The treatment period was divided into two parts. The first part consisted of one week during which the experimental group students were trained to construct concept maps. One preliminary session was assigned at the beginning of the week to introduce concept mapping, then an example of a concept map was provided followed by guided practice. For the rest of the week students in the experimental group were accorded, towards the end of each session, some time to practice the construction of concept maps using a concept list provided by the teacher. The concept lists were related to the material taught in class, they included chemistry concepts known to students in order to help them focus on learning the process of concept mapping. Students received feedback on their concept maps.

During the second week, students in the experimental group were required to construct concept maps using concept lists identified in class. These concept maps were scored using the researcher scoring rubric developed by the researchers and turned back the next day to the students. The scored maps included detailed feedback to help students improve their concept mapping skills. At the end of the second week, the second part of the treatment started and the experimental and control groups started the acid-base titration chapter, which took four more weeks to complete. During this 4-week period students in the experimental group were required to submit twice per week a concept map constructed by using the concepts taught in class. The teacher did not provide the list of concepts to the students. Students in the control group completed traditional homework assignments during the six weeks of the study. These assignments were scored and students were provided with detailed feedback. At the end of the treatment period, both the experimental and control group students took the post-test at the same time.

RESULTS

Pre-Test

The mean score of the pretest for the experimental group was found to be 30.66, while that of the control group was found to be 29.28 out of a maximum possible score of 45. A t-test for independent samples showed that there were no significant differences between the two groups ($t = 0.68$, $p > 0.05$).

Post-Test

Because there were no significant differences on the pretest, it was assumed that the two groups started out with equivalent means. Table 1 presents the means and standard deviations of the posttest results for the control and experimental groups. These results include the scores on the knowledge (K-post), comprehension (C-post), and application-and-above (App-post) level questions along with the total scores on the chemistry achievement post-test (Tot-post). The maximum possible scores are as follows: Knowledge level questions = 11, comprehension level questions = 7, application Level-and-above questions = 22, and chemistry achievement post-test = 40.

A t-test for independent samples was carried out to test whether the experimental and control groups differed significantly on the post-test achievement in chemistry (Tot-post). No significant differences were found ($t = 1.55$, $p > 0.05$). In addition, a t-test for independent samples was carried out to test whether the scores of the experimental and control groups differed significantly on the questions at different cognitive levels. A significant difference was found for the questions at the knowledge level (k-post) ($t = 1.97$, $p < 0.05$) on which the experimental group scored 8% higher than the control group. No significant differences were found at the comprehension level ($t = 1.75$, $p > 0.05$) and application-and-above level ($t = 1.07$, $p > 0.05$). Results are shown in Table 1. Nevertheless, Table 1 shows that the scores of the experimental group were consistently higher than those of the control group while the standard deviations were consistently lower.

Table 1. Means and Standard Deviations of the Variables Used in the Study for the Control and Experimental Groups

	Control			Experimental			t
	N	M	SD	N	M	SD	
K-post	30	7.53	2.08	29	8.45	1.40	1.97*
C-post	30	3.81	2.29	29	4.71	1.61	1.75
App-post	30	13.48	5.37	28 [a]	14.75	3.55	1.07
Tot-post	30	24.83	8.92	28 [a]	27.84	5.68	1.55

*P < 0.05
[a] One of the scores on the Application level in the experimental group was not valid
K-post = scores of knowledge level questions in the post-test (the maximum score is 11).
C-post = scores on comprehension level questions in the post-test (maximum score is 7).
App-post = scores of the Application-and-above level questions in the post-test (Maximum score is 22).
Tot-post = Total scores on the post-test (the maximum score is 40).

Table 2. Analysis of Variance for Group-Sex Interactions on the Chemistry Achievement Post-Test (Tot-post)

Source	SS	df	MS	F
Sex	0.33	1	0.33	0.002
Group	177.81	1	177.81	1.12
Sex X Group	158.47	1	158.47	2.84***

*** P < 0.1

Table 3. Mean Scores of Males and Females on the Chemistry Achievement Post-Test (Tot-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Males	20	26.01	8.39	14[a]	26.21	6.06
Females	10	22.45	9.91	14	29.46	4.95

[a] One of the achievement scores in the males' experimental group was invalid.
[b] Total score on the Chemistry Achievement Post- Test is 40.

Table 4. Analysis of Variance for Group-Sex Interactions on the Knowledge Level Questions (K-post) in the Chemistry Achievement Post-Test

Source	SS	df	MS	F
Sex	1.24	1	1.24	0.10
Group	17.87	1	17.87	1.42
Sex X Group	12.56	1	12.56	4.13*

* p< 0.05

Table 5. Mean Scores of Males and Females on the Knowledge Level Questions in the Chemistry Achievement Post-Test

	Control			Experimental		
	N	M	SD	N	M	SD
Males	20	7.95	1.99	15	8.13	1.51
Females	10	6.70	2.11	14	8.79	1.25

Note: The total score on the knowledge level questions is 11

Table 6. Analysis of Variance for Group-Sex Interactions on the Comprehension Level Questions in the Chemistry Achievement Post-Test (C-post)

Source	SS	df	MS	F
Sex	0.44	1	0.44	0.04
Group	15.16	1	15.16	1.23
Sex X Group	12.29	1	12.29	3.20***

*** p< 0.1

Table 7. Mean Scores of Males and Females on the Comprehension Level Questions in the Chemistry Achievement Post-Test (C-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Males	20	4.06	2.30	15	4.17	1.30
Females	10	3.30	2.31	14	5.29	1.74

Table 8. Analysis of Variance for Group-Sex Interactions on the Application Level and above Questions in the Chemistry Achievement Post-Test (App-post)

Source	SS	df	MS	F
Sex	0.24	1	0.24	0.01
Group	31.77	1	31.77	1.16
Sex X Group	27.46	1	27.46	1.29

Table 9. Mean Scores of Achievement Level I and Achievement Level II Groups on the Chemistry Achievement Pre-Test (Tot-pre)

	Control			Experimental		
	N	M	SD	N	M	SD
Achlevel I-pre	16	23.25	3.68	12	23.46	5.15
Achlevel II-pre	13[a]	36.69	3.29	17	35.75	4.82

[a] Achlevel = Achievement level of students on the pre-test in chemistry
[b] One of the achievement Pre-test scores in the control group was invalid.
[c] Total score on the chemistry Achievement Pre-test is 45

Sex Group Interaction. Another test was conducted to investigate whether or not there were group-sex interactions. To investigate group-sex interactions a two-way ANOVA was conducted with sex and group as the two variables. Table 2 shows that there was a significant interaction between group and sex. To find the sources of the interaction, the means of males and females on the post-test for the control and experimental group were calculated (Table 3). Table 3 shows that while the scores of females in the control group were lower than those of the males; their scores increased more significantly then the males. The mean of the females in the experimental group was 18% higher that that of the females in the control group, while the mean of the males did not differ significantly between groups.

A two-way ANOVA was performed to check whether there were group-sex interactions for the different level questions. Table 4 shows that there was a significant interaction between group and sex at the knowledge level. To find the sources of the interaction, the means of males and females on the knowledge level post-test questions were calculated for the control and experimental groups (Table 5). Table 5 shows that while the females' scores in the control group were lower than those of the males', their scores increased more significantly then those of the males. The mean for the females in the experimental group was 19% higher than that of the females in the control group, while the mean of the males increased by 9%.

Table 6 shows that there was a significant interaction between group and sex at the comprehension level. To find the sources of the interaction, the means of males and females on the comprehension level post-test scores were calculated for the control and experimental groups (Table 7). Table 7 shows that while the scores of the females in the control group were lower than those of the males; their scores increased more significantly then those of the males. The mean of the females in the experimental group was 28.4% higher than that of the females in the control group, while the mean of the males increased by 1.5%. Finally, there was no significant interaction between group and sex at the application level scores (Table 8).

Group - Achievement Level Interactions. Students in the experimental and control groups were reassigned to one of two achievement levels based on the Tot-pre scores. Students who scored below the mean on the chemistry pre-test were assigned to one achievement level (Achlevel I-pre) and students who scored above the mean were assigned to another achievement level (Achlevel II-pre). Consequently, a comparison was carried out to see whether there were differences between the means for different achievement levels and groups on the total scores of the chemistry achievement pre-test. Table 9 shows that the mean of the Achlevel I-pre in the experimental group is very close to that in the control group. While the mean of the Achlevel II-pre in the control group is only 2% higher than that in the experimental group. Note that 59% (17 out of 29) of the students in the experimental group scored above the mean (Achlevel II-pre), while in the control group only 45% (13 out of 29) scored above the mean.

Other analyses were performed to check the effect of using concept maps as homework tools on the achievement level of the students in the posttest. Based on the Tot-post scores, students in the experimental and control groups were reassigned to one of two achievement levels. Students who scored below the mean on the chemistry post-test were assigned to one achievement level (Achlevel I-post) and students who scored above the mean were assigned to another achievement level (Achlevel II-post). Consequently, means were compared to see whether there were differences between the means for different achievement levels and groups on the total scores of the chemistry achievement post-test. Results are shown in Table 10, which shows that the mean of the Achlevel I in the experimental group is 8% higher than that in the control group. While the mean of the Achlevel II-post in the control group is 5% higher than that in the experimental group. Note that 68% (19 out of 28) of the students in the experimental group scored above the mean (Achlevel II-post) while in the control group only 47% (14 out of 30) scored above the mean.

Another comparison of the means was performed to check whether there were difference in achievement for the experimental and control groups in the two achievement level groups, at the knowledge, comprehension, and application-and- above level questions in the post-test respectively (Tables 11,12, and 13). Table 11 presents the results of the analysis at the knowledge level. Table 11 shows that students in Achlevel II in the experimental group scored 5.4% higher than those in the control group on the knowledge level questions. In addition, Achlevel I in the experimental group scored 4.0% higher than those in the control group on the knowledge level questions.

Table 12 presents the results of the mean scores comparison at the comprehension level. The means of Achlevel I and Achlevel II at the comprehension level were calculated for both control and experimental groups (Table 12). Table 12 shows that the mean of the Achlevel I in the experimental group is 21.5% higher than that in the control group while the mean of the Achlevel II in the control group is 7% higher than that in the experimental group. Note that the number of students who scored above the mean (Achlevel II) in the experimental group (19 out of 29) is larger than that of the students who scored above the mean (Achlevel II) in the control group (14 out of 30).

Table 13 represents the results of the comparison of scores at the application-and above level questions. The means of Achlevel I and Achlevel II group scores at the application -and-above level were calculated for both control and experimental groups. Analysis of these results shows that the Achlevel I group mean in the experimental group is 8% larger than that of the control group while the mean of the Achlevel II in the control group is 8% higher than that in the experimental group.

Table 10. Mean Scores of Achievement Level I and Achievement level II groups on the Chemistry Achievement Post-Test (Tot-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Achlevel I-post	16	17.69	5.16	9[a]	21.06	2.63
Achlevel II-post	14	32.98	3.49	19	31.05	3.37

[a] One of the achievement scores in the males' experimental group was invalid.
[b] Total score on the chemistry Achievement test is 40
[c] Achlevel = Achievement level of students on the post-test in chemistry

Table 11. Means of Achievement Levels in the Control and Experimental Groups at the Knowledge Level in the Chemistry Achievement Post-Test (K-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Achlevel I-post	16	6.50	2.10	10	7.1	1.20
Achlevel II-post	14	8.71	1.33	19	9.16	0.90

Achlevel = Achievement level of students on the post-test in chemistry
K-post = scores of the knowledge level questions in the chemistry achievement post-test.
The Total score on the Knowledge level questions is 11

Table 12. Means of Achievement Levels in the Control and Experimental Groups at the Comprehension Level in the Chemistry Achievement Post-Test (C-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Achlevel I-post	16	2.05	1.37	10	3.55	1.38
Achlevel II-post	14	5.82	1.17	19	5.31	1.39

Achlevel = Achievement level of students on the post-test in chemistry
The Total score on the comprehension level questions is 7

Table 13. Means of Achievement Levels in the Control and Experimental Groups at the Application and Above Levels in the Chemistry Achievement Post-Test (App-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Achlevel I-post	16	9.14	3.08	9[a]	10.89	1.83
Achlevel II-post	14	18.45	1.90	19	16.58	2.53

[a] One of the scores on the Application levels in the experimental group was not valid
The total score on the Application Level -and-above questions is 22

Table 14. Correlation between Concept Map No. 4 Subscores and the Post Achievement Test Scores

	K-post	C-post	App-post	Tot-post
Students (n=28)				
CMSal	0.19	0.12	0.18	0.18
CMConv	0.39	0.31	0.61**	0.55**
CMTot	0.41	0.32	0.61**	0.55**

**Correlation is significant at the 0.01 level (2-tailed).
C-post= scores on the comprehension level questions in the chemistry achievement post-test.
K-post = scores of the knowledge level questions in the chemistry achievement post-test.
App-post = scores of the Application -and-above level questions in the chemistry achievement post-test.
Tot-post = Total scores on the chemistry achievement post-test.
CMSal= salience score on the last concept map
CMConv=convergence score on the last concept map
CMTot= Total score on the last concept map

Note that the number of students that scored above the mean (Achlevel II) in the experimental group (19 out of 28) is larger than that of the students who scored above the mean (Achlevel II) in the control group (14 out of 30).

Correlation between Chemistry and Concept Mapping Subscores. The experimental group students' chemistry test scores were correlated with the corresponding concept map subscores on salience, convergence, and Total on the last concept map constructed by the students (Concept Map No. 4*)*. Results are shown in Table 14, which shows that the salience score did not show significant correlation with any of the scores.

The convergence scores, however, showed a significant correlation with the scores on the application-and-above level questions and the total scores and showed non-significant correlations with the knowledge and comprehension levels. Finally, the total scores on the concept map, showed a significant correlation with the scores on the application-and-above level questions and the total scores and non-significant correlations with the knowledge and comprehension levels. It is worth noting that a high CMSal score means that the student concept map includes a high number of correct propositions. A high CMConv score means that the student concept map is close to the expert concept map. A high CMTot score means that the student included in his or her concept map a larger number of directional correct propositions.

DISCUSSION

Using concept maps as homework tools was expected to result in higher achievement in chemistry. This expectation was based on the assumption that using concept maps helps organize information, fosters metacognition, and engages students in building their knowledge structures.

Results showed that the mean score of the chemistry achievement post-test for the experimental group exceeded that of the control group; however the different was not statistically significant. Further analyses investigated the interaction between sex and the effect of using concept mapping as a homework tool. There were no significant interactions between sex and the intervention at the application-and-above level. However, concept mapping favored girls over boys in the total scores in the chemistry achievement test and when knowledge and comprehension level questions were considered.

The significant interactions between using concept maps and gender can be interpreted in light of the cognitive style theory that categorizes males and females into different learning styles. According to Wapner (1986), males are field-independent learners while females are field-dependent learners. Field independent individuals, such as males, use active reasoning patterns that include cognitive structuring skills, while field dependent individuals, such as females, accept reality and may become passive learners. The concept mapping technique, used as a homework tool, presented students with a novel experience in which structure was absent and involved them in an active process of identifying links between concepts, leading to the inference that the concept mapping should favor males over females, but this is not the case in this study.

At a first glance, the results of this study might seem to contradict the conclusions derived from cognitive style theory. However, a closer look at the results may provide some clarification. On the one hand, studies have shown that concept map construction is difficult (Lehman et al., 1985) and that students need excessive training to master the concept mapping technique (Beyerebach & Smith, 1990; Brandt et al., 2001). Thus, it is possible the learning style of females would enable them, more so than males, to master the new technique of building the concept map. The field-dependent learners (females) must have been more conforming to teachers' demands and more consistent in their work than the field-independent learners (males) in following the instructions to master the technique of building the concept map. Consequently, because mastery is crucial for deriving benefit from concept mapping (Beyerebach & Smith, 1990; Brandt et al., 2001), students who conformed to teachers' demands benefited more from using concept maps as homework tools.

Other analyses dealt with the differential effect of using concept maps on high- and low-achieving students. Achievement level interactions were not detected at the knowledge level. However, significant interactions were achieved at the comprehension and application-and-above levels. In addition, a significant interaction was found when the total scores were considered. The means of achievement level group I (Achlevel I-post -- students who scored below the mean) in the experimental group were higher than those in the control group for the comprehension level questions, the application-and-above level questions, and for the total scores. These results showed that concept mapping helped students who scored below the test scores mean (achievement level group I) to achieve better on high cognitive level questions.

What deserves attention is that the means of achievement level group II in the experimental group on the post-test (Achlevel II-post) at the comprehension and application-and-above level questions and at the total scores, were slightly lower than those in the control group. The differences between the experimental and control group means, for the achievement level group II, were not significant for the comprehension level and total scores. However, the achievement level group II students in the control group scored higher, at the application-and-above level questions, than those in the experimental group with. Stensvold and Wilson (1992) got similar results in their two studies with grade 9 and high school students. Among students with high abilities, those who constructed concept maps scored lower on the comprehension test than those who did not construct maps. However, among students with lower abilities, those who constructed concept maps scored higher than those who did not. Stensvold and Wilson suggested that concept maps might have disadvantaged high ability students because they might have had there own successful strategies which were not applied when they used concept maps.

The correlation between the chemistry total post-test scores and the concept map subscores, (Salience, Convergence, and Total) indicated that students who mastered concept-mapping skills performed better on high cognitive level questions. These results are in agreement with Novak's (1994, 1998) description of meaningful learning as the establishment of non-arbitrary relations among concepts in the learners' minds. Moreover, it highlights the importance of chemistry instruction that emphasizes identifying key concepts and stresses on teaching concepts and their relationships (Novak, 1994). Thus, it can be concluded that concept mapping involved students who mastered concept mapping in actively relating new information to prior knowledge resulting in meaningful learning and consequently higher achievement. This situation, however, does not suggest that concept mapping is a solution for all problems in learning chemistry because, as Zoller (1990) suggests, there are chemistry concepts that are abstract, nonintuitive, and not directly interrelated and cannot be taught by using concept mapping.

CONCLUSION

The results of the study support using concept mapping as homework to engage students in constructing and altering their own knowledge structures, with the understanding that there is a need to help males become more engaged in using the technique because of its possible benefits. In addition, concept maps were successful tools in helping low achievers improve their grades. Nevertheless, concept mapping may become effective for high achievers too if they are encouraged to periodically check their maps during the learning process. Moreover, there is a need for longer training sessions and direct feedback to give learners the opportunity to master concept mapping the technique.

While promising, the results of this and others studies on using concept maps are not conclusive. Consequently, more research should be conducted to test further the effect of concept mapping as homework with a larger number of students, in different types of schools, and for different age groups. Other areas for further investigation include the amount of time needed to reap the benefits of using concept maps in a classroom setting and the possible benefits derived from using computers in the process.

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Appendix A
Examples of items from the Chemistry Pre-Test

1. Gases A, B, C, D and E are all diatomic. The heat change, in KJ/mole, that takes place when each of them dissolves in water is given. On the basis of the energy consideration *only*, which gas do you expect to have the lowest solubility at room temperature?
   a. $\Delta H = +100$
   b. $\Delta H = -100$
   c. $\Delta H = -10$
   d. $\Delta H = +20$
   e. $\Delta H = -30$

2. Which equation represents what happens when H_2SO_4 dissolves in water?
   a. $H_2SO_4 \longrightarrow H_2^{+}{}_{(aq)} + SO^{-4}{}_{(aq)}$
   b. $H_2SO_4 \longrightarrow 2\,H^{+}{}_{(aq)} + 4\,SO^{-2}{}_{(aq)}$
   c. $H_2SO_4 \longrightarrow H_2^{+}{}_{(aq)} + SO_4{}^{-2}{}_{(aq)}$
   d. $H_2SO_4 \longrightarrow 2\,H^{+}{}_{(aq)} + SO_4{}^{-2}{}_{(aq)}$
   e. $H_2SO_4 \longrightarrow 2\,H^{-}{}_{(aq)} + SO_4{}^{+2}{}_{(aq)}$

3. Which of the following four chemicals is soluble in water?
   a. $ZnSO_4$
   b. $Pb(OH)_2$
   c. $CuCO_3$
   d. Fe_2O_3
   e. All of the above are insoluble

4. A few drops of $Na_2SO_{4(aq)}$ were added to a test tube containing little of $BaCl_{2(aq)}$. What equation represents the reaction that is expected to take place in the tube?
   a. $Ba^{+2}{}_{(aq)} + 2SO_4{}^{-}{}_{(aq)} \longrightarrow Ba(SO_4)_2{}_{(s)}$
   b. $Ba^{+2}{}_{(aq)} + SO_4{}^{-2}{}_{(aq)} \longrightarrow BaSO_4{}_{(s)}$
   c. $Na^{+}{}_{(aq)} + Cl^{-}{}_{(aq)} \longrightarrow NaCl_{(aq)}$
   d. $Ba^{+2}{}_{(aq)} + SO_4{}^{-2}{}_{(aq)} \longrightarrow Ba(SO_4)_2{}_{(s)}$
   e. $Na^{+}{}_{(aq)} + Cl^{-}{}_{(aq)} \longrightarrow NaCl_{(s)}$

4. Sulfuric acid is a hygroscopic liquid. What can you predict about its solubility in water with respect to i) heat of reaction and ii) equilibrium. Justify your answer.

5. Using Le Chatelier principle, explain why a layer of scale forms when tap water is heated.

6. The solubility product constant, K_{sp}, of PbS is $4x10^{-28}$ at $25^{0}C$. Find the maximum mass of PbS that can dissolve in 200 cm^3 solution at the same temperature. Molar mass of PbS = 239g/mol.

Appendix B
Examples of items from the Chemistry Post-Test

1) Which of the following dissolves in water to produce a strong electrolyte?

CH_3COOH ii. CH_3COONa iii. NH_4Cl
   a) ii only
   b) ii and iii only
   c) i and ii only
   d) i and iii only
   e) iii only

2) 0.1M HCl (aq) was gradually added to 25 cm^3 of 0.1 M $NaOH_{(aq)}$ in a beaker and the conductivity was measured at regular intervals. Which of the reported observations describes the variation of conductivity of the resulting solution as the acid is added until it is in excess?
   a) The initial conductivity was high. It drops as the acid is added.
   b) The lowest value of conductivity will be recorded when the volume of acid added is $25cm^3$.

3) As acid is added beyond the equivalence point, the conductivity will increase slowly.
   i) a and b only
   ii) a only
   iii) a, b and c
   iv) a and b only
   v) a and c only

4) What is the $[H^+]$ of a solution labeled 0.01M $KNO_{3(aq)}$?

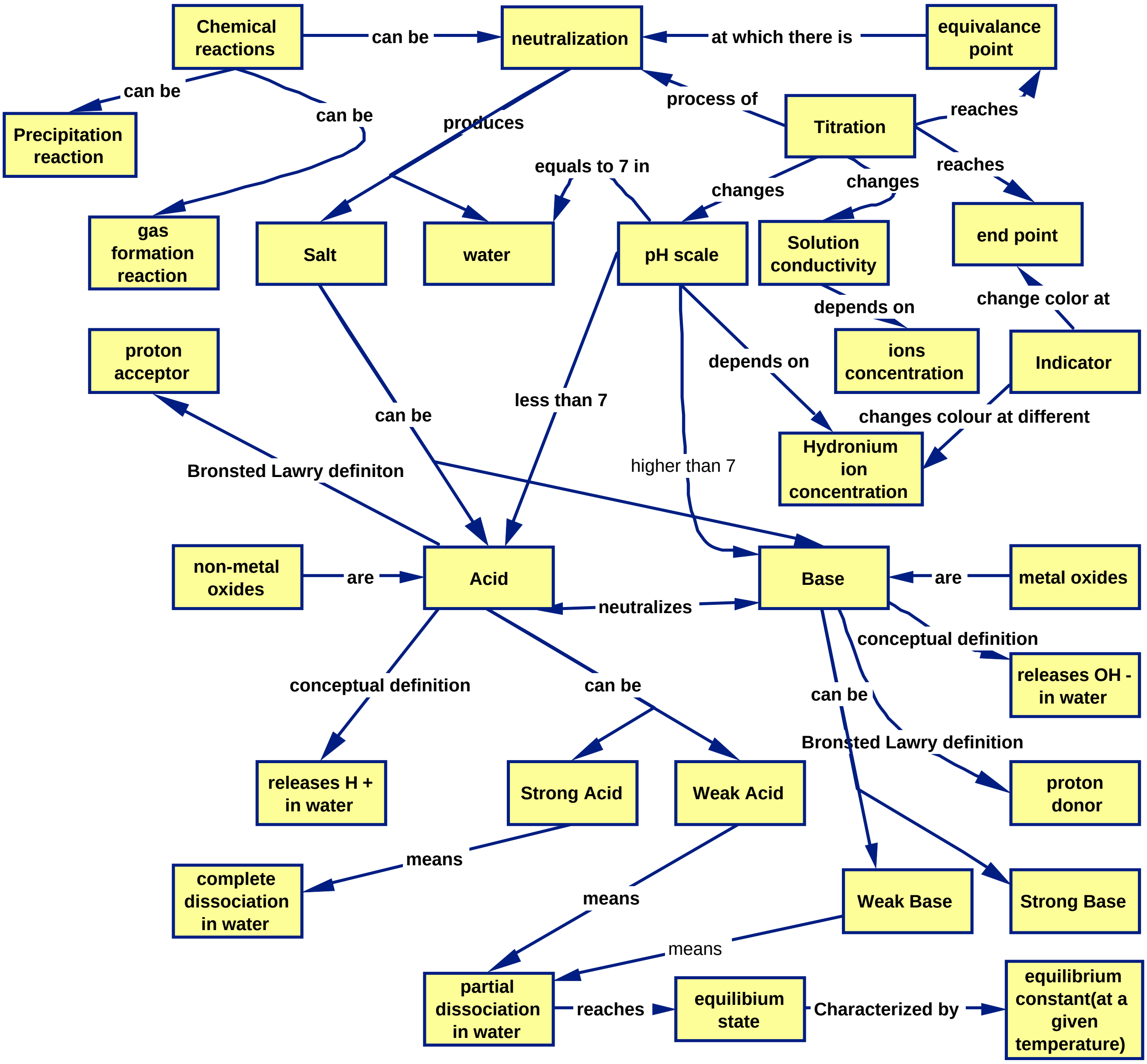
5) 3.65g of HCl were dissolved in 500 cm^3 solution. What is the $[OH^-]$ in the resulting solution? [H=1.0, Cl=35.5]

6) The pH of 0.1 M $CH_3COOH_{(aq)}$ solution is 3. What is the $[OH^-]$ in the solution? Determine the pH value of the resulting solution when the conductivity of the solution reaches its lowest value.

7) HNO_2 and HF are both weak acids. HF is a stronger acid than HNO_2 .
   a) Calculate the volume of 0.10M NaOH solution needed to neutralize 50.0 ml of 0.10M HNO_2 solution .
   b) Deduce the volume of 0.10M NaOH needed to neutralize 50.0ml of 0.10M HF solution.

8) An average adult produces between 2 to 3 l of gastric juice daily. Gastric juice is an acidic digestive fluid. It contains 0.03 M H^+ acidic solution. The purpose of the highly acidic medium within the stomach is to digest food and to activate certain digestive enzymes.
   a) Calculate the pH of gastric juice solution in the stomach. [log 3=0.48]
   b) From the text, explain why drinking water during a meal causes digestive problems.

Appendix C
Expert Concept Map

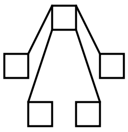
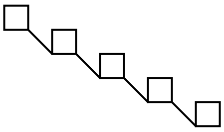
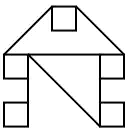


Appendix D
Scoring Rubric of the Concept Map

Student Name:

1. Map Structure:

a. Spoke b. Chain c. Net

2. # of Correct Hierarchy levels:_________

3. # of Correct Cross-Link:_____________

4. Quality of Propositions

Invalid proposition: __________x 0 =_____

Possible relationship: _________x 1 =_____

Correct-label proposition: _____x 2 = _____

Directional correct proposition: _x 3 =_____

5. Convergence Score =____________

6. Salience Score =____________

Total =_____________

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The Quality of Lower Secondary Students' Discussions During Labwork in Chemistry

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The aim of this project is to study the quality of the discussions in groups of students during laboratory work. The project builds on a study of the role of communication in science classrooms with students aged 14-15 years. An intervention with role-playing for example reporting to another group is carried out to foster discourses that focus students' use of science knowledge. The discussions have been divided into sequences. In each sequence the students are discussing one separate part of the lab work activity. A revised version of the SOLO-taxonomy has been used in the analysis of tape recordings from students' discussions during lab work and from the reporting to another group. The students talk about the experimental procedure as well as the science content. In most of the groups the analysis show a long-term development towards higher quality mixed with unistructural sequences. During the reporting to another group the students describe the experiment using new knowledge and new concepts. Almost all the reporting groups use two or more concepts well integrated. The reporting to another group stimulates students' discussions. The SOLO-taxonomy makes it possible to assess group learning and interaction in lab groups.

Keywords: Chemistry, Lab work, Lower Secondary School, Solo-Taxonomy, Using Science Knowledge

BACKGROUND, AIMS AND FRAMEWORK

The aim of this project is to study students' science learning by investigating their ability to use science knowledge when talking about laboratory experiments that they carry out. The framework for learning involves both individual construction of knowledge and social interaction between individuals and that understanding emanates from social interaction.

Practical work is according to Jenkins (1999) an important element in science education and is important for students' learning. Jenkins argues that working with concrete materials can give the students a feeling for the phenomena that can help them to understand how difficult it is to obtain knowledge about the natural world. He means that it is easier to learn about the natural world by using practical work. According to Jenkins practical work in school science should involve more discussions about planning an investigation, realizing, data collecting and interpreting. White (1996) also talks about students using science knowledge but he means that there is a risk that students miss the links between the theoretical and the practical education. The aim of laboratory lessons is to support meaningful learning by complementing theories and to stimulate development of analytical and critical capacity (Lazarovitz & Tamir, 1994).

The science classroom environment is very difficult to catch and many research projects on the relationship between students' achievement and the quality of learning environment in classrooms have been carried out during several decades. Students' perceptions in the science laboratory were approached by a group of science educators in Australia, who developed and validated the *Science Laboratory Environment Inventory*

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(SLEI) (Fraser, McRobbie, & Giddings, 1993). This instrument consists of five learning environment scales: *cohesiveness, open-endness, integration, rule clarity, and material environment.* These scales were found to be sensitive to different approaches to laboratory work and in different science subjects. The SLEI has been used in several studies conducted in different parts of the world.

The CLES (Taylor, Fraser, & Fisher, 1997) is another learning environment instrument that enable teacher-researchers to monitor their development of constructivist approaches to teaching.

The research on learning environment in both Western and non-Western countries has been focused on using questionnaires that assess students' perceptions of their classroom learning environment. Fraser (2006) sums up the implications for science education from such studies:

- Measures of learning outcomes alone cannot give a complete picture of the educational process in the classroom
- More feedback from students about classrooms should be used
- Science teachers should strive to use research results to develop learning environments
- Evaluation of new curricula should include classroom learning environment instruments.

Fraser shows a wide field of application for using learning environment assessment for research as well as practical purpose. He also proposes international projects with new questionnaires that tap nuances and uniqueness of classrooms in particular countries. Fraser means that the next generation of learning environment studies could benefit from new methods of data analysis.

In an European project on lab work Millar et al (2002) want to investigate the effectiveness of lab work for achieving the goals. One aim of science education and the lab work activities is to help students develop their understanding of the natural world. In this project they are studying the varieties and the effectiveness of lab work in school science teaching. They present a profile of a lab work task that could be used to analyze instructions for and student's activities during lab work activities. The coding scheme has the following aspects:

- Intended learning outcome
- The cognitive structure of the task.

Millar et al find a wide field of application for the coding schemes they used in this project:

- Producing a detailed description of lab work tasks
- Comparing differences and similarities in lab work tasks
- Comparing types of lab work tasks used with students of different ages and stages in different countries.

Lunetta, Hofstein & Clough (2006) present an analysis of Research, Theory and Practice. They found among other things that there are both similarities and differences between the way the scientific community and the learners in school come to understand their world.

Tytler (2006) discusses science literacy from the aspect of developing science capabilities of citizens. He asks questions about how citizens use "science" in their daily lives and when discussing socio-scientific issues. He refers to studies with laymen, which show that meaningful science learning can occur when citizens interact with science in their lives. Tytler means that in school science we need to stress the nature of science and the way it operates. These studies must include more sophisticated versions of scientific investigations with focus on analytic thinking and problem solving, communication and creativity.

Language is according to Lemke (1990) the most important mechanism for developing, testing and communicating knowledge. He states that lab work offers unique possibilities for students to talk science to each other and to write notes on what they do.

Newton, Driver, & Osborne (1999) describe a study where they tried to focus the communication pattern in a classroom. The study produces knowledge about what happens in the classroom in a broad sense. Lemke (2007) concludes that using knowledge demands deep understanding and a critical perspective. Deep understanding means both that you have examined the subject in depth and that you have looked at it from different perspectives. You must also be able to talk about it in many different ways. With critical perspective Lemke means thinking about both the subject and why the subject is studied.

Sutton (1998) describes learning science in school as 'learning to talk in new ways' and to use science knowledge when talking about everyday phenomena. Solomon (1983) describes it in a similar way when she says that students develop their ability to use new ways of explaining on an individual level, and that they then reorganise and reconstruct the new information on a social level. Tytler (2002) finds that if school science knowledge should be useful to the students, continual links must be made between school experiences and social uses of the science knowledge. Many researchers e.g. Eskilsson and Helldén (2003) mean that students use everyday language parallel to science language. Wells and Mejia-Arauz (2006) have found that there is increasing agreement among those studying classroom activities that learning is likely to be most effective when students are actively involved in the dialogic construction of meanings that are significant for them.

Ann L. Brown et al (1997) and Mercer (1996) conclude that students have to learn strategies for successful learning and that they have to learn about how to cooperate. The teachers can foster certain discourses. Mercer's and Brown's papers have inspired this study. Brown et al initiate a research program FCL, Fostering Communities of Learners, with four key ideas: agency, reflection, collaboration and culture. Propitious conditions for productive discussions involve students talking to each other, solving problems, and that working together is stimulated. Reciprocal teaching groups are designed to help students to monitor their comprehension. Brown et al discuss why students not are aware of their learning strategies. She claims that students need to learn how to learn and she focuses a/ remembering and b/ monitoring. She uses Bruner's (1996) four concepts for good learning environments: agency, reflection, collaboration and culture. A focus in the learning culture was to make learning development clear for the students. Brown states that FCL was more and more influenced by Vygotskyan theories during the project. Mercer too means that students have to learn more about collaboration. Favourable conditions for fruitful discussions involve that teachers must stimulate students to talk to each other when solving a problem. Tytler (2006) too discuses engaging the science learners and concludes that the ways in which teachers shape communities of learners and develop the science language are stressed by sociocultural approaches.

Mercer (1995) studies students' talk and finds three ways of talking and thinking:

- Disputational talk: disagreement and individual decision-making, challenge
- Cumulative talk: speakers build positively but uncritically on what the other has said. Repetition, confirmation and elaboration
- Explorative talk: engage critically but constructively with each other's ideas.

Vygotsky's theories have in comparison with Piaget's theories more room for teachers' as well as learners' construction of knowledge as a joint achievement. Vygotsky provides us with a theory of the development of thought and language.

Hofstein (2004) summarizes new information based on scholarly research about laboratory work. He means that school laboratory activities have special potential as media for learning. The teachers need knowledge about enabling students to interact intellectually and physically – both in hands-on work and minds-on reflection. Nakhleh, Polles, and Malina (2002) mean that there is need for more research about assessing group learning and interaction during lab work and about students' perspectives on lab work.

Table 1. Categories in the SOLO-taxonomy (Biggs & Collis, 1982)

P: Prestructural – bits of unconnected and inadequate information
U: Unistructural – focus on one relevant domain, simple connections can be made
M: Multistructural – pick up more than one relevant feature, no integration
R: Relational – integration between relevant data, relations to the whole
E: Extended abstract – can generalise and transfer the principles and ideas

METHODS AND SAMPLES

The research-questions for the present study are:

- How do students' discussions during lab work stimulate learning science in the group?
- How can stimulated interaction have an influence on students' use of science knowledge?

This study is based on Brown's et al (1997) FCL project and is part of a two-year study on learning and communication in science classrooms involving 25 students aged 14-15 years. The intervention in this unit concerns students working in groups of three, where one of them is chairperson, one is secretary, and one of the students prepares an oral report to another group. All the students in a group take part in the practical work.

Students' communication and learning is studied by analysing their use of scientific knowledge. The lessons are video recorded and in each group the discussions about the experiments are tape-recorded. The topics for the lab work studied are foodstuff chemistry. Half of the groups experiment with coagulating egg white protein that is a/ heated, b/ added an acid, and c/ added a solution of copper sulphate so that the protein coagulates. The others experiment with fats: grease spot as test for fats, and testing solvents for fats. Each group experimenting with fats then have to report to a group experimenting with proteins about what they have done and about their conclusions and vice versa.

Students' science talk in the video recordings and tape recordings are analyzed. The analysis is based on the SOLO-taxonomy (Structure of the Observed Learning Outcome) described by Biggs and Collis (1982) and later developed by them (1991).

Modified versions of the SOLO-taxonomy have also been used by e.g. Panizzon (2003) identifying cycles of students' understanding of diffusion, Tytler (1998) studying the structure of primary school students' explanations of air pressure, and Berg (2005) classifying the structural complexity in the responses from university students in chemistry. The modifications often are adjustment for the use of the taxonomy.

Table 2. Categories used in this study accorting to a revised SOLO-taxonomy

Category in the present study	SOLO-category by Biggs and Collis
U1/ describes the experimental prodecure	Unistructural
U2/ mentions relevant concepts	
U3 / comments on concrete as pects of phenomena	
M4/ uses more than one relevant concept in a relevant way but no integration	Multistructural
R5/ uses two or more concepts well integrated in a relevant way	Relational
R6/ all data is integrated	

Table 3. Examples from the discussions during the laboratory work

T: Has the protein coagulated? S1: When you mix **hydrochloric acid** in a **protein** it will **coagulate**. T: What has coagulated? S2: The **protein** S3: Milk contains much **protein** and it coagulates with **soured milk**.	Many students: **Lactic acid** T: Soured milk has sour taste S3: I do not like **sour milk**! S2: (checks with T to see if she has understood) When they produce sour milk they use **lactic acid** in milk? T: Yes they put many lactic acid bacteria in the milk

When analyzing the discussions in the groups, these discussions are divided into sequences. In each sequence the students are discussing one separate part of the lab work activity. These sequences are analyzed using a version of the SOLO-taxonomy. See Table 2.

The focus of the study is students' use of their science knowledge. This revised version of the SOLO-taxonomy makes it possible to get information about the structure of students' use of science knowledge and of the quality of students' knowledge in the science conceptual area.

No categories corresponding to *Prestructural* and *Extended abstract* are used. These categories are not relevant in this study. The sequences categorized as *Prestructural statements* are not relevant for this subject field, since they do not show how students use their science knowledge. According to *Extended abstract* the students are supposed to formulate generalized principles, which they are not in this study. In some of the other categories sublevels have been formulated. All statements from the students originate from talking with other students or their teachers.

RESULTS

When students are doing lab work they talk about what they are doing and then they often use science knowledge and scientific concepts. In Table 3 there is one example from these discussions. Students' use of their scientific knowledge is marked in extra bold type.

Talking during the experimental work

The discussions then are divided up in sequences that have been analyzed. Examples from the categorization of parts of sequences using categories in Table 2:

> S1: We will bring the egg white to boil.
> S2: The egg white becomes white! (U1)

Students use one or more concepts.

> Shall we take new protein? (U2)

Students are discussing what will happen in the experiments.

> What will happen when we mix protein with an acid? How shall we do this experiment? (U3)

Many students use different aspects when talking about their experiments.

> S3: How can we know when it will coagulate?
> S4: We warm it and see what happens.
> S3: It turns white - at a temperature of 60 to 70 degrees (M4)

Some students try to interpret the instruction and widen the discussion.

> We should find out at which temperature the egg white will coagulate. It is the same thing. (R5)

In one group the students describe how they examine if food contains fat.

> If you put the food on a paper and then take it away, you will see if a spot will remain – then there is fat in the food (R6)

These SOLO categories have been used to analyze students' use of science knowledge during laboratory lessons.

The analysis of the discussions during lab work is summarized in Table 4.

Table 4. Discussions during the lab work activities

Group	SOLO-categories	Change of categories	Number of sequences
A	4xU1. U3–R5	Varying – falling	11
B	2xU1. U2–M4	Falling	6
C	3xU1, U2–M4	Constant	9
D	2xU1. U2–M4.	Increasing on every sub-experiment	11
E	3xU1. U2–R5	Increasing on every sub-experiment	10
F	5xU1. U2–R6	Increasing to high level many times	15
G	3xU1. U2–R5	Increasing to R5 in each experiment	18
H	1xU1. U3–M4	Increasing	5
I	3xU1. U2-U3	Increasing	8

Table 5. The analysis of the discussions during the reporting to another group

Group	SOLO-categories	Changing	Number of sequences
I	U1– M4	Increasing	2
II	U2 (discussion) –R5	Increasing	5
III	M4–R5	Even	4
IV	U1 (discussion)+3xR5	Increasing	6
V	M4–R5	Increasing	3
VI	M4–R6	Increasing	3
VII	2xR6	Even	2
VIII	2xU3–M4	Falling	4
IX	R5–R6	Increasing	3

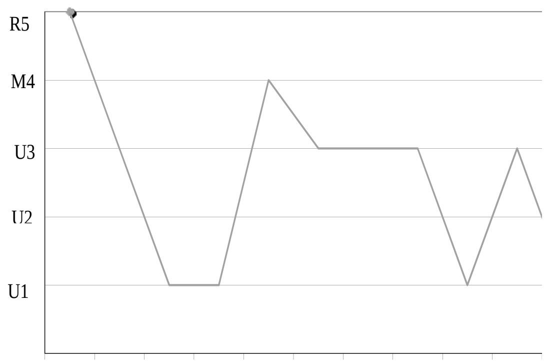

Figure 1 .Example from categorization group B

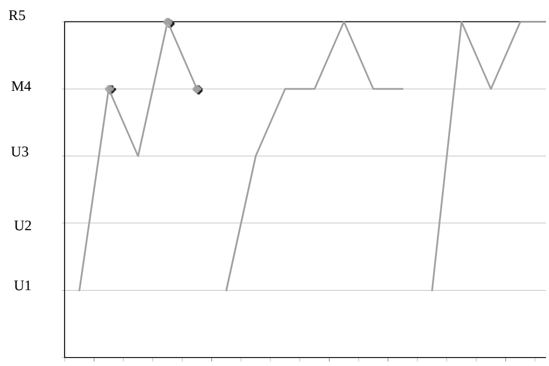

Figure 2. Example from the categorization of group G

As an example the sequences from the discussions in group E are described: The sequences are categorized: U1, M4, U1, U2, R5, U3, U1, R5, M4, M4. 3xU1 means that there are three sections with descriptions of the experimental procedure. U2-R5 means that besides the U1 there are sections categorized U2, U3, M4 and R5. Change of categories is a short summary of the quality changes in the sequences. In this example "Increasing on every sub-experiment" means that in all three parts of the experiment the quality of the sequences increases.

Six of the nine groups had increasing quality of their science talk during the experiments. Many of the sequences had category U1 when they started with each sub experiment. Students used words and concepts introduced in the laboratory lesson as well as earlier introduced words. Five groups had at least 10 sequences identified. The students seemed to be stimulated to use science knowledge when doing lab work. There also were three groups with six or less sequences. This can be due to shy students or that they are not so sure in understanding the chemistry words used in the lesson

The time scale diagrams Fig. 1 and Fig. 2 describe categories during the experimental work.

4xU1. U3–R5 Varying – falling

This group was experimenting with proteins. The sequences from the discussion were categorized in different categories. The long time trend seems to be falling to lower quality. The variation cannot be explained by working with new experiments.

3xU1. U2–R5 Increasing to R5 in each new experiment

This group was experimenting with proteins.

They have eighteen sequences analyzed and twelve of them are in M4 or R5 (multistructural or relational), which mean that they have high quality in their use of science knowledge. The group was very active. They only had one U1 in each sub experiment. Often this was from discussing the experimental procedure.

Explaining to another group that has not done these experiments

The reporting groups work in different ways. Some of them read from their papers and the other group write it down. In some groups there are many discussions and questions. Only a few sequences categorised U1-U3 can be found. The categories corresponding to structures of higher quality are more

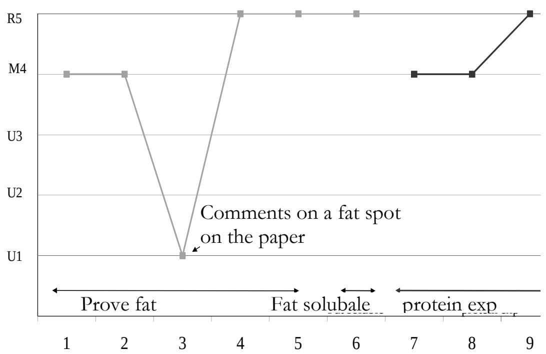

Figure 3. Analysis of sequences in the presentations – example A.

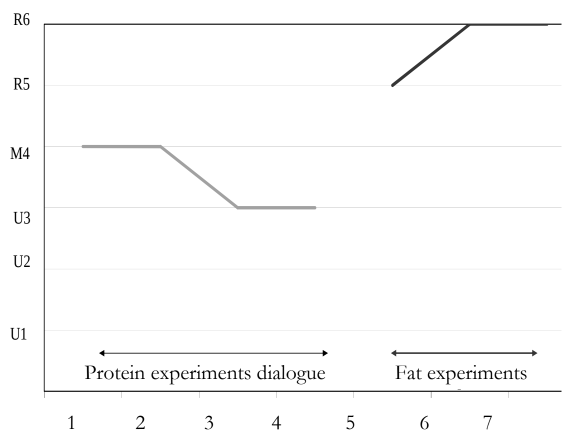

Figure 4. Analysis of sequences in the presentations – example B.

common than during the lab work discussions. There are not so many categories in each reporting group. The intervention with ideas from Brown (1992) seems to stimulate students' ability and capacity to use science knowledge. All groups but one have R-categories. Almost 40% of the statements are analysed to R-categories.

Here follows examples from students' use of science knowledge during the reporting to other students that have not done the same experiments (part of sequences):

Some students describe what happens.

> The cooking oil and the butter: we get a spot of grease on the paper. (U1)

Other students use science concepts when they report about their experiments

> We had to examine what happened with drops of water, butter and cooking oil on a paper. The water evaporated. (U2)

The students also refer to concrete aspects of the phenomena during the report

> S5: What happens when you mix an acid and a protein?
> S6: It will coagulate?
> S5: Does everything coagulate?
> S6: No not the protein in the eggs. (U3)

When talking about the experiments the students sometimes complete their results with comments on the substances

> S7: How does heavy metals act on protein?
> S8: The protein coagulates. It was protein mixed with water in the beginning. (M5)

The students try to integrate different concepts in a relevant way.

> Petrol and acetone was the best and fat was not soluble in ethanol. (R5)

A few students can integrate and generalise all relevant different aspects.

> We had to show how to identify fat. We put drops of the substances on a paper. If the spot remains it contains fat. (R6)

In the discussions after the experiments the students had to summarize what happened and their conclusions of the experiments to classmates that had not done the same experiments. The analysis then focused presenters and not the questions from the other students. See Table 5.

The quality of the students' use of science knowledge during their presentation, as analyzed with a revised Solo-taxonomy (Table 2), is higher in the presentation than in the lab work discussions. The students seem to learn to be sure in the use of their knowledge to a higher degree. In five of the presentations there only were three or less sequences analyzed. This can depend on that the students presented their results in bigger parts. In seven of the presentations there was at least one sequence analyzed as R5 or R6. In six of them the quality was increasing.

In figure 3 and figure 4 the analysis of some of these presentations is shown. In each diagram there are two graphs. One of the graphs shows the categorization of the presenting of the experiments with protein and the other the categorization of the presenting of the experiments with fats

VIII: 2xU3–2xM4 Falling

The presentation of the protein group is on U3 and M4 level. The downward tendency can depend on the content of discussion.

IX: R5–R6 Increasing

The analysis of the "fat group" presentation is on the multistructural or relational level all the time.

IV: U1 (discussion)+3xR5 Increasing

The sequences in "fat group" presentation were analyzed multistructural or relational level all the time except on sequence 3 when the students' discussed a fat spot on the paper.

V: M4–R5 Increasing

The sequences of the presentations of the protein group were high and stable M4 or R5.

CONCLUSIONS AND IMPLICATIONS

The focus in this study is on group learning and interaction during lab work (Nakhleh, Polles, & Malina, 2002) and how learning and interaction can be stimulated (A. L. Brown, Campione, Metz, & Ash, 1997).

In the discussions about the experiments the students use science knowledge as well as everyday talk. They talk about the experimental procedure as well as the science content. Talking to each other during lab work as well as reporting to another group of students show how they can use science knowledge instead of everyday talk (Sutton, 1998).

The analysis with a revised SOLO-taxonomy was used to study only one aspect of students' perception in the school laboratory, how students use their science knowledge during lab work. The analysis also shows different learning environment aspects from the SLEI-project (Fraser, McRobbie, & Giddings, 1993). In sequences analyzed as multistructural or relational the students talk about cohesiveness, open-endness, and integration. During the reporting to another group student's involvement become apparent. The analysis of students' use of science knowledge completes the picture of the educational processes in the classroom (Fraser (2006). The SOLO-taxonomy also perhaps could contribute to what Fraser (2006) call the new generation of learning environment studies. Many of the aspects described in "profile of a lab work task" (Millar, Tiberghien, & Le Marechal, 2002) could be compared with the SOLO-analysis used in this project: e.g. the process of using data to support a conclusion, learning facts in chemistry, exploring relationship, accounting for observations, and testing predictions. The Millar et al profile can be used to improve the analysis with the revised SOLO-taxonomy.

Using the modified SOLO-taxonomy (Biggs & Collis, 1982) makes it possible to study the quality of the students' science talk. The analysis of the discussions during the laboratory work shows a long-term development towards higher quality in most of the groups even if there also are some unistructural sequences. The intervention stimulates the students to use science knowledge. When having to report to another group the students focus their work on understanding the experiments and on preparing the presentation and when reporting they describe the experiment using new knowledge and new concepts. Almost all reporting groups use two or more concepts well integrated. This findings correspond to conclusions from other researchers (A. L. Brown, Campione, Metz, & Ash, 1997; Bruner, 1960; J. L. Lemke, 1988). The teaching sequence could be followed up by Tytler´s ideas of more sophisticated scientific investigations.

An analysis method like the SOLO-taxonomy could also be used to assess group learning and interaction in lab groups.

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Students' Attitudes Toward Computer Use in Slovakia

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ICT has a very short history in Slovakia. A majority of Slovak schools accessed computers and internet only after 2000. Different financial support and schools' participation in various projects resulted in non-random distribution of computers across Slovakian elementary schools. We examined whether 1) attitudes toward computers could be affected by the accessibility of computers at schools and 2) how the use of computers between school and home environment differ. Attitudes toward ICT were positive and gender differences were weak. Although we found school had an effect on the behavioural dimension of attitudes, it was not caused by the accessibility of computers per se. However, large numbers of students per computer (up to N = 68) greatly reduced student's use of computers at schools. Lack of internet connection at home caused greater supplementation of internet-related activities in schools relative to home. Gender and age-related differences in ICT participation were greatly influenced when comparing the home and school environment.

Keywords: Attitudes, Computer, ICT-use, Schools, Pupils, Slovakia.

INTRODUCTION

All schools should be highly computerised, all teachers should be able to use the technology to enhance their working methods and all young people should be able to broaden their horizons. These goals are among the priority objectives for 2010 that the education and training systems of EU countries have set themselves in the follow-up to the Lisbon strategy (Key Data on Information and Communication Technology in Schools in Europe, 2004).

Introduction of information – communication technologies (ICT) into education in European countries was at the end of 1970's and at the beginning of 1980's. For the first time, ICT was accepted as a subject of education. Only later, it was understudied as an educational tool. The European commission published the plan "Learning in the Information Society" in 1996. The plan included four aims:

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- support creating electronic networks among schools,
- support the preparation of teachers for using ICT,
- provide information about possibilities of using ICT,
- support the development of multimedia tools in education (Information and Communication Technology in European Education Systems, 2001).

The aims underlying the introduction of ICT into the education system in Slovakia are expressed in terms of ICT knowledge and skills required at each level of education:

enabling acquisition of the basic skills needed to use computers in optional subjects at the first stage of primary education,

- enabling acquisition of the basic skills needed to use the Internet and appropriate software for individual school subjects at the second stage of primary education and secondary level,
- attaching particular importance to the study and use of ICT to research sources, so that software specific to certain subject areas can be used in higher education.

Programme Declaration by the Minister of Education relating to curricula defined for each level of education and approved by the Minister: principle relating to the thorough development of higher education in the 21st century and principle relating to the development of education for the new millennium.

The Ministry of Education and the regional authorities are involved in introducing ICT into Slovak schools namely through the pilot project Infovek, or under agreements with Microsoft which supplies schools with Microsoft Windows operating systems and with Microsoft Office. Since 1998 aims of the project Infovek had been to introduce ICT into teaching and learning in primary and secondary schools, by connecting these schools to the Internet before the end of 2002, training their teachers and enabling all pupils to master basic computer skills before the end of 2003 (Sýkora et al., 1999). The initial global plan of the project Infovek to engage all schools to the project till 2004 failed. The principal reason was economic limitation. The objective assumes that about 50 – 60 % of all schools could be engaged in the project.

New technologies are the instruments for change and innovation. The educational value of ICT was confirmed by variety of experiments. Students who use ICT achieve better results in communication, co-operation and in solving problems (Williams, 2003). Graff (2003) and Mikropoulos et al. (2003) claims that ICT support the improvement of pupils' mental and creative activities. Creative use of ICT can increase creative thinking (Wheeler, 2002). Brosnan (1998) confirmed the significant effect of computers at home on knowledge which was obtained from computers. The primary schools with high level of computerisation obtained significantly better results in national testing (Bussière & Gluszynski, 2004). Pupils highly rated using animation, visual design and design software (Kreisel, 2003). Interestingly, several studies have shown that ICT usage at home differs from those at school (Kent & Facer, 2004; Sutherland, Facer, & Furlong, 2000). For example, school students reported that they spend more time with computer games at home than in the school (Kent & Facer, 2004).

Using new technologies contributed to positive attitudes of pupils toward ICT (Neo, 2003). For example, Haunsel and Hill (2002) found out that pupils using computers had more positive attitude towards biology and natural sciences than pupils who were educated by traditional styles. Several studies found gender differences in attitudes toward ICT. Brosnan (1998) showed that 6-11 year old boys had more positive attitudes towards computers than girls. Graff (2003) found that girls were less likely to use computers and were less confident in using ICT than boys. Pupils' attitudes towards computer exercises were highly positive (Ogilvia, 1999) and, additionally, most of students could work at their own speed and their computer literacy improved. The current study of Palaigeorgiou et al. (2005) also confirmed that both men and woman had similar engagement with computers and held concerns for the future effects of continuous computer use, but women were more anxious about hardware usage, and judged less positively the consequences of computers in personal and social life.

In the present study, we examined effects of variations in ICT facilities in Slovak elementary schools on students' attitudes toward ICT use. In addition, we examined differences of selected computer activities both at home and in schools.

METHOD

A total of eleven elementary schools from different part of Slovakia were asked to collaborate on the research. All school agreed to answer a basic questionnaire focusing on their implementation of computers. The results of the questionnaire are listed in Table 1. Four of these schools (first four columns in Table 1) entered into with further collaboration aimed on the investigation of students' attitudes toward ICT (ATICTQ) and their utilization of computers questionnaire (UCQ). Full versions of each questionnaire are available via the author upon request. Unfortunately, it was impossible to administer both

Table 1. The distribution of computers and basic characteristic of ICT implementation in 11 schools in Slovakia

Total number of students	470	821	174	245	665	420	723	769	895	470	665
Total number of teachers	28	53	12	19	45	31	37	47	49	41	44
Number of PC for students	28	12	21	20	13	19	30	15	30	15	11
Number of PC for teachers	4	2	4	3	2	3	3	4	10	15	11
Number of PC connected with internet	25	14	16	22	7	26	30	19	40	12	12
Total number of PC	37	14	25	24	17	28	45	23	40	20	16
Mean no. of students per one PC	16.79	68.43	8.29	12.25	51.15	22.11	24.1	51.27	29.83	31.33	60.45
PC in special classrooms	y	y	y	y	y	y	y	y	y	y	y
PC in classrooms	n	n	y	y	n	n	y	n	y	n	n

ATICTQ and UC together, and the anonymity of participants was essential. Thus, we obtained data which could not be examined as related variables although high relatedness between participants of both questionnaires is expected. We therefore evaluated this data separately, but we believe that there is close relationship between responses on both questionnaires.

Attitudes toward ICT

Overall, 214 secondary students (105 boys, 109 girls) aged 10 – 14 yrs from four different Slovak elementary schools participated in the ATICTQ. In order to examine factors influencing students' attitudes toward ICT, each student completed a questionnaire which consisted of 35 items. Questions were carefully divided into three attitude dimensions (cognitive, behavioural and affective). Each item was scored by participants using Likert-type scale ranged from 1 (strongly disagree) to 5 (strongly agree). Both positive and negative items were used in the test, while negative items were scored in the reverse order. Also, students were asked to provide information such as gender, their most favourite school subject, ownership of home computer and number of hours they spend using computers. Participants' favourite school subjects were then categorised into one of three categories – social sciences, natural sciences and others (art and physical sciences). One open ended question was related to the type of activity the pupils spend with computer (What activities do you use computers most frequently for?). After the data collection was completed, we used factor analysis to determine internal relationships between items within each dimension. Due to the weak correlations with other items, three items from the cognitive dimension (Items 18, 19, and 29) and three items from the behavioural dimension (Items 4, 7, 27) were excluded from the further analysis. Reliability of the test was calculated by Guttman split-half reliability (0.72), Cronbach's alpha of all items together (0.87), and for each dimension separately (Tab. 2). Values of reliability were higher than 0.7 which indicate that the instrument used in our study can be considered as reliable (Nunnaly, 1978; Pallant, 2001).

Utilization of computers

In total, 145 students (66 boys, 79 girls) from the same four schools and the same age group participated in the UCQ. The UCQ consisted from 12 items focusing on the use of computers at home and in the school. The aim of UCQ was to examine whether there are differences in the kind of activity with computers at home and in the school. Each item, except two basic questions Do you have computer at home? and Do you have an internet connection at home? was scored following frequency of use, from 1 (never), 2 (once per month), 3 (once per week) to 4 (everyday). Five items were related with the use of PC, computer games, the use of MS Word, searching information from internet and the use of e-mail at home. The same items were used in context of their use in the school. Pooled data from all four schools were than examined by factor analysis with varimax rotation.

RESULTS

General characteristic of participated schools

Total number of students per school varied from 174 to 895. The number of students per PC varied greatly – from 8 to 68 (mean = 34). All schools had computers in separate classrooms and only four of eleven have computers also in normal classrooms. Seven schools reported utilizing computers in other school subjects than ICT, and about half of the schools (six) held special sessions for students with higher interest in ICT. More than half of participants (175 of 214) reported having computer at home.

Students' attitudes toward ICT (Attitudes Toward ICT Questionnaire (ATICTQ))

Students' responses on behavioural, cognitive and affective dimension can be considered positively, because their values were higher than average expected values (see Figure 1).

Behavioural dimension

The high number of independent variables did not allow us to examine their effect using a single test. We therefore used a series of univariate ANOVAs with Bonferroni adjustments recommended by Jaccard and Wan (1996) and Holland and Copenhaver (1988) to retain the overall Type I error rate at the 5% ($p < 0.05$) and 1% ($p < 0.01$) levels, respectively.

In this procedure, the probability values obtained

Table 2. Descriptive characteristic of three basic components of attitudes

Dimension	Number of items	Cronbach's alpha	Discriminant validity	Inter-item correlation
Behavioural	10	0.7	0.71	0.19
Affective	12	0.71	0.65	0.18
Cognitive	7	0.7	0.69	0.23

from all significance tests are rank ordered from highest (most significant) to lowest (least significant). The first test is considered significant if the obtained p value exceeds the alpha level (0.05 or 0.01) after it has been divided by the total number of tests. The second test is considered significant if the obtained p value exceeds the alpha level after it has been divided by the (number of tests – 1). The third test involves dividing the obtained p value by the (number of tests – 2). This procedure is followed until a non significant test result is obtained.

We found that boys had higher mean scores than girls (mean ± SE, 35.3 ± 0.49 vs. 33.15 ± 0.47, n1 = 105, n2 = 109), number of minutes positively correlated with mean score of the questionnaire ($r = 0.21$) and mean scores differed between schools (Fig. 1). All these differences were significant at least at 0.05 levels. Tukey HSD post-hoc test revealed significant differences between School 2 and 3 ($p < 0.01$) and marginal difference was found between School 2 and 4 ($p = 0.06$). If the relative number of students per computer could be major predictor of differences between schools, one would expect that lowest scores (i.e. less positive attitudes) should have occurred in the School 1 (see Table 1 for student/computer values). However, as shown in Figure 1, the relative number of students per computer seems to be not the best predictor of differences between students' attitudes. We failed to find effects of age, owning home PC and student's professional orientation on students' behavioural attitudes toward ICT.

A majority of students agreed that work on a PC makes activities more effective (Items 1 (60%), 2 (70%), 34 (53%), and work with a PC makes their work more creative or interesting (Items 14 and 35 with 64 and 73 per cent agreement). In contrast, about 50 per cent of students need help when problem with their PC

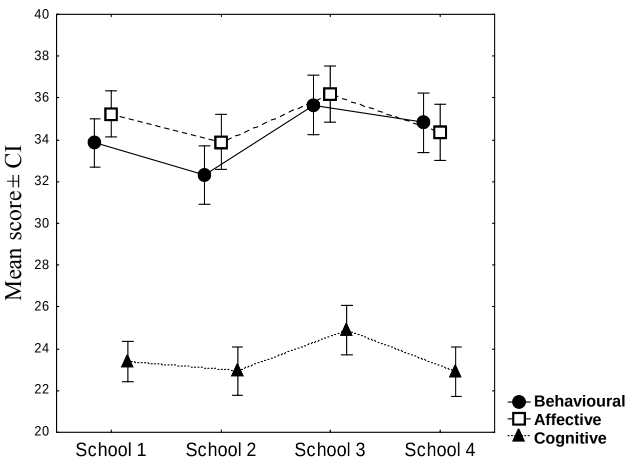

Figure 1. Distribution of attitudes toward computer use in four different schools in Slovakia.

emerges (Items 21 and 26) and little more (67 per cent) showed that they are really good when using PC (Item 33). About 77 per cent of students see benefits when using e-mail and about 65 per cent would like to use computer in biology lessons (Item 25).

Cognitive dimension

We failed to find any effects of the examined predictors on responses from the cognitive dimension. Only marginal effect of school was found ($p = 0.06$), but it also disappeared after Bonferroni adjustment. Correlation between time spend with a PC remained also non-significant ($r = 0.08$).

About 70 per cent of participants agreed that the use of computer is necessary (Item 16) and the use of e-mail allow us to learn more about different cultures (Item 12). Interestingly, the role of e-mail in elaboration of our own ideas (Item 10) and learning from each other (Item 8) was not clearly supported (about one third of participants agreed and about 40 per cent were unresolved in both cases). The majority of students (more than 70 per cent) agreed that the use of computer increased their knowledge (Item 17) in general; however, only 39 per cent of participants reported that computer help them better understand learning in the school (Item 23). Almost 80 per cent of participants would like to know more about computers (Item 31).

Affective dimension

We used the same procedure as in the previous case. Gender ($p < 0.05$) and time spend with computers showed similar tendency as in the previous case ($r = 0.145$, $p < 0.05$), but after Bonferroni corrections this significance disappeared. Other variables remained non-significant.

More than 60 per cent agreed that they very much like to use computers for communication with other people (Items 5 and 6). About half of participants said that they feel to be a part of society when using the internet (Item 11) and about 80 per cent did not feel isolated from other people when working on a computer (Item 28). About half of participants would like to spend more time with computers (Item 20), 65 percent would like to have computing as a special school subject (Item 30) and 82 per cent are happy when they can use a PC in any school subject (Item 24). About 55 per cent of participants feel good when their work is printed out (Item 3), but less than half (44 per cent) feel to be successful when using computers (Item 13). Only few participants (5 – 7 per cent) reported that they did not enjoy contact with computers (Items 15, 22, 32).

Relationships between dimensions

Total scores from all three dimensions significantly correlated with each other. These similar trends can be found in Fig. 1. All correlations were positive with Pearson's r ranged from 0.523 to 0.72 (all $p < 0.001$).

Activity with the computer use

A total of 206 out of 214 participants responded to open ended questioning related to the type of activity spent with the computer. Because several students provide more than one activity, the sum of activities exceeds 100 %. Thus we compared each activity in respect to gender and age separately.

Pooled data from all schools showed that the most frequent activity was playing computer games (64% responses), then working on the internet (27% responses), writing (26% responses) and others. We found out that boys preferred playing games whereas girls preferred writing (Figure 2). The use of internet was similar between two sexes.

We used Pearson chi-square test to examine whether activities on computers were affected by age. We found no effect of age on playing games ($\chi2 = 8.89$, df = 5, $p = 0.14$), nor writing ($\chi2 = 4.01$, df = 5, $p = 0.54$). However, marginal effect was found in the case of the use of internet ($\chi2 = 10.73$, df = 5, $p = 0.057$). Older students tended to use the internet more frequently in comparison with younger ones. Differences are shown in Fig. 3.

Students' responses toward utilization of computers questionnaire (UCQ)

Factor analysis extracted three factors (PC1 – PC3) from ten UCQ items (Table 3).

This means that the use of PCs in the school was very consistent (PC1), but the use of e-mail and information from the internet at home was quite different than the use of PC for games or MS Word. Analysis of means shown in the Table 3 confirms this finding.

Relative different usage of e-mail and information from the internet at home is probably caused by infrequent internet connectability of home PCs. While the majority of participants (119 of 145) owned a home PC, only 25 students had home internet connections. Thus, access to internet related activities at home could be considered as very limited. Students use computers at least one day per week, but its use is different between home and school. Computers at homes were used mainly for computer games, while prevalent activities in schools were related with searching for information from the internet and using e-mail. Importantly, values for computer use at schools varied from about 1.68 to 2.36 which suggest that students use computers in general about once per month.

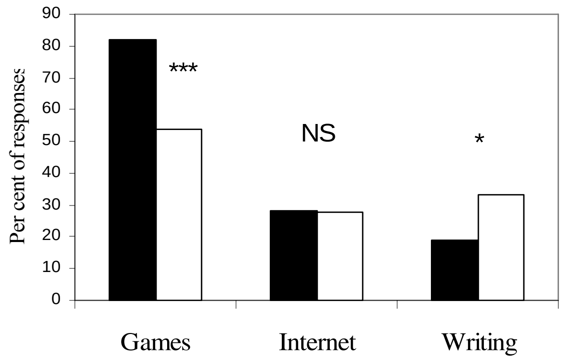

Figure 2. Responses of boys (solid bars) and girls (open bars) on their most frequent activity on computers. Differences were calculated by 2 x 2 chi-square test (* p < 0.05, *** p < 0.001).

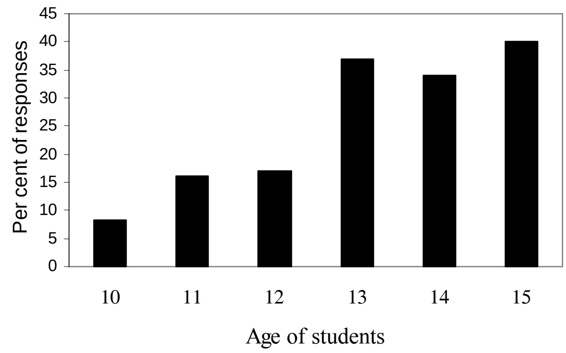

Figure 3. Age-related differences in the use of the internet.

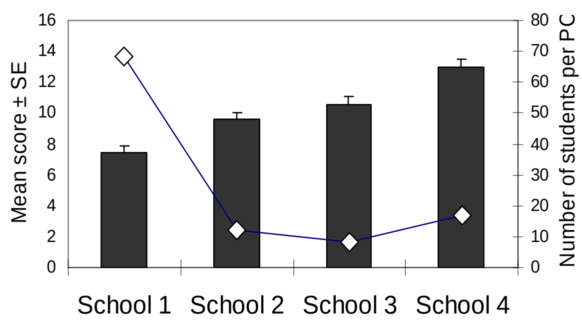

Figure 4. Responses on computer use in schools (black bars) and total number of students per computer in each school (open squares connected with a line).

Table 3. Categorization of items following factor analysis. Values lower than 0.3 not shown

		PC1	PC2	PC3	Mean score	SE
Home	PC		-0.74		2.89	0.1
	Games		-0.68		2.71	0.1
	MS Word		-0.33		1.94	0.08
	Information			0.68	1.39	0.07
	E-mail			0.79	1.26	0.05
School	PC	-0.68			2.36	0.07
	Games	-0.54			1.79	0.08
	MS Word	-0.77			1.86	0.08
	Information	-0.78			2.24	0.08
	E-mail	-0.56			1.68	0.08
	Explained variance	3.27	2.17	1.47	-	-

Table 4. The variation of computer use in four different schools when controlling the effect of age

	SS	DF	MS	F	P
Age	112.63		1112.63	14.38	0.0002
Gender	0.029		10.03	0.003	0.95
School	515.19		3171.73	21.92	0.00001
Gender × School	20.79		3 6.93	0.88	0.45
Error	1065.46		136 7.83	-	-

We did not detect any differences in the mean scores for the use of PC in the school between PC owners and non PC owners or between internet connected or non connected PCs.

Finally, we examined possible differences in computer use in schools. We used ANCOVA, where gender and school were defined as categorical predictors and age was considered as a covariate. Sum of responses from items belonging to PC1 was dependent variable. The results are shown in Table 4. The mean score increased significantly with age ($r = 0.295$, $p < 0.001$). This means that older students used computers in schools more frequently than younger ones. Regardless of the effect of age, strong differences in computer use were found between four schools (Fig. 2). Tukey post-hoc HSD test revealed that all differences (except those between School 2 and 3) were significant at least at 0.05 level. Visual analysis of Figure 4 shows that School 1 which demonstrated the highest the relative number of students per computer, the lowest frequency of computer use in the school. Thus, it seems that the relative number of students per computer significantly limited students' work with computers.

Interestingly, when we used responses of items from PC2 and PC3 (i.e. the use of home PCs) as dependent variables, gender as predictor and age as a covariate, we failed to find the effect of age ($F_{2,141} = 1.5$, $p = 0.2$), but the effect of gender was clearly significant ($F_{2,141} = 6.83$, $p = 0.001$). Boys showed higher scores in both PC2 (mean ± SE, 8.45 ± 0.33 vs. 6.78 ± 0.31) and PC3 (2.86 ± 0.17 vs. 2.48 ± 0.15) dimension.

DISCUSSION

This is the first study which reports differences among attitudes and ICT use after the implementation of ICT in Slovakia. There is great variation in the relative number of students per computer which leads to less frequent work on computers, but students' attitudes toward ICT were not affected by the mentioned variable.

The level of school computerisation between schools in Slovakia widely varies. In most countries, there are about 5 - 20 pupils per one computer, but few European countries show over 40 pupils per one computer. Our results suggest that Slovakia is one of least computerized countries.

Computer facilities are intended mainly for administrative and teaching staff. After that, they are made available to pupils. In countries in which computerisation is less widespread, pupils may generally access computer facilities in special rooms for this purpose away from the classroom, whereas in schools in countries in which computerisation has reached a more advanced stage, the computers may be located both within classrooms and outside them (in a special room offering computer facilities or multimedia library) (Key Data on Information and Communication Technology in Schools in Europe, 2004).

Attitudes

We found out that attitudes toward ICT use among schools were different; this was, however, not caused by the relative ratio student: computer per se. The effect of gender was weak, because we found significant differences only in the behavioural dimension. This is somewhat surprising, because greater differences especially in the affective dimension could be expected (Beckers & Schmidt 2001; King, Bond, & Blandford, 2002; Palaigeorgiou et al., 2005). On the other hand, no relationships between ownership of home computer, age, or students' professional orientation were found. Interestingly, the time spent with computers positively correlated only with the behavioural dimension.

In summation, we failed to find major predictors of students' attitudes toward ICT. The effect of ownership of home computer can be partly camouflaged by the low sample of students without computers. In contrast, very low numbers of students had internet connections at home. These differences with additional effects of school environments did not allow us to examine whether for example children without a home computer and limited access to computer at school have less positive attitudes toward ICT.

Computer related activities at home and at school

Low numbers of home internet connections available to children probably resulted in the shift of internet-related activities from home to school. In contrast, other activities, such as playing computer games were greatly filled at home. In contrast, weak differences were found in the use of MS Word in comparison between home and school activities (see Kent & Facer, 2004). Surprisingly, the use of computers in everyday school activities was low; generally, students used ICT approximately once per week to once per moth. Older students used ICT more frequently than younger ones. Importantly, we found that the effect of school played a very significant role in computer-related activities in schools. Our data suggest that students with great student: computer ratios have limited access to computers and their computer activities between schools strongly differ. This would lead in greater ICT compensations in out of school activities or lower ICT skills, but our data does not allow us to explain these potential effects.

Computer limitations in schools could indirectly explain differences found in the use of home computers. While boys were significantly more active in the use of home PCs, gender differences at school disappeared. In addition, the effect of age was significant only in relation to ICT in schools. Thus, we suggest that boys and girls together spend similar time with ICT at school for example in curriculum use. This is probably more accessible for older children. In this scenario, younger children in general and boys in particular cannot spend enough time with ICT at school, thus, they must compensate their time with ICT at home. Girls that are not as much interested in ICT as boys therefore spend less time with ICT at home.

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Technology in Learning: Narrowing the Gender Gap?

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The introduction of Information and Communication Technology (ICT) into the school curricula raised some hopes that it could minimize gender differences in learning. The interactive nature of ICT materials was believed to provide a favorable environment especially for girls to learn. This article reports the findings of the study that analyzed students' gender differences in learning using computers in Botswana junior secondary schools in the year 2006. Variables considered were usefulness and enjoyment of using computers in learning, anxiety in learning when using computers and interaction among students of both sexes. Data were collected using structured interviews with closed and open-ended questions, and analyzed using qualitative and quantitative techniques. The findings of the study indicated that while gender differences existed in anxiety and usefulness variables, some positive aspects in learning were visible when computers were used. At the end, suggestions on the way forward are outlined.

Keywords: Classroom Instruction, Computer Curriculum, Gender Gap, ICT.

INTRODUCTION

When ICT was introduced in schools many years ago, it was perceived as a male domain facility and boys were considered people with technological know- how, where girls were "guests" and boys "hosts" (Elkjaer, 1992 in Jones and Smart, 1993). The interactive nature of ICT materials was believed to provide the opportunity for students to analyze the process, assimilate and work independently. Such an opportunity was also believed to be useful to especially girls where some classroom practices were found to create an undesirable learning environment for girls (Kaino and Mazibuko, 2001). Calculators and computers are instruments where students could interact independently in classroom instruction. Compared to traditional classroom learning, it was assumed, calculators, computers and other forms of ICTs could offer neutral environments for both sexes in learning process. Earlier studies on the use of ICT in instruction did not consider a computer to be a neutral value, and attitudes towards information technology were claimed to be even more extreme than those towards other educational media (Anderson, 1985). If gender-related differences in attitudes toward the computer had to follow similar patterns to those established for science or math, as girls tended to associate computers with math and technology (Levine, 2006), then there would be little hope for improved attitudes toward learning among girls when computers are integrated in instruction. Some studies had already indicated that boys' attitudes towards computers were generally more positive than those of girls (Clariana & Schultz, 1993; Levine & Gordon, 1989; Sutton 1991). Also other studies had indicated that boys and girls differed in their perception of the role of computers in learning, and in their preference for different types of computer-based activities (Hall & Cooper, 1991; Sanders 1984).

Studies on students' perceptions on usefulness have been linked to participation in the subject studied. In mathematics for example, students' perceptions on usefulness were associated with activities and tasks performed in class (Meyer and Koehler, 1990). Students' perceptions on the usefulness of computers are associated with student enjoyment in using computers. Enjoyment in learning has been associated with the

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value students attributed to the subject studied. The study by Kulm (1990) indicated that students enjoyed subjects they valued. Value was associated with the subject that students performed well (Wigfield and Meece, 1998). It was beyond the scope of this study to establish whether value attributed to computer studies contributed to gender differences in enjoyment. Student usefulness and enjoyment of using computers is also associated with student anxiety when using computers. Computer anxiety has been found to differ according to age groups where for example female university undergraduates were found to be more anxious than male undergraduates (Chua, Chen & Wong 1999). An earlier study in Botswana secondary schools (grades 17 to 18) that girls had more anxiety than boys in using calculators (Kaino & Salani, 2004) is one of such related cases in the use of technology. Studies have established a correlation that students who had more anxiety in learning had less enjoyment of the subject studied (Muthelo, 2003). Anxiety in learning has been described to affect confidence among learners (Wigfield and Meece, 1988; Richardson and Suinn, 1972). Confidence was described as one of important affective factors in learning (Reyes, 1984).

Conceptual Framework

This study considered four variables, i.e. usefulness in using computers in learning, enjoyment in using computers, anxiety in learning using computers and interaction among students of both sexes in learning using computers. Two approaches of learning involving the constructivist theory of learning were considered. These were the cognitive and social constructivist theories of learning. Cognitive constructivism as developed by Piaget (1953 &1955) asserts that learners create their own knowledge through personal experiences that enabled them to create mental images in their minds. This argument has a premise that thought arises through appreciation of the significance of operations done by the learner himself/herself with materials and not from the performance of the materials themselves. Some studies have also indicated that learning was constructed through mental and physical activities (Adeyinka & Mayor, 2005; Epstein 2002) whereby the learner got direct sense impressions like touching, seeing and/or smelling. In such a process, learners were able to discover knowledge themselves.

The use of computers in this study put across the premise that knowledge could be actively constructed by the thinking of the learner and not passively received from the teacher. It also put across the notion of learner-centeredness where learners were believed to build confidence, create an anxiety-free atmosphere for learning (Pulist, 2005). The learner-centered approach was said to empower learners to take control of their learning as also they control their destiny (Muller, 1997). Furthermore, through this approach learners were provided with greater autonomy and control over the choice of subject matter, learning methods and pace of study (Gibbs, 1992). Learner-centeredness was also said to encourage individual discovery where learners evolved their own truths or understanding (Walker and Daets, 2000). In this learning process, the learners were given the opportunity to process information, solve problems and make their own decisions (Blumenfeld et al, 1991).

On the other side, social constructivism was based on specific assumptions about reality, knowledge and learning. Social constructivism emphasizes the importance of culture and context in understanding what occurs in society and constructing knowledge based on this understanding (Derry, 1999; McMahon, 1997). Social constructivists believe that reality was constructed through human activity and that members of a society together invent the properties of the world (Kukla, 2000). For the social constructivist, reality cannot be discovered: it does not exist prior to its social invention. Also to social constructivists, knowledge was a human product, and was socially and culturally constructed (Ernest, 1999; Gredler, 1997; Prat & Floden, 1994). They argue that individuals created meaning through their interactions with each other and with the environment they lived in. Social constructivists view learning as a social process that did not take place only within an individual or as a passive development of behaviors that were shaped by external forces (McMahon, 1997). It is argued that meaningful learning occurred when individuals were engaged in social activities. The use of computers in this study also had a supposition that interaction and cooperation among students of both sexes in computer classes could have a social influence on their learning process.

This study was therefore embedded in the two construct theories of learning where learners were believed to acquire knowledge not only through working independently, to discover and create their own knowledge but also through interaction with colleagues in class and cooperation among themselves in computer classes. The interactive nature of using computers tends to provide the opportunity for learners to work independently as well as in cooperate atmosphere. In particular, the opportunity for female learners to work independently as individuals as well as in groups was considered to be useful in coeducation schools where the classroom environment was described to contain undesirable climate for females to learn conducively (Kaino, 1997; Anstey 1997; Jungwirth 1997). The premise put forward by this study was whether the use of computers in instruction and the interaction of students with computers, and between students themselves could minimize the gender gap in learning.

This premise was made with knowledge of the existence of classroom gender practices among students of both sexes as well as from teachers during instruction as reported in various studies elsewhere (Kaino and Mazibuko, 2001; Kaino, 1997).

Aim of the study

The study aimed at analyzing students' gender differences in learning using Information and Communication Technology (ICT). Specifically, the study analyzed gender differences in learning using computers at form two secondary school level. The study was guided by the following research questions: (i) what were the views of students on the usefulness of computers in learning by gender? (ii) did students enjoy the use of computers in learning? (iii) did students get anxiety in learning when using computers? and (iv) what was the nature of interaction and cooperation among students of both sexes in computers lessons?

METHODOLOGY

The study employed both qualitative and quantitative techniques. Structured interviews with closed and open-ended questions were used to get information from students. Form two students (of ages between 12 and 15 years of age) were selected to represent the sample at junior level. The sample comprised 72 students from 10 junior schools (36 girls and 36 boys) selected at random from each class stream. Ten schools were selected from 9 districts in the country (one school from each district) and one school from Gaborone city. Pre-test and validation were done before main data collection. The quantitative data involving closed-ended questions was analyzed using the Statistical Package for Social Sciences (SPSS). Responses were analyzed using a 4-point Likert scale and frequencies. The Likert scale had the following weightings: Very useful (4), Useful (3), Averagely useful (2) and Not useful (1); Strongly agree (4), Agree (3), Disagree (2) and Strongly disagree (1) and Very Much (4), Much (3), Somehow and Not at all (1). Total score of responses were computed and average scores determined. The average values indicated levels of usefulness and agreement; and significances were tested at 0.01 and 0.05 levels. From the qualitative data, involving open-ended responses, individual responses were recorded. The number of similar views were noted and presented in frequencies and then transformed into percentages. The t-test method was used to determine any differences that existed between boys' and girls' responses. The t-test analysis was also done on a combined sample between two sexes to detect any differences.

FINDINGS AND ANALYSIS

Students were asked to state on the usefulness of using computers in learning by indicating the four levels of usefulness. The majority of participants (94%: 31/33 males; 100%:36/36 females) said computers were very useful. Likert scale averages (boys-3.46 and girls-3.6) also indicated that students of both sexes considered computers to be useful in learning though girls' average was higher than those of boys. While more girls than boys indicated that computers were useful, the differences were not significant at 0.05 levels.

Students' reasons why computers were useful

Students who indicated that using computers in learning was useful were asked to state their reasons why they agreed. The views, which were open-ended, were analyzed and categorized into six types for boys and into seven for girls as shown in Table 1 below.

Many boys (about 36%) said computers were useful in searching for jobs while about 31% of girls said were useful for internet access. About 28% of girls also said computers were useful in searching for jobs. The t-test on similar views did not show any significance difference between boys and girls at 0.05 (0.50<0.59). Dominant views from both girls and boys indicated that computers were useful in search for jobs, Internet, access to information and knowledge.

Students' enjoyment of using computers in learning

Students were asked to indicate the level of enjoyment in learning when using computers. The 4-point Likert scale was used and responses were recorded in frequencies and then computed into percentages. Most students (86%:29/34 males, 84%:30/36 females) indicated that they enjoyed using computers in learning. On the average, many students of both sexes enjoyed computers and the analysis showed no significant differences of enjoyment among sexes at 0.05 levels. Some reasons were sought from girls who said did not at all enjoy learning using computers. The reasons were given as " I hate computer classes (2), "I do not know much about computers (1), and "The teacher is the one who does almost everything (1).

Students' anxiety in using computers

To determine student anxiety in using computers, students were asked to state whether they were comfortable and when they encountered the state of 'confusion" when using computers.

Table 1. Students' reasons why computers were useful

Boys		Girls	
Reasons	**Percentage/number**	**Reasons**	**Percentage/number**
Helpful in job search	30.6% (11)	Provide access to Internet	27.8% (10)
Provide accurate information	16.7% (6)	Helpful in job search	25% (9)
Fast in communication	13.9% (5)	Using computers is added knowledge	16.7%(6)
Helpful in doing assignments and research	8.3% (3)	Provide accurate information	5.6%(2)
Using computers is added knowledge	8.3% (3)	Fast in communication	5.6%(2)
Provide access to Internet	8.3% (3)	Useful for typing and printing pictures	5.6%(2)
No response	13.9%(5)	Provide accurate answers	2.8%(1)
		No response	11.1% (4)

Table 2. Boys' and Girls' reasons why they felt girls preferred to work alone

Boys		Girls	
Reasons	**Percentage/number**	**Reasons**	**Percentage/number**
They are shy	2.8%(1)	Cultural Influence	2.8%(1)
They feel they can work better alone	5.6%(2)	No idea	2.8%(1)
Girls are afraid of boys	2.8%(1)	They feel they Know everything	2.8%(1)
Cultural Influence	2.8%(1)	They feel superior	5.6%(2)
No idea	2.8%(1)	They don't follow instructions	5.6%(2)
They feel they know everything	8.3%(3)		
They feel superior	8.3%(3)		

Students' comfort in using computers

While many boys and girls in junior schools were comfortable with the use of computers, many students (76%: 25/33 males, 50%):18/36 females) were very comfortable. Three girls who said were "much" uncomfortable gave the reasons as "Because I haven't learnt much about computers" (1), "Sometimes I don't know what to press" (1) and "The teacher is fast " (1). The differences in comfort among the two sexes were not significant at 0.05 levels.

Students' worries in learning using computers

More boys (61%: 22/36 males) than girls (33%:12/36 females) were not worried when using computers in learning. A small number of girls of who indicated much worries said, " learning with computers was difficult (3)", "there were many buttons and instructions to follow (1)" and " I am dealing with something am not sure of (1)". The reasons for boys who also indicated much worries were "little knowledge in computers (5)", "many instructions (1)" and "feeling that am not doing something right (1)". The differences among the two sexes were not significant at 0.05 levels.

Students' interaction in computer classes

Students were interviewed to seek information on how they cooperated and interacted among themselves in computer classes. In order to gather information on how boys and girls interacted in computer classes, information was sought to know whether both sexes worked together during computer lessons. Many girls (80%: 27/34) than boys (67%: 24/36) disagreed that boys preferred to work alone during computer lessons, indicating that few girls (20%) than boys (33%) were of the view that boys did not cooperate in computer classes. These views showed difference among the two sexes where more boys felt girls did not cooperate. Reasons were sought from 7 girls who said boys preferred to work alone and from 12 boys who said girls preferred to work alone, Tables 2(a) and 2(b). While both girls and boys gave different reasons, some similar views were noted. These were:" boys' feelings of superiority", "boys' claims of knowing everything" and "cultural influences". The differences noted were not significant at 0.05 levels.

DISCUSSION

The general view by many students that they found learning using computers to be useful was a positive sign towards the use of technology in instruction. Some differences that put girls above average on usefulness were not significant. However, differences emerged on reasons why computers were usefulness where many boys found computers to be useful in searching for jobs, whereas many girls found them useful in internet access without mentioning reasons for access. Students of both sexes did not indicate the usefulness in particular contents of the study and a small percentage indicated usefulness in accuracy of answers and information. At the time of conducting the study, students (in form two) were expected to have covered knowledge in basic computer skills that involved keyboard skills, creating new documents and editing; word process and spreadsheet. The syllabus used at this level looked more general in design and reflected the responses of students who could not specify the usefulness in particular content areas of study. However, students' views that computers were useful could be considered as an appreciation to the use of technology in instruction. An earlier study in a number of schools in Botswana showed that students did not consider the use of calculators to be useful in learning (Kaino and Salani, 2004). Such a finding could be regarded as a setback at the time when traditional ways of instruction were to be innovated and improved to cope with current developments in technology.

The finding that girls had more anxiety in learning than boys concurred with some other researchers elsewhere though in some studies different findings have been documented in grades 7 to 11 where girls were less anxious than boys (King, Bond & Blandford, 2002). A deeper study on computer anxiety would be useful to establish whether anxiety was caused during computer classes or was a pre-existing computer anxiety as found in a study by Gaudron & Vignoli, (2002). It could also be found out whether anxiety was related to computer literacy and experience (Beckers & Schimidt, 2001; Bozionelos, 2001), the components that were not studied by this research. Also the findings of this study that there were good interaction and cooperation among students indicated a conducive atmosphere of learning between both sexes. Some studies have reported undesirable classroom environment for females to learn (Kaino, 1997; Anstey 1997; Jungwirth 1997). However, a deeper analysis was required to study interaction in instruction. Many studies have also indicated that the teacher was instrumental in creating conducive classroom setting for constructive learning and in providing a learning environment that was stimulating and orderly all the time (Cheng, 1993; Fraser, 1986). It was thus important to find out further whether teachers had an influence in a good cooperation atmosphere that was found between boys and girls in computer classrooms.

Concluding Remarks

Learning using computers was found useful by most students of both sexes and some differences on reasons of usefulness were consistent with other studies elsewhere on gender disparities. However, the nature of the computer curriculum used at this level of schooling, might had an influence on the usefulness of computers in learning. Boys' enjoyment in learning using computers with less or no anxiety than girls was also consistent with findings by other researchers. Anxiety found by this study among girls could not be related to enjoyment in learning using computers. Though gender differences were noted in anxiety and some differences on reasons for usefulness, there were indications that students had the opportunity to work independently to explore and discover knowledge. At the same time, students had the opportunity to work together, in a classroom environment they were comfortable with. It was therefore plausible that some aspects of the two constructs of learning, i.e. cognitive and social constructs were visible in instruction though further studies for deeper understanding are recommended. While the findings of this study could not be generalized to reflect gender attitudes in all schools in the country, it was felt that attention should be drawn to the following for further study: (i) the nature of computer studies curriculum that targeted particular content areas where learners could identify as useful, and (ii) teaching using computers that involved particular activities and exercises (from identified content areas) that could motivate students especially girls to feel comfortable in learning and enjoy computer lessons without anxiety.

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Lithuanian University Students' Knowledge of Biotechnology and Their Attitudes to the Taught Subject

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The impact of genetic engineering on peoples' everyday life has become present reality. In order to establish the level of the available schoolchildren and university students' knowledge of biotechnology, various investigations have been conducted. However, the current situation in Lithuania remains unclear. A total of 287 students - pre-service teachers from Lithuanian universities participated in the survey focused on attitudes to and knowledge of biotechnology. Our results confirmed the conclusions reached in other countries: students' knowledge of biotechnology is very miserable and attitudes frequently contradict one another. Research results clearly show the necessity for the increase and development of teacher training in the field of biotechnology and point to the ability to obtain and apply knowledge at international level in work practice. Research confirmed the opinion that the history and principles of developing biotechnologies as well as a legal and institutional system of using biotechnologies in Lithuania and the European Union needed to be more exhaustively introduced to all students.

Keywords: Science Education, Biotechnology, Attitudes, University Students.

INTRODUCTION

In recent times, the problems of science and technological education are given increased attention. One of these unique educational fields is knowledge of biotechnology and students' attitudes towards this subject[1]. It is supposed the impact of the latter area on people's everyday life is steadily growing (Lappan, 2000). Society accepts some technologies as controversial tools causing certain risks (Fischoff, Slovic, Lichtenstein, 1978). On the other hand, biotechnologies are deeper penetrating into public life wider using their potentialities. The Bulletin of the European Communities (2007) underlines that the sciences of animate nature and biotechnology are rapidly progressing fields making a direct impact on business and politicians in Europe. These two areas are getting more and more important and publicly acknowledged. Modern biotechnologies are also accepted as one of the major fields of the development of high technologies.

Modern biotechnology includes different types of technologies related to animate organisms or their products used in the food and medicine industry and helps with cultivating plants and animals, forming organisms for specific use and improving human health and local surrounding. However, biotechnology is an

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old and strongly developed branch of science. Since the ancient times, flora and fauna have been selectively bred whereas micro organisms have been used to make such products as bread, cheese, wine and beer. Some of the archaeologists' findings can be dated 5000 BC. Modern biotechnology based on recombinant DNA or hybridoma technology (technology for producing specific antibodies) is applied for manufacturing new food and formation products and assists in solving environmental problems. Therefore, biotechnology covers a few fields including agriculture, industry, environment and pharmacology (Biotechnologijos apžvalga, 2008).

The term 'biotechnology' was first used by the Hungarian engineer Karl Ereki in 1917. He described the process of breeding pigs applying the industrial method the basis of which was using sugar beets. The scientist referred to biotechnology as to the process of work when products were produced from material using animate organisms. The European scientists agree that biotechnology is a science that employs different fields of science to stimulate technological processes (biochemistry, microbiology, genetics and chemistry) supported by the structures of microbiological and mammalian cells (Biotechnologijos Lietuvoje, 2008).

Biotechnologies are present and future reality. It is worth emphasizing that due to genetically modified organisms (GMO), the world seems to be divided into two separate groups – the ones who support the idea of a further development of biotechnologies (for instance, such powerful international corporations and business establishments as MONSANTO, BASF etc.) and those who oppose this position (for instance, movement Gene Protection Initiative; the majority of the EU countries impose a limit on genetical modifications in order to change the use of the organisms). The foregoing idea is supported by undertaking as biotechnologies are definitively a profitable (relatively useful) area. The opposing side states that the impact of biotechnologies on nature still needs more investigation, for example, GMO impact on nature and human in general is not clear enough. Brazauskienė (2007) accepts there is no doubt that supporters' vigilance and responsibility are thrown into the shade by a strong interest and expected profit whereas the opponents rely on students' honesty, objective attitude and a deep feeling of obligation. Consequently, society's informativeness must be appropriate and objective. Some of the countries try to restrict the use of GMO. For instance, since 2 February 2006, Greece, Austria and Poland have been countries free from GMO. (http://gmolt.wordpress.com/zonos-be-gmo/). Even Romania, which is one of the most opened countries to genetically modified (GM) plants, pushes forward the idea of changing its position (http://gmolt.wordpress.com/2008/04/09/rumunija-permasto-savo-pozicija-del-genetiskai-modifikuotu-augalu/). The above mentioned facts only confirm the conclusion that GMO are not in demand in Europe.

Though Raney and Pingali (2007) approve biotechnologies and believe they are absolutely necessary in the modern world as 'genetically modified plants can help with overcoming poverty and famine, nevertheless, a new green revolution must consider and follow barely satisfied requirements'. The article argues that the present-day man must be well informed, inquisitive, concerned, responsible and critically thinking in order to properly apply the latest biotechnologies and do not cause any harm neither to him/herself nor to other people or the environment s/he lives in. To find out secondary school learners and university students' (Barman, 1980; Dawson, et. al. 2003) varying positions on biotechnology, a large number of research have been carried out in different foreign countries (Sterling, Halbrendt, Kitto, 1993; Macer, Azariah, Srinives, 2000; Prokop, Leškova, Kubiatko, Diran, 2007; Bal, Keskin Samancý, Bozkurt, 2007).

It should be stressed that when discussing the problems of biotechnology, Lithuanian general education is not out of question. For example, General Primary Education Programmes for Lithuanian Comprehensive School (2007) present the goal of science education and point out that to achieve it '…students take an interest in the development of sciences and technologies in Lithuania and abroad and are involved in acknowledging the priority trends towards the development of sciences and technologies at national level…' The supposed Development of Students' Abilities describes the 9th and 10th - formers abilities to 'reasonably evaluate modern biotechnologies (cloning, use of genetically modified organisms, biological fuel etc.); characterize the process of developing genetically modified food products and with reference to the examples given, rationally discuss the qualities and possible dangers of these products; on the basis of the patterns of using microorganisms in biotechnology, explain the importance of the variety of these organisms.' The new document puts emphasis on the attitude to critically evaluate the use of biotechnologies. The guidelines on science education of forms 5, 6, 7 and 8 also suggest how to develop students' understanding of biotechnologies. For example, the guidelines on education of forms 5 and 6 indicate that 'when examining the benefit of achievements in sciences for humankind, it is essential to remember defining the impact of accomplishments on the social and natural environment and to show how the new technologies frequently bring not only progress but also cause social and ecological problems'. Analogically, the same situation is reflected in the guidelines on sciences of forms 7 and 8. For instance, 'an evaluation of the impact of science and technologies on human being, society and environment frequently reveals a contradictory situation'. It should be acknowledged that the prior General Programmes (1997, 2004) narrowly focused on learners' understanding of biotechnologies and their abilities to adopt personal attitudes (Lietuvos bendrojo lavinimo mokyklos...., 2007).

More than a year ago (2007-05-17), the conference 'Biotechnology in Lithuanian Universities' organized by the Commission of Biotechnology under Lithuanian Academy of Sciences and UAB Sicor Biotech was held in Lithuania. Although the representatives of Lithuanian universities discussed the situation of biotechnology in the establishments of higher education, the condition and future prospects of fundamental / applied research and possible collaboration between science and undertaking institutions, however, the questions of education were not considered. The issues of educating the young generation at university level almost were not examined. There is no doubt biotechnology is really the field of the future the significance and impact of which will gain more weight. Bumelis supposes that biotechnologies are very attractive fields of science, and therefore a student finds them as a completely new stage of gaining knowledge (Bumelis, 2004). Thus, to sum up, further in-depth research is necessary in order to convey an adequate knowledge of biotechnology and to form positive and right attitudes to biotechnology.

The object of research is the attitudes to and knowledge of biotechnology of the students studying pedagogical curricula in higher schools. The goal of research is to establish students' attitudes to biotechnology and the level of the available knowledge of biotechnology.

METHOD

General Characteristics of Research

Research was carried out in January-February, 2008. A total of 287 students (77.7% female (N=223) and 22. 3% male (N=64)) from two universities training pre-service teachers participated in the survey.

Table 1. Respondents' distribution considering the year of studies

Year of studies	N	%
First	118	41.1
Second	69	24.0
Third	73	25.4
Fourth	27	9.4
Total	287	100.0

The table shows that in the majority of cases, the first year students participated in the survey whereas the fourth year students were the least active. 137 (47.7%) respondents study biology, the rest of those (150 / 52.3%) have chosen the curricula of other profile including pedagogy of primary education, pre-school and primary school education, pedagogy of physical education and sport etc.

The students from Vilnius Pedagogical University study sciences and biology. Though no clear marking exists, the students of sciences are trained for work with 5th and 6th form children in basic school since the pre-service teachers of biology are prepared for work in the higher forms. However, the pre-service teachers of sciences have a broader view on sciences and its cohesion. It can be maintained that the studies of biology students are deeper while on the contrary the curricula of the students dealing with sciences are broader. The students studying social sciences counting educology (pedagogy of primary education) and psychology were also involved in research. The educologists study an integrated course on nature, geography and history along with didactics of world study while psychologists certainly examine human biology and zoopsychology. The respondents from the Department of Educology represented the University of Siauliai where the curricula of other subjects rather than natural sciences are implemented. Only a few of the modules such as 'a holistic conception of natural phenomena' reflect the field of sciences.

It is likely that the 1st year students of biology study the course on general biology which mainly does not approach the topics of biotechnology. It can also be stated that the students of the further courses have more knowledge of biotechnology. Therefore, it is essential to compare the attitudes of the latter two groups to biotechnology presuming that their statistical significance should be wide. The respondents aged from 18 to 29 (average age is 20.41 / SD = 1.45) took part in research.

Instruments and Statistical Analysis

An interval Likert scale (Prokop, Leškova, Kubiatko, Diran, 2007) made of 37 statements was applied to analyze the attitudes and a similar scale containing 16 statements was used to examine knowledge of biotechnology. Thus, the instrument of research was compiled from 53 statements. Each of those was evaluated from 1 (strongly disagree) to 5 (fully agree). Number 3 indicated a neutral position. The list of the statements is presented in the tables below. The statistical averages of each of the statements were calculated. The false/negatively worded items were scored in reverse order. To fix statistical deviations, the Student-t criterion for unrelated samples was chosen.

RESEARCH RESULTS

Respondents' Knowledge of Biotechnology

The following arrangement of the assessed students' evaluations was made (Table 2). The table displays evaluations considering each of the statements. The assessed respondents' answers preliminary confirm the hypothesis that students' knowledge of biotechnology is poor.

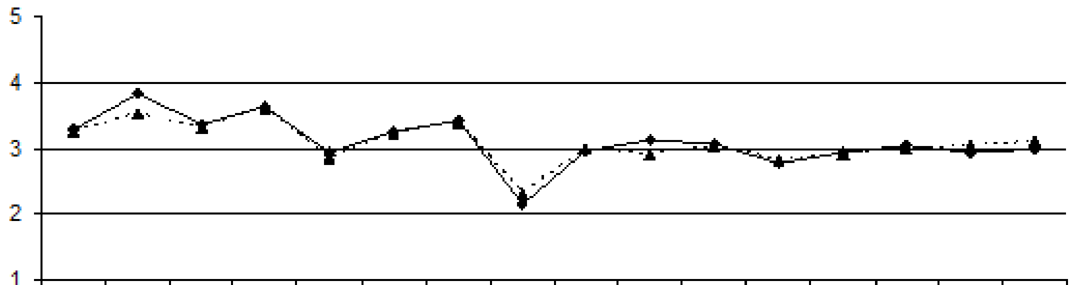
In order to improve the quality of food, extensive investigations into GM food products are conducted. For example, the increase of the quantity of vitamins A and E in food products can help with reducing the number of certain diseases. Experiments on raising the quality of proteins in vegetal products, decreasing the number of allergens in milk and grains etc. are conducted. The obtained findings reveal that the respondents mainly do not know the situation as the average of the answers to Statement 8 makes 2, 23 (the respondents principally disagree with the statement that foods with increased nutritional value and vitamins can be created through genetic modification). In terms of Statements 5, 9 and 16, the respondents had no position which shows a notable lack of knowledge about biotechnology. The respondents agreed on Statements 1, 2, 3, 4 and 7. Averages deviate from 3, 27 to 3, 67. It can be maintained that in the majority of cases, the respondents are not certain about their available information. Those having at least rudimentary knowledge certainly should accept the first four statements as in reality, practical application of GM plants may increase productivity and resistance of plants against diseases, GM organisms are used in medicine etc. The respondents in the main suffer from shortage of knowledge of whether genetical modification is painful for animals.

A comparison of knowledge of the respondents studying biology and other subjects was made (Table 2, Figure 1). The graphical chart clearly shows that none of the statements was fully supported or strongly objected by the surveyed participants.

The chart indicates that both the students of biology and those studying other subjects have no understanding of whether genetical modifications are painful for animals. Apart from Statement 2, the rest were almost equally answered by all respondents i.e. the parametrical Student-t criterion did not establish any statistically significant deviations between two groups of the respondents – the students of biology ant those studying other subjects. An interesting situation can be observed discussing Statement 2 which is Manipulation with DNA changes genes of GM organisms. It seems to be typical that in this case, statistically significant deviations between two groups of the respondents can be noticed. Knowledge of the students of biology about manipulations with DNA is slightly better than those of other respondents ($t=2{,}765$, $df=285$, $p=0{,}006$). A presumption that such situation can be determined by a deeper knowledge of the students of biology in the field of general biology is acceptable.

Table 2 presents the results considering each of the statements. A comparison of the results obtained in both groups of the respondents was drawn.

Although in respect of other statements (except Statement 2), knowledge of the students in both groups do not substantially differ, however, some points are worth paying attention. For example, Statement 12 focuses on transferring genetic material between dissimilar organisms. Nevertheless, information on the ability of microorganisms to transfer genetic material to other organisms and cause plant, animal and human diseases is introduced in the middle of the course on biology in the curriculum of secondary comprehensive school. It could be admitted that the students of the humanities and social sciences feel lack of such



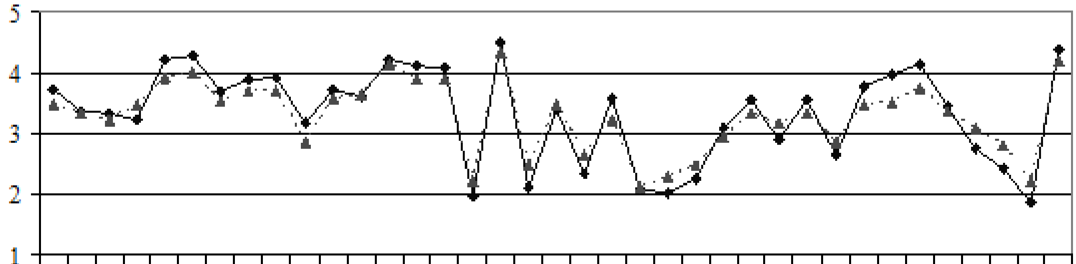
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Biology	3,29	3,82	3,38	3,63	2,94	3,27	3,43	2,15	2,96	3,11	3,07	2,77	2,92	3,04	2,92	2,99
Non-Majors	3,25	3,53	3,32	3,61	2,84	3,22	3,39	2,31	3	2,9	3,05	2,81	2,91	3	3,03	3,09

* Numbers from 1 to 16 in the Figure are the numbers of the statements shown in Table 2.

Figure 1. Comparison of the respondents' knowledge of biotechnology in both groups.

Table 2. Comparative characteristics of knowledge of biotechnology in both students' groups

Statements	Biology		Non-Majors	
	X	SD	X	SD
1. Practical application of GM plants may increase productivity and resistance of plants against diseases.	3.29	1.16	3.25	1.16
2. Manipulation with DNA changes genes of GM organisms.	3.82	0.84	3.53	0.93
3. Application of GM methods on animals can increase animal resistance against diseases.	3.38	1.07	3.32	1.01
4. GM organisms are used in medicine (e.g. insulin production with GM microorganisms).	3.63	1.00	3.61	0.83
5. Genetical modification is painful for animals.	2.94	1.05	2.84	0.86
6. GM organisms contain many dangerous chemicals.	3.27	1.04	3.22	1.07
7. Genetical modification to plants can increase nutritional quality and flavour of fruits and develops traits to withstand shipping process.	3.43	1.19	3.39	1.25
8. Foods with increasing nutritional value and vitamins can be created through genetic modification.	2.15	1.01	2.31	1.09
9. Microbes should be genetically engineered to make them more efficient at decomposing human sewage.	2.96	1.11	3.00	0.88
10. Consumption of GM food can destroy human genes.	3.11	1.12	2.90	1.13
11. GM organisms are always bigger than normal.	3.07	1.03	3.05	1.14
12. It is possible to transfer genetic material between dissimilar organisms, such as animals and plants, because DNA is chemically identical.	2.77	0.98	2.81	0.87
13. GM modification of poultry results in greater proportion of lean.	2.92	0.86	2.91	0.91
14. Porcine somatotropin is a hormone active in hogs that directs dietary energy away from fat disposition toward production of lean muscle.	3.04	0.74	3.00	0.65
15. GM crops are sterile.	2.92	0.92	3.03	0.94
16. Recombinant bovine somatotropin is an animal drug that increases milk produced by dairy cows.	2.99	0.85	3.09	0.77



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Biology	3,7	3,4	3,3	3,2	4,2	4,3	3,7	3,9	3,9	3,2	3,7	3,6	4,2	4,1	4,1	2	4,5	2,1	3,4	2,3	3,6	2,1	2	2,3	3,1	3,6	2,9	3,6	2,6	3,8	4	4,2	3,5	2,8	2,4	1,9	4,4
Non-Majors	3,5	3,3	3,2	3,5	3,9	4	3,5	3,7	3,7	2,9	3,6	3,7	4,1	3,9	3,9	2,2	4,3	2,5	3,5	2,6	3,2	2,1	2,3	2,5	3	3,3	3,2	3,3	2,9	3,5	3,5	3,8	3,4	3,1	2,8	2,2	4,2

Figure 2. Comparison of the respondents' attitudes to biotechnology in both groups.

knowledge; however, the students of biology definitely should have before-mentioned information even though they do not attend a special course on biotechnology as the data of this kind is analyzed during the classical courses on genetics, microbiology etc. at university level. Statement 15 indicates a similar situation as the students of biology should know that the majority of modified plants are sterile i.e. cannot be reproduced and interbred. In fact, the respondents fail to know that somatotropin is not a drug but growth hormone that increases growing all textures and bones and has a strong impact on mobilization of sebum.

Thus, an assessment of the respondents' answers discloses that knowledge of biotechnology of the students in both groups does not largely differ.

Table 3. Comparative characteristics of attitudes to biotechnology in both students' groups

Statements	Biology		Non-Majors		t-statistics
	X	SD	X	SD	
1. I am opposed to transfer of genetic material between plants and animals.	3.72	1.14	3.47	1.06	
2. Manipulations with DNA are unethical.	3.35	1.15	3.34	1.08	
3. Men do not have rights to intervene to DNA, it is against nature.	3.33	1.26	3.23	1.19	
4. I agree with use of cloning for saving of endangered species.	3.22	1.38	3.47	1.30	
5. Use of genetic modification to change plants should be strictly regulated.	4.23	0.82	3.91	1.04	t=2.872, p=0.004
6. Use of genetic modification to change animals should be strictly regulated.	4.29	0.87	4.01	0.99	t=2.526, p=0.012
7. Altering the genes in fruit to improve their taste is not acceptable to me.	3.70	1.17	3.54	1.14	
8. I am against altering the genes of fruits and vegetables to make them stay fresh longer.	3.89	1.12	3.69	1.24	
9. Consumption of genetically modified food is risky.	3.93	0.96	3.70	0.96	
10. Use of GM microbes to decomposing human sewage is acceptable to me.	3.16	1.15	2.86	0.96	t=2.414, p=0.016
11. I support the use of genetic engineering for non food purposes such as production of human medicines.	3.73	1.11	3.59	1.20	
12. I agree with production of insuline with using genetically modified microbes.	3.60	1.04	3.65	0.89	
13. Nobody know what genetic engineering will bring in the future.	4.23	0.90	4.14	0.95	
14. I would not give GM food to children.	4.12	1.02	3.89	1.01	
15. I agree with the use of genetic engineering if it helps with therapy of genetically determined diseases.	4.07	0.92	3.89	0.87	
16. Genetically modified food does not influence human health.	1.96	0.94	2.23	1.01	t=-2.343, p=0.020
17. Universal labelling of genetically engineered foods should be required.	4.50	0.88	4.34	0.87	
18. I would eat genetically modified tomatoes.	2.12	1.03	2.46	1.09	t=-2.735, p=0.007
19. Genetically modified food contains dangerous chemicals.	3.38	0.99	3.47	0.90	
20. I think that genetically modified products taste better.	2.34	1.06	2.64	1.04	t=-2.396, p=0.017
21. During shopping I am interested whether the product is made from genetically modified stuff.	3.58	1.19	3.21	1.11	t=2.721, p=0.007
22. If I find that the product is made from genetically modified stuff, I will buy it.	2.09	1.01	2.12	0.89	
23. Inserting genes from human cells into the fertilized eggs of sheep is acceptable to me.	2.03	1.09	2.27	1.07	
24. I support changing the genes in cattle to make their meat more nutritious to eat.	2.26	1.13	2.47	1.09	
25. Using genetically engineered sheep to produce medicines for humans is not acceptable to me.	3.09	1.19	2.95	1.07	
26. I support the use of food biotechnology to modify plant' genetic structure to be more resistant to damage by insects, thereby reducing pesticide applications.	3.56	1.14	3.32	0.94	
27. Altering the genes of plants so that they will grow better in salty soils is acceptable to me.	2.89	1.08	3.16	0.99	t=-2.210, p=0.028
28. We should not alter the genes in plants to get them to make more oils useful in manufacturing.	3.56	1.11	3.33	0.92	
29. I agree with the use of plants in which genes increasing quality and productivity were inserted.	2.63	1.16	2.85	1.05	
30. Genetic manipulations disturb ecological relationships.	3.77	1.01	3.46	0.99	t=2.598, p=0.010
31. There is a threat of hybridization between genetically modified and normal plants which would endanger original genetic resources of wild plants.	3.97	0.85	3.50	0.95	t=4.402, p=0.000

Table 3. Continued

Statements	Biology		Non-Majors		t-statistics
	X	SD	X	SD	
32. Genetically modified plants can displace original plants in natural habitats.	4.15	0.95	3.76	0.95	t=3.490, p=0.001
33. I would support a ban on the production and purchase of genetically engineered products.	3.45	1.19	3.35	1.08	
34. I trust the food industry to take necessary actions to provide safe genetically engineered foods.	2.76	1.17	3.07	0.93	t=-2.528, p=0.012
35. I think current governmental regulations are sufficient to protect the public from risks associated with genetically engineered foods.	2.42	1.03	2.81	0.93	t=-3.364, p=0.001
36. Public is sufficiently informed about risks associated with genetically engineered foods.	1.87	0.98	2.23	0.94	t=-3.160, p=0.002
37. I want to know more about genetically engineered foods.	4.39	0.83	4.20	0.91	

Respondents' Attitudes to Biotechnology

The following distribution of the assessed respondents' evaluations is given below (Table 3, Figure 2). An assessment of the distribution shows that none of the statements is fully supported by the respondents. All surveyed participants mainly do not agree with Statements 16, 18, 20, 22, 23, 24 and 36 i.e. in terms of genetically modified food, the respondents' attitudes are negative. They think that such food does not taste better and would be tend not to buy if found it genetically modified. All respondents disagree on the statement that public is sufficiently informed about risks associated with genetically engineered foods. The students are inclined to agree on the first 15 statements except from Number 10 as they believe that manipulations with DNA are unethical and it still remains unclear what genetic engineering will bring in the future. The respondents should try to protect children from genetically modified food. They accept the idea that universal labelling of genetically engineered foods should be required. Without regard to the curriculum of studies, all surveyed participants would like to know more about genetically engineered foods.

The attitudes of the students of biology and those studying other subjects were individually compared (Table 3, Figure 2). A chart clearly indicates that none of the statements was fully supported or strongly objected by the surveyed participants.

Table 3 shows the results in view of each of the statements. The obtained results in both respondents' groups were compared.

The attitudes of the respondents in both groups principally agree. 14 of the 37 attitudes statistically differ. The statistical-t criterion for unrelated samples established deviations under the some statements when $p<0.05$ and df=285.

An evaluation of the use of genetic modification to change plants and animals shows that the students of biology are more demanding than those studying other subjects. However, both groups suppose that the situation should be strictly regulated. In terms of the use of genetically modified microbes to decompose human sewage, the respondents took a neutral position. Nevertheless, the students of biology rather than their colleagues dealing with other subjects are less biased in favour of the latter statement. Both sides believe that genetically modified food influence human health but in this case, the students of biology are more critical. They are also deeper interested during shopping whether the product is made from genetically modified stuff. The students of biology rather than the rest agree that genetic manipulations disturb ecological relationships and that there is a threat of hybridization between genetically modified and normal plants which can endanger original genetic resources of wild plants. Supposedly, similar differences can be influenced by a deeper knowledge in the field of the students of biology who disagree on the statement that public is sufficiently informed about risks associated with genetically engineered foods. In terms of the latter statement, other students support a more neutral position. Accordingly, the pre-service teachers of biology rather than other students are tending to think that the food industry fails to take necessary actions to provide safe genetically engineered foods.

DISCUSSION

The development of biotechnologies should definitely change society's position on this field of science. Due to insufficient and often inadequate information, the public has a wrong opinion about this area. In the context of society, the question of morality becomes a burning issue, especially discussing genetic engineering, cloning etc. It can be maintained that biotechnology as any of innovations in science is mainly neither a good nor a bad idea because everything depends on how achievements in this field of science are applied in practice. In this case, a crucial point is that society should have an adequate knowledge in this area and form appropriate attitudes.

Different international investigations point to a poor knowledge of biotechnology. R. Lock and C. Miles (1993) questioned 188 students and found out that one third of the sample, and more males then females, did not know what biotechnology or genetic engineering was, and nearly half the sample could not give examples of either biotechnology or genetic engineering. A similar situation occurred in Taiwan and the United Kingdom between 17 – 18 years old respondents - in both countries 50 per cent of students were able to give examples of biotechnology and about 60 per cent were able to give examples of genetic engineering (Shao-Yen Chen, Raffan, 1999). On the other hand, the learners find knowledge of biotechnology interesting and significant if the field is properly introduced (Dori, Tal, Tsaushu, 2003). Some of research showed that the interest of students in biotechnology and genetic engineering develops at an age of about 16 (Todt, Gotz, 1998). At this stage, the learners are more interested in moral-ethical questions rather than in a real knowledge of biotechnology. Our investigation only confirmed the statement on the links between knowledge and attitudes – poor wrong knowledge has an appropriate impact on forming the wrong attitudes. The fact is approved by the previous research conducted in different countries (Jallinoja, Aro, 2000; Prokop, Leškova, Kubiatko, Diran, 2007).

The results of the passers-by questioned in the street should probably be similar to those received during student survey and introduced in this article. Literacy of the latter respondents on this issue should be insufficient. It is likely, that a phobic point of view on the use of biotechnologies should prevail: 'what will happen if …', 'no idea what will be created in the future', 'will they manage to control genetical processes' etc.

Similarly to students' research, two levels of understanding should probably become evident: one is formed only looking to the future i.e. biotechnologies used in food, medicine etc. have a direct impact on human life (for example, medicines, disease prevention … will receive a more favourable evaluation. How to understand a similar situation? Does it mean that of the two evils is chosen the lesser?); the second is an indirect one, for example, biotechnologies applied for run-off cleaning. Although the latter topic is also globally important, however, it is less intriguing. The same kinds of biotechnologies are not strictly evaluated. Despite the fact that it is a shortsighted attitude, such position exists. Lack of qualified scientific analysis and interpretation in the field of education forms a wrong attitude to the above mentioned problem.

The Post Soviet World faces another problem. Along with the process of creating and developing legal basis, numerous examples of ignoring laws exist (for instance, disorder in marking food products). Practice shows that people in Lithuania improperly examine the labels on the products. The expiration date of a product is the major part consumers are frequently focused on.

Biotechnologies are not properly introduced to society. The articles in the daily papers often include rumours as scientific periodicals are read by a small amount of readers. Nevertheless, research indicates that the larger part of the respondents would like to get more information on biotechnology.

Thus, what are the steps to be followed?

- Biotechnologies should be more exhaustively discussed in the final classes of secondary school. Communication between scientists and teachers is very important at this stage of education.
- Biotechnologies as a subject of studies could be examined not only in the curricula of natural but also in social sciences. For example, the module *A Holistic Conception of Natural and Social Phenomena* taught at the University of Siauliai is included in all curricula of studies as a general course which minimally covers and discusses the questions of biotechnologies.
- The methods of active teaching/learning could provoke discussions and help with developing critical thinking. A purposeful idea is arranging meetings between learners and experts working in the field of biotechnologies. Training students at modern level is impossible without the integration of educational institutions with research and scientific-production organizations. Close cooperation with research centres allows students to gain practical experience of work, to become acquainted with the latest scientific achievements, to participate in fulfilling real scientific and technical developments, to prepare term and degree works in actual research areas (Troshkova, Karabintseva, 2007).
- A valid point is an extensive use of TV, radio and the Internet disclosing information on the questions of biotechnologies to society.
- Knowledge improvement should not be the only purpose. A proper understanding of usefulness, risks and drawbacks occurring in this field of study is extremely important to the students of comprehensive schools and universities.

CONCLUSIONS

A conclusion of the carried out research reveals that:

- knowledge of biotechnology of the students studying pedagogical curricula at university level is poor, contradictory and frequently unfairly treated;

- 9 of the 16 presented statements have not been validly answered by the students who made an attempt to give an answer only to 7 statements i.e. to agree or disagree on the statement given;
- no statistically significant deviations between the students of biology and those studying other subjects (not related to biology) have been established. It is supposed that the available information in the field is largely based on general education rather than on knowledge gained in university. However, knowledge of the students is rather limited. It is likely that the curricula of biology sharply focus on classical rather than on modern fields of biology.
- the surveyed participants have a position on the question dealing with biotechnology (position 3 - no opinion - was chosen to answer one fourth of the statements given) and agree that a part of those have a dramatic impact on the environment;
- all respondents acknowledge that society is not sufficiently informed about the risks related to genetically modified organisms and engineered food products. Food manufacturers, mass media and politicians must properly concentrate on these burning issues;
- certain deviations in the attitudes of biology students and of those studying other subjects can be noticed. The students of biology surely have more knowledge of biotechnology which determines their attitudes to the subject.

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Promoting Inquiry Through Science Reflective Journal Writing

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The purpose of this research paper is to detail how reflective journal writing can be used to facilitate science students' curiosity and engagement in laboratory work. This study advocates reflective journal writing as an instructional tool and a student-created learning resource that can serve additional formative assessment purposes. The researchers tracked a single teacher and his class over a period of five weeks and documented the changes that occurred when reflective journal writing was used to supplement the teaching and learning of specific curriculum items (the usage of scientific equipment and the particulate nature of matter). Findings presented show that the number and quality of students' questions rose over time. While the number of research studies carried out with inquiry as the focus is plentiful, this paper outlines a generative strategy to enhance questioning which constitutes the essential first step in any inquiry process for any particular science content area.

Keywords: Reflective Journal Writing, Inquiry Science, Questioning, Formative Assessment

INTRODUCTION

One of the distinctive characteristics of inquiring learners is their ability to use questioning techniques as they reflect in and on their actions (cf. Chin, 2004). Reflection is a cognitive activity that involves, but is not restricted to, capturing, mulling over and evaluating experiences (Boud, Keogh, & Walker, 1985), looking backwards and projecting forward to the future (Jarvis, 1987) and stepping back from what one is doing in order to achieve some measure of perspective (Ellis, 2001). Yet, while it is important to acknowledge the role reflective thinking can play in the development of 'thinking people' (Dewey, 1933) it is vital for teachers to note two things: the heart of all learning lies in the way students process their experiences, critically, and reflective learning involves recalling from experiences and reasoning out how these connect to present and future 'learning' situations (Kolb, 1984). On these bases, we maintain that reflection can play a key part in promoting inquiry in middle-level science students' learning. We also believe that engagement in reflective activity can be a driving force in bringing about positive changes in laboratories especially in the areas of teacher-student interactions and in breaking away from the notion, where it exists, that scientific facts are absolute or unquestionable truths.

There has been an abundance of, and great enthusiasm for, research activities relating to inquiry science methods over the last decade. Learning science is no longer regarded as remembering the facts of science but should also include the the inculcation of the practice of science among learners. Rather than learning about science, science education is about learning to be scientists. In other words, the goal should be developing skills, attitudes, and knowledge of how scientists do science (Barab & Hay, 2001; Fusco & Barton, 2001). What this implies is that, school science should emulate authentic practices such that students assume the agency of knowledge constructors and interact with phenomena in informed, reflective, and

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critical ways (Rodgriguez, 1998). As such, inquiry science examines the need to allow students to improve their ideas as they encounter new and conflicting evidence (Harlen, 2004). This is similar to activities carried out by working scientists.

Science inquiry is incorporated as part of the science curriculum in many school districts in the United States and notably in all schools in Singapore (CPDD, 2007). According to the National Science Education Standards (NRC, 1996), doing scientific inquiry includes (1) identifying and asking questions; (2) designing and conducting experiments; (3) analyzing data and evidence; (4) using models and explanations and finally (5) communicating findings. When students are equipped with the abilities of scientific inquiry and understandings of scientific inquiry, they will be better prepared to learn the content in science. One of the core abilities identified here is identifying and asking questions and this is the specific skill which we aimed to develop through science reflective journal writing.

To facilitate science students' curiosity and engagement in laboratory work, reflective journal writing can be used as an instructional tool and student-created learning resource that has formative assessment benefits especially in terms of self-assessment (Black & Wiliam, 1998). Reflective journal writing also allows students to identify and record their attitudes and beliefs. It provides an avenue for giving expression to doubts and frustrations about science itself and about learning science. However, it is important to note that reflective writing is not appealing to all. In some contexts, inexperienced or unskilled journal writers have difficulty finding things to write. This point highlights the need for teachers to guide their students in writing regular journal entries. The following section details how this can be done.

PROCEDURE

A small-scale study was conducted with a class of grade 7 girls from an average school, which is partially funded by the government in Singapore. The class, which was noted for its reticence and deference to sources of authoritative knowledge, was involved in learning two units of work in general science: using laboratory equipment (e.g., lighting the Bunsen burner) and the particulate nature of matter. A willing and experienced male chemistry teacher, working in collaboration with academics from a local research center, issued each student with a small notebook measuring approximately 9cm x 14cm. The students, who were of average academic ability and generally reluctant to ask questions openly in class for fear of losing face, were instructed to write their name, class and the title, 'Science Reflective Journal' (SRJ) on the front cover of the notebook. Subsequently, at the end of each lesson or laboratory lesson for a period of half a term (5 weeks), the teacher gave the students five minutes to write their reflections in their SRJ. As the practice of writing science journals was new to the students, the teacher provided three broad headings for their entries:

1. Questions I have about today's lesson
2. Something I have learned today
3. Some thought-provoking incident in class today

At the end of each week, the SRJs were collected and a research assistant compiled the entries on behalf of the teacher. Each entry was read, counted and categorized. A word-processed file containing all of the students' comments was prepared and returned to the teacher for his information and consideration. The SRJs were returned to the students in time for use in the week to come.

The researchers' field notes showed that the teacher was very adept at weaving his responses to the points raised in the SRJs into his regular lesson content without revealing any particular student-author identities. In order not to discourage inquiry, questions that went beyond immediate curriculum matters were not ignored. Instead, every point raised had the potential to lead to a useful learning opportunity. Some questions were answered directly in class but other issues were 'thrown back' to the learners and they were encouraged to source for their own answers in groups outside of class time. To scaffold these extra-curricula investigations, the teacher suggested possible sources of information including the Internet, journals and local libraries. The learners were also encouraged to involve their parents and/or other adults in their follow-up work. The flow chart below (Figure 1) summarizes the process of using the SRJs in study classroom.

OUTCOMES

In this section, we present evidence to show the impact of keeping science reflective journals on the students' abilities to ask questions. At the beginning of the study period, the teacher's topics were laboratory safety, the use of laboratory apparatus and the role of science in society. The specific instructional objectives for the first week's work were as follows:

- Observe laboratory rules at all times in the science laboratories;
- Know the symbols representing different hazardous substances;
- Use the Bunsen burner;

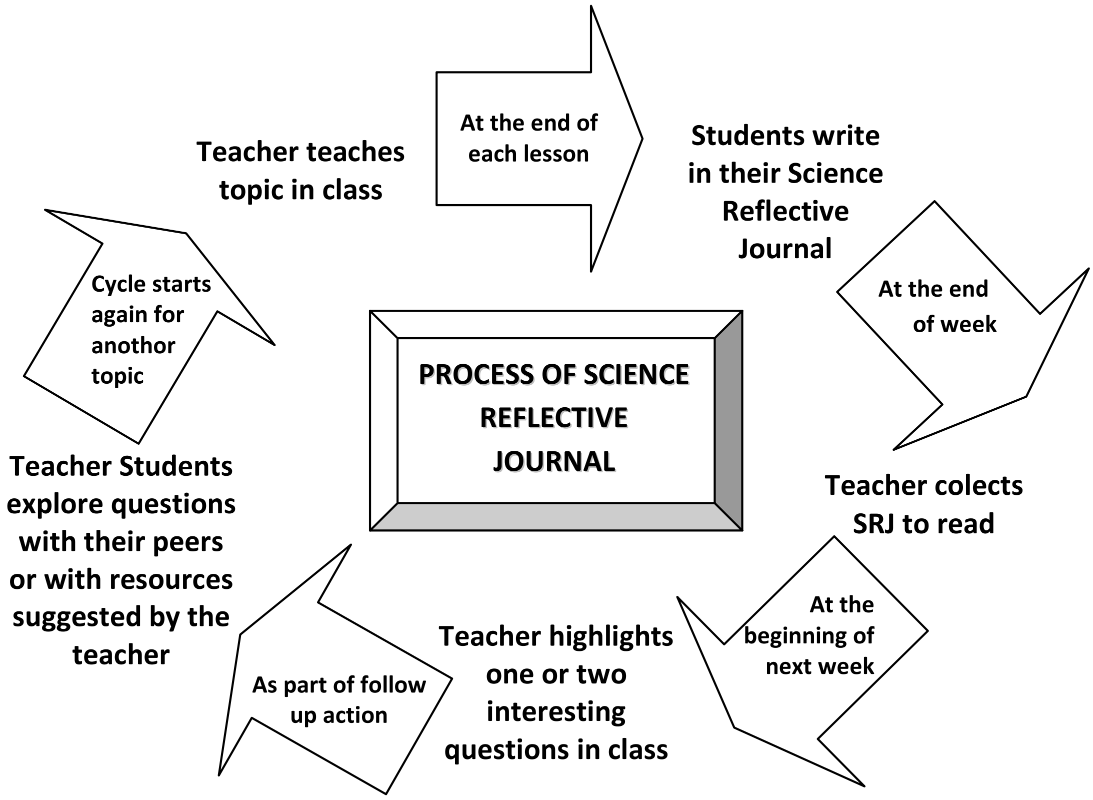

Figure 1. Process of Science Reflective Journal Writing

- Discuss the uses and benefits of science and technology to society;
- Develop an awareness of the limitations of science and technology in solving societal problems; and
- Develop sensitivity to the benefits and abuses of the applications of science.

The students' SRJ entries were largely factual and superficial, although in the instance of the question about biological hazards, there is a positive sign that the student was attempting to connect the world of science in the classroom to her out-of-school life experiences (the numbers in parentheses denote the number of entries along similar lines).

Science Reflective Journal Entries (Week 1, unedited)

1. *Questions I have about today's lesson*
   a. What are basic thinking skills? (2)
   b. How biological hazard does happens? Can it kill? I saw the radioactive sign on a truck? Why is it on the truck?
   c. What is a nuclear reactor?
   d. What are elements?
2. *Something I have learned today*
   a. Benefits of science (19)
   b. Abuses of science (18)
   c. Safety rules in the laboratory (22)
   d. Science process skills such as thinking skills (17)
   e. Signs and symbols (10)
   f. Limitations of science (8)
   g. Safety rules when heating or mixing chemicals, e.g., Point mouth of test tube away from yourself and friends when heating chemicals, Do not place flammable substances near any source of heat, always use test tube holder when heating a test tube (6)
   h. Scientific method of doing experiments (5)
   i. Attitudes of learning science (16)
   j. Science process skills such as define a problem, ask questions, suggest a possible hypothesis, design experiment to test hypothesis, make observations and measurements, communicate the results effectively, interpret the results and draw a conclusion (3)
   k. When experimental results support the hypothesis, it turns to a theory (2)
   l. Different ways of answering questions
3. *Some thought-provoking incident in class today*
   a. We must abide by safety rules to ensure our safety
   b. The abuses and usage of science is interesting as they have been seen in movies but I did not know that they were used in real life
   c. Attitudes are very important in the learning of science
   d. Results in an experiment may not support a hypothesis

e. I know more about the abuses of Science and how some people use their knowledge of Science to harm others. I find the people using drugs, bombs, and viruses to harm or kill to others, very cruel. Even though people are getting smarter, they are more abuses.

The student's question about whether radioactive substances can kill (1b) related directly to the instructional objectives of the uses and benefits of science and technology to society; the limitations of science and technology in solving societal problems and understanding benefits and abuses of the applications of science. This question could possibly serve as a platform for further inquiry-based activities and investigations to be carried out.

After a couple of weeks, the class progressed onto the topic of the particulate nature of matter. The instructional objectives for this topic were:

- Show an awareness that matter is made up of small discrete particles which are in constant and random motion;
- Show an understanding of the simple model of solids, liquids and gases, in terms of the arrangement and movement of the particles; and
- Distinguish among the three states of matter – solid, liquid and gas using the particle models.

It can be seen that by week four, the students' questions and comments became bolder and more adventurous. Features entries from the students' SRJs showing the development of critical, multi-faceted, inquiring scientific minds.

Science Reflective Journal Entries (Weeks 4 and 5, unedited)

1. *Questions I have about today's lesson*
   a. If we put a solid material or a liquid under a microscope, can we see these particles or are they just imaginary?
   b. If particles are present in all matter and they can vibrate, how come we cannot feel the vibration when we touch the matter?
   c. Why is it when we put chemicals like iron into the non-luminous flame, it will change the color?
   d. What is the chemical that causes the flame to change color?
   e. The solid iron can turn into liquid iron if heated to a high temperature. Is it because the particles in liquid can be packed closer than a solid at a high temperature and bombard it?
   f. How is it possible that liquids can taste like acids?
2. *Something I have learned today*
   a. Solid, liquid and gas particles (9)
   b. Reasons for the definite or indefinite shape and volume of solid, liquid and gas (18)
   c. Different colors of flames (16)
   d. Different kinds of chemicals can make non-luminous flame change color (22)
   e. Different way of lighting the Bunsen burner (7)
   f. How to draw models of particles (6)
3. *Some thought-provoking incident in class today*
   a. The burning of powder is used in fireworks
   b. I must be very careful in my observations during laboratory tests
   c. I have learnt to light the Bunsen burner properly and it helped me overcome my fear of fire
   d. I like the luminous flame because when it's dancing it looks beautiful

As can be seen from the questions recorded in Weeks 4 and 5, there is some evidence of complex thinking about the particulate nature of matter. For example, in questions 1a, 1b and 1e, the students considered what they saw (materials versus molecules) and felt (stationary materials versus the vibrations of particles) and made connections between their daily experiences and scientific kinetic theory. Thus, there is support for the claim that the instructional objectives of ensuring that students show an awareness that matter is made up of small discrete particles which are in constant and random motion and also to show an understanding of the simple model of solids, liquids and gases, in terms of the arrangement and movement of the particles were achieved. That said, the SRJ entries also signal that there is scope for a deeper exploration of the kinetic theory as it relates to the topic at hand.

The points raised in question 1e indicated that the student in question was aware of the three states of matter – solid, liquid and gas using the particle models. However, this question also revealed a lack of conceptual understanding of how the model can actually be used to explain phenomena observed in everyday circumstances. This issue could be used as a primer for students to explore alternative ways of explaining the melting of iron at high temperature to better appreciate the completeness and complexity of the particle model.

EVALUATIONS AND IMPLICATIONS

The SRJ exercise provided a channel of communication between the teacher and students involved and there is promising evidence to suggest that its purposes were recognized and valued. In particular, the students' writing allowed for issues to be dealt with by the teacher in the classroom, which may not have surfaced, at all, through any other means. The journals helped the students view the learning of science as an on-going process whereby they stopped at regular intervals to think about what they were doing. The journals also helped the students hone their laboratory skills in two specific ways: (i) they kept records of their experiences, and (ii) they practiced analyzing by thinking about the questions they wanted to ask in relation to their laboratory experiences. These are benefits which can be derived for any science content area using the procedure outlined in Figure 1.

If students can be facilitated in formulating questions about their laboratory learning in writing, there are equally encouraging signs that they can also be assisted in conducting dialogic exchanges with their teacher and peers in classroom interactions. For example, here is an extract from a classroom exchange between the chemistry teacher and the class on another task shortly after the SRJ exercise which demonstrates an interesting transfer effect.

Teacher [to class] Have you finished?

Student 1: I want to ask you the meaning of *constituency*.

Student 2: That means the elements that make up the thing.

Student 3: What thing?

Student 2: The compound or mixture … constituency is the elements that make up either the compound or the mixture.

Student 5 [with hand raised persistently] Mixtures are not chemically mixed, eh, joined together, then how are they joined together?

Teacher: … instead of by chemical means, by physical means. Like when you just pour it into a container and stir it up—that's physical mixing. If there's a chemical reaction, then that's a chemical means.

Mid-level science students have many questions to ask and comments to make about their laboratory learning experiences but may (as is the case in Singapore) fear making mistakes or feel more at ease answering the teacher's questions directly. Given sufficient teacher support and a willingness to respond to students' inquiries, SRJ writing, we argue, can be the foundation for a less intimidating questioning culture in science laboratory learning – one of the essential features of inquiry science. SRJs also have the potential to inform teachers of how students think as they learn science and this can be an invaluable source of information for formative assessment purposes. Overall, the SRJ exercise raised the visibility of students' thoughts in science and helped reduce assumptions made by the teacher about his students' abilities. It also increased the accuracy of the teacher's decision-making in lesson planning and implementation as a crucial result.

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Reform-Based Curriculum and Motivation in Geometry

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The aim of this study was to compare motivation of sixth-grade students engaged in instruction using reform-based curriculum with sixth-grade students engaged in instruction using a traditional curriculum. There were 273 sixth- grade mathematics students, 123 in the control group and 150 in the treatment group, involved in the study. This study took place in North Florida. The researchers used a questionnaire, the Course Interest Survey (CIS), administered to the students before and after a five-week of instruction. The paired-samples t-test, the independent-samples t-test, and ANCOVA with $\alpha = 0.05$ were used to analyze the quantitative data. The study showed that there was a statistically significant difference in motivation between the groups favoring the treatment group. In other words, the reform-based curricula designed on the basis of van Hiele theory, compared to a traditional one, had more positive effects on students' overall motivation in learning geometry at the sixth grade level.

Keywords: Curriculum, Motivation, Reform, Middle School, Geometry

INTRODUCTION

Over the past few decades, researchers have documented that many students encounter difficulties and show poor performance in geometry classrooms in both middle and high schools (e.g., Burger & Shaughnessy, 1986; Crowley, 1987; Fuys, Geddes, & Tischler, 1988; Gutierrez, Jaime, & Fortuny, 1991; Mason, 1997; Halat, 2007). Moreover, research shows a decline in students' motivation toward mathematics courses (c.f., Gottfried, Fleming & Gottfried, 2001). Indeed, Ryan & Pintrich (1997), Keller (1998) and Dev (1998) stated that there is a positive correlation between students' performance and motivation in mathematics.

The longitudinal study of Gottfried et al. (2001) indicated that academic intrinsic motivation declined significantly from middle school through late adolescence in mathematics. Results of the Third International Mathematics and Science Study (TIMSS) in both 1995 and 1999 clearly exemplify a general decline in academic performance between fourth and eighth graders. Both TIMSS studies revealed that the US fourth graders' achievements in mathematics were at the top level among students from 38 countries that participated in the study. However, US eighth-grade students did not show the same level of success as fourth-grade students. Their mathematics performances were at the average level. A decline in the performance of the US students in mathematics between fourth and eighth grades is evident. According to Billstein & Williamson (2003), "declines in positive attitudes toward mathematics are common among students in the middle school years" (p.281). It is important to know what

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causes students' low performances in mathematics at the middle school level.

Variables Affecting Students' Motivation

Research has documented that there are many internal and external factors, such as feeling valued, perception of cognitive competence, benefits and threats from peers and teachers, perception of parents' support, perception of success, fear of punishment, environment, task difficulty, real-life activities, instruction, and gender that appear to play prominent roles in students' motivation in mathematics classes (e.g., Reeve, 1986; Driscoll, 1994; Wentzel, 1997/1998; Stipek, 1998; Middleton, 1999; Alderman, 1999; Halat, 2006). For instance, Middleton & Spanis (1999) state that students' perception of success in mathematics has a great effect on students' motivational attitudes. Wentzel (1998) posits that parents' support, peers' help and teachers' care are vital factors playing important roles in students' learning. However, Stipek (1998) claims that teachers have more influence on students' motivation in learning mathematics than parents do because of the fact that students spend most of their times in the schools. In addition, students who felt supported and valued by their teachers are willing to engage in classroom activities and highly motivated to be successful in the mathematics class (Wentzel, 1997).

According to Usiskin (1982), many students fail to grasp key concepts in geometry, and leave the geometry classes without learning basic terminology. He says that systematic geometry instruction might help students gain greater geometry knowledge and proof writing success. Burger & Shaughnessy (1986) claim that sequencing instruction has positive impacts on students' achievement and feelings about self, the topic, and skills. If initial activities are frustrating and not interesting, students might not be motivated to learn what the teacher is trying to teach them. At the same time, if the activities are too easy, they might not attract students' attention to the topic and might fail to generate a sense of success. The tasks in instruction should contain respectable challenges that students can achieve (Hoffer, 1986; Messick & Reynolds, 1992).

Messick & Reynolds (1992) state that the students in any given classes may show variation in interests, capabilities, and intelligences. In response to this variation, the instructors should show different ways for students to succeed based on their learning styles. Furthermore, carefully structured instructional design including clear and meaningful task activities and level of difficulty have a great impact on students' achievement and motivation in mathematics, Stipek (1998) and Middleton & Spanis (1999).

The Van Hiele Theory

Knowledge of theoretical principles provides an opportunity to devise practices that have a greater possibility of success. The van Hiele model of thinking that was structured and developed by Pierre van Hiele and Dina van Hiele-Geldof between 1957 and 1986 focuses on geometry. The van Hieles described five levels of reasoning in geometry. These levels are level-I (Visualization), level-II (Analysis), level-III (Ordering), level-IV (Deduction), and level-V (Rigor). Studies (e.g., Mayberry, 1983; van Hiele, 1986) have proposed that movement from one level to the next level includes five phases: information, bound (guided) orientation, explicitation, free orientation, and integration. Today, this model is a foundation for several geometry curricula implemented in mathematics classrooms. Research since the early 1980s has helped to confirm the validity of the theory (e.g., Usiskin, 1982; Mayberry, 1983; Fuys, Geddes, & Tischler, 1988).

Research has been completed on various components of this teaching and learning model. Wirszup (1976) reported the first study of the van Hiele theory, which attracted educators' attention at that time in the United States. In 1981, Hoffer worked on the description of the levels. Usiskin (1982) affirmed the validity of the existence of the first four levels in geometry at the high school level. In 1986, Burger and Shaughnessy focused on the characteristics of the van Hiele levels of development in geometry. Fuys, Geddes, and Tischler (1988) examined the effects of instruction on a student's predominant van Hiele level. In other words, several researchers (e.g. Usiskin (1982), Mayberry (1983), and Burger & Shaughnessy (1986)) confirmed the validity of the levels and investigated students' behavior on tasks. Others (Usiskin (1982), Senk (1989), Gutierrez, Jaime, & Fortuny (1991), Mason (1997), and Gutierrez & Jaime (1998) evaluated and assessed the geometric ability of students as a function of van Hiele levels. Moreover, there have been some studies with pre-service elementary and secondary mathematics teachers regarding their reasoning stages in geometry (e.g., Mayberry, 1983). Surprisingly, these studies have found that many of the prospective mathematics teachers do not attain an appropriate level of geometry knowledge they are expected to teach.

Purpose of the Study

The aim of this current study was to compare motivation of sixth - grade students engaged in instruction using a reform-based curriculum with sixth-grade students engaged in instruction using a traditional curriculum. This study addresses "the need . . . for classroom teachers and researchers to refine the phases of learning, develop van Hiele theory based materials, and implement those materials and philosophies in the classroom setting" (Crowley, 1987, p.15). The instruction following the reform-based curriculum designed on the basis of van Hiele theory used the textbooks *Shapes and Designs* (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1996); and *Discovering Geometry: An Inductive Approach* (Serra, 1997). The comparative group's instruction used *Middle School Math Course I* (Charles, Dossey, Leinwand, Seeley, & Embse, 1998). The following question guided the study.

Question: What differences, if any, exist with respect to motivation between students instructed with a reform-based curriculum and students instructed with a conventional one in geometry?

The researchers agree with the recommendation of NCTM (2000) that educational theories and approaches be used in teaching and learning to help students overcome their difficulties in mathematics. In addition, knowledge of theoretical principles gives teachers an opportunity to devise practices that have a greater possibility of success (e.g., Swafford, Jones, & Thornton, 1997). Furthermore, standards-based curricula have positive influences on students' performance and motivation in mathematics (e.g., Billstein & Williamson, 2003; Chapell, 2003).

Definitions

Van Hiele Theory-based curriculum was a geometry curriculum in which the authors designed teaching materials based on educational theories, in particular the van Hiele theory. The implementation of this theory in geometry classrooms was recommended by the NCTM (2000).

Traditional curriculum was a regular mathematics curriculum in which the authors did not implement the characteristics of the van Hiele theory in their presentation of geometry.

METHODOLOGY

Methods of Inquiry

In the study the procedure of quasi-experimental design was used. With this design technique, the researchers had a control group to compare with the experimental group, but participants were not randomly selected and assigned to the groups (Creswell, 1994; McMillan, 2000). According to Creswell (1994), the nonequivalent (Pretest and Posttest) control group design model is a popular approach to quasi-experiments. In this design model "the experimental Group A and the control Group B are selected without random assignment. Both groups take a pretest and posttest, and only the experimental group receives the treatment" (Creswell, 1994, p.132).

The researchers chose the experimental research method because "it provides the best approach to investigating cause-and-effect relationships" (McMillan, 2000, p.207). In the study pre-and-posttests were given to the students before and after the instruction. The researchers investigated the effects of an instruction using a reform-based curriculum on students' motivation in learning polygons in geometry. The comparison of students' motivational levels was made. Therefore, this experimental approach enabled the researchers to evaluate the effectiveness of an instruction that uses the reform-based curriculum with the results of a questionnaire in mathematics classroom.

Participants

In this study the researchers followed the "convenience" sampling procedure defined by McMillan (2000), where a group of participants is selected because of availability. Participants in the study were sixth-grade students enrolled in twelve mathematics classes at two public middle schools in Florida. The researchers chose these two schools based on their curriculum practices and permissions of the schools' principals. One of the schools was following a reform-based curriculum, and the other one was not using a reform-based curriculum in their geometry teaching. There were a total of 273 sixth- grade mathematics students, 123 in the control group and 150 in the treatment group, involved in the study. The majority of the students in both schools were from families of low socio-economic class. Almost 80 percent of the students involved in the study were eligible for the federal free or reduced-price lunch program as reported by the state. This percentage is considered to be a major indication of the students' family income level.

Data Sources

The data collection process began with giving students a questionnaire, *Course Interest Survey (CIS)*. This questionnaire used as pre-and-posttests in the study was administered to the participants during a single class period by the researchers before and after the five-week instruction period. The questionnaire *Course Interest Survey (CIS)* consists of 34 statements categorized into four parts, Attention, Relevance, Confidence and Satisfaction. Using a liker-type rating scale including statements, some positive and some negative, relating to the attitude being measured, this questionnaire was administered for 15 minutes. The CIS was taken from the study of Keller (1999) by his oral permission. The course interest survey is designed to evaluate a situational measure of students' motivation in a specific classroom setting. The goal with this instrument is to investigate how students are motivated, or expected to be, by a particular setting. Reliability estimates of CIS were obtained by using Cronbach's alpha measure for each subscale. They were: Attention: .84, Confidence: .81, Relevance: .84, Satisfaction: .88, Total Scale: .95. In the study, students in both groups met for an hour of instruction in a day for five days a week.

Instructional Curricula

The instruction following the reform-based materials used a curriculum designed on the basis of van Hiele theory. This curriculum used the textbook *Shapes and Designs* and *Discovering Geometry: An Inductive Approach* in which authors wrote their materials based on the first three van Hiele levels (Level-I: Recognition, Level-II: Analysis, and Level-III: Order). The instruction not following reform-based materials used the textbook *Middle School Math Course I* that also covers material at the first three van Hiele levels.

Topics in both curricula consisted of polygons, such as triangles and quadrilaterals, properties of the figures, angle relations and transformation and tessellation.

There were four mathematics teachers involved in the study, all of whom were females. Both mathematics teachers in the treatment group attended the Connected Mathematics Project's (CMP) training programs. They both implemented the CMP's instructional model: "launch, explore and summarize" in their teaching that is problem-centered teaching opens the mathematics classroom to exploring, conjecturing, reasoning, and communicating.

This model of instruction involves three main phases. In the *launch* phase the teacher introduces the problem to the class. The teacher makes sure that students understand the problem and are engaged in it. It is important that problems be interesting and make connections with earlier concepts in mathematics or with past experiences of students. It is also an opportunity for the teacher to introduce a new idea.

In the *explore* phase students work on the task individually, in small groups or occasionally as a whole class. The students work on the problem by searching for patterns, gathering data, trying special cases, making conjectures, and exchanging ideas; and the teacher moves around the classroom, observing students' work and offering help as appropriate. The teacher provides encouragement and confirmation to on-track behavior, and may ask guiding questions and offer redirections when needed. He or she may also offer additional challenges for those students who quickly solve the problem or may not find it challenging enough.

The *summarize* phase begins when most students make sufficient progress towards a solution to the problem. Students discuss their solutions and share their strategies they used to reach a solution. They will appreciate other approaches to the problem, and can see ways to enhance their own strategies. The teacher also offers guidance and suggestions for a deeper understanding of the concepts and more effective and efficient problem solving strategies (e.g., Lappan, Fey, Fitzgerald, Friel, & Phillips, 1996; Reys, Reys, Lappan, Holliday, & Wasman, 2003).

One of these teachers had 15 and the other had 4 years of teaching experience. On the other hand, the mathematics teachers in the control group followed the traditional way of teaching. In other words, the mathematics teachers told the students facts, demonstrated procedures, showed how to solve the problems and then students memorized the facts and practiced the procedures. One of these teachers had 14 and the other had 5 years of teaching experience.

Test Scoring

The Course Interest Survey (CIS) Scoring Guide: The response scale ranges from 1 to 5. According to this scale, the minimum score is 34 on the 34-item survey, and the maximum is 170 with the midpoint of 102. The minimums, maximums, and midpoints vary for each subscale because the numbers of item distributions are not the same, as shown below. Keller (1999) also gives an alternative scoring method to find the average score for each subscale and the total scale instead of using sums. For each respondent, divide the total score on a given scale by the number of items in that scale. This converts the totals into a score ranging from 1 to 5 and makes it easier to compare performance on each of the subscales. He noted, "Scores are determined by summing the responses for each subscale and the total scale. Please note that the items marked reverse are stated in a negative manner. The responses have to be reversed before they can be added into the response total. That is, for these items, 5=1, 4=2, 3=3, 2=4, and 1=5."(p. A-41). Attention consists of 8 items, 1,4 (reverse), 10, 15, 21, 24, 26 (reverse), and 29. Confidence consists of 8 items, 3, 6 (reverse), 9, 11 (reverse), 17 (reverse), 27, 30, and 34. Relevance consists of 9 items, 2, 5, 8 (reverse), 13, 20, 22, 23, 25 (reverse), and 28. Satisfaction consists of 9 items, 7(reverse), 12, 14, 16, 18, 19, 31(reverse), 32, and 33.

Analysis of Data

The data were responses from students' answer sheets. First the researchers run the independent-samples t-test statistical procedure with $\alpha = .05$ on the students' pretest scores to see if there exist any initial differences on students' motivation levels between the two groups. The t-test procedure showed mean score differences between the two groups favoring the control group on students' motivation. Then, scores from the questionnaire (CIS) were compared using one-way analysis of covariance (ANCOVA) with $\alpha = 0.05$, which is a variation of ANOVA. The ANCOVA was used to adjust for pretest differences that exist between control and treatment groups. In other words, because of the initial differences in students' motivational levels between the two groups, ANCOVA was employed to analyze the quantitative data in the study. The pretest motivation scores from the Course Interest Survey served as the covariate in the motivation analysis by curricula. ANCOVA enabled the researchers to see the results of comparisons of CIS scores.

Furthermore, the paired-samples t-test with $\alpha = 0.05$ was used to detect the mean differences between pre- and posttest scores of students in each group separately based on the questionnaire. The paired-samples t- test procedure compares the means of two variables for a single group. It computes the differences between values of the two variables for each case. This also helped the researchers see the effects of each curriculum on students' motivation for each group.

RESULT

Question: What differences, if any, exist with respect to motivation between students instructed with a reform-based curriculum and students instructed with a conventional one in geometry?

Table 1 presents the descriptive statistics and the paired-samples t-test for students' motivation based on the CIS scores by the curricula in both the treatment and control groups, and shows that there is a gain in overall motivation of students for both groups. According to the paired -samples t-test (Table 1), the mean score differences in terms of motivation between the pre-and posttests on the CIS in the treatment group is statistically significant, [$p < .001$, significant at the $\alpha/2 = .025$ using critical value of $t_{\alpha/2} = -1.960$], and the mean score differences in motivation between the pre-and posttests on the CIS in the control group is also statistically significant, [$p < .025$, significant at the $\alpha/2 = .025$ using critical value of $t_{\alpha/2} = -1.960$]. In other words, both curricula, whether reform-based or not, positively impacted students' motivation in the study.

Table 2, however, displays the analysis of covariance (ANCOVA) for both groups with regard to students' motivation, and is based on the Course Interest Survey. It shows that a significant main effect for students' motivation toward a reform-based curriculum was obtained, [$F(1, 272) = 5.660$; $p < .05$]. Furthermore, Table 1 indicates that students instructed with a reform-

Table 1. Descriptive Statistics and the Paired-Samples T-Test for Students' Motivation Based on the CIS Scores by Curricula

Groups	N	Pretest		Posttest			Posttest*	
		M	SD	M	SD	t	M	SE
Treatment	150	119.81	15.3	129.53	14.0	-11.738**	132.042[a]	.7
Control	123	127.48	17.6	132.32	16.3	-5.034**	129.257[a]	.8
Total	273							

Note. a: Evaluated at covariates appeared in the model: Pre-motivation =123.26, *Estimated Marginal Means, CIS: Course Interest Survey. ** $p < .001$, significant at the $\alpha/2 = .025$ using critical value of $t\alpha/2 = -1.960$.

Table 2. Summary of ANCOVA for Students' Motivation Based on the CIS Scores by Curricula

Sources	Sum of Squares	df	Mean Square	F-statistic
Pretest	38450.674	1	38450.674	437.800
Group	497.139	1	497.139	5.660

Note. $\alpha = .05$, $p < .05$, CIS: Course Interest Survey.

Table 3. Frequency Table for Students' overall Motivation Based on the CIS Scores by Curricula

Groups	N		Low*		Average**		High***	
			n	%	n	%	n	%
Treatment	150	Pre-motivation	15	10	104	69.3	31	20.7
		Post-motivation	1	0.7	92	61.3	57	38
Control	123	Pre-motivation	12	9.8	59	48	52	42.2
		Post-motivation	4	3.2	58	47.2	60	48.6

Note. * CIS scores in the range of 34 -101, ** CIS scores in the range of 102-135, *** CIS scores in the range of 136-170. CIS: Course Interest Survey, n is the number of students in the selected group.

based curriculum outscored the ones who were instructed with a traditional curriculum in geometry, [the mean score of the treatment group is 132.042[a], and the mean score of the control group is 129.257[a]]. In other words, Table 3 shows that growth in students' motivation from low and average levels to high in the treatment group is higher than that of the control group. For instance, a 17.3% (38% - 20.7%) change occurred with students in the treatment group, while a 6.4% (48.6% - 42.2%) change occurred with students in the control group (see Table 3). Table 3 was constructed with Keller's (1999) scoring scale. According to his scale, the minimum score is 34 on the CIS, and the maximum is 170 with midpoint of 102. In this study, the researchers used levels representing "Low", "Average" and "High" based on students' CIS scores. "Low" means that students' CIS scores are in the range between 34 and 101. "Average" means that students' CIS scores are in the range between 102 and 135. "High" means that students' CIS scores are in the range between 136 and 170.

In summary, the ANCOVA indicated a statistically significant difference in students' motivation toward the reform-based curricula.

DISCUSSION

Students' Motivation

The question of this study was pertinent to whether there exist any differences in terms of motivation between students instructed with reform-based curriculum and a traditional one. Students exposed to reform-based curricula showed a greater motivational performance level in learning geometry in the sixth grade than the ones exposed to the conventional one. This finding does not support the claims of Eccles & Midlegy (1989), and Gottfried, Fleming, & Gotfried (2001) that there is a decline in students' motivation toward mathematics courses.

A number of variables, such as teaching method, socio-economic level, environment, parental support, task difficulty, teacher-care, curriculum, success, peer support, and others are vital in students' learning, but in general students' learning is more affected by instruction than other factors (i.e., Fuys, Geddes & Tischler, 1988; Stipek, 1998). For instance, Wentzel (1998) found that parents, teachers, and peers appear to play relatively independent roles in children's lives, and the impacts of having multiple sources of support on motivational and academic outcomes are primarily additive rather than compensatory. This is in line with the claim of Stipek (1998) who maintained that teachers have great opportunities to affect students' motivation to accomplish in school. Parents are influential, but teachers are more influential on students' motivation than the parents because teachers have more control over most aspects of instruction and the social climate of the classroom. Hence, they can easily enhance their students' motivation in mathematics (Stipek, 1998). Students who feel supported and valued by their teachers are willing to engage in classroom activities and highly motivated to be successful in the mathematics classes (Wentzel, 1997).

Many of the important factors affecting motivation were similar between the two groups in the study, except for the method of instruction. All teachers were females with similar amount of teaching experiences. The students in both groups were from low income families as described in the methodology part. The major difference between the two groups in the study was the curriculum practice in terms of variables affecting motivation. The mathematics teachers in the treatment group implemented reform-based geometry curriculum with its own instructional model: launch, explore and summarize (e.g., Reys, Reys, Lapan, Holliday, & Wasman, 2003). Real-life examples or activities were major motivating factors in the reform-based mathematics classrooms. According to Middleton (1995), teachers believe that using real-life applications, group practices, hands-on activities, and other strategies play important roles in students' motivation.

Although each one of the variables mentioned above has an impact on students' motivation in learning geometry, the instruction strongly influenced by the curriculum has more effect on students' performance and motivation in the mathematics classes than others (e.g., Stipek, 1988; Driscoll, 1994; Wentzel, 1997; Middleton & Spainas, 1999; Reys et al., 2003). In this study, the reform-based curriculum based on the van Hiele theory made a more positive impact on students' overall motivation in learning geometry at the sixth grade level.

IMPLICATION & LIMITATION

The current study showed that the curriculum based on van Hiele theory, compared to a traditional one, had a more positive impact on students' overall motivation in learning geometry at the sixth grade level. It suggests that if mathematics teachers pay more attention to reform-based curricula, and prepare their geometry lessons under the guidance of the van Hiele theory, they could be more successful in motivating their students toward their courses. They could more easily understand the difficulties of their students because of the fact that the van Hiele theory has its own well-defined levels that are in a hierarchical order.

Many researchers found that most of the students in both middle and high schools lacked motivation in geometry classes (e.g., Usiskin, 1982; Gottfried et al., 2001; Halat, 2006). Therefore, the reform-based curricula designed on the basis of van Hiele theory may help students enhance their motivation in geometry.

A student can perform better in one area; yet not show the same performance level in other areas (Fuys et al., 1988; Burger & Shaughnessy, 1986). The geometry topics investigated in the study were polygons and tessellations. Therefore, the findings of the study may not necessarily be applicable to all geometry topics. Also, the amount of time allotted by the schools for the topics to be covered was likely inadequate. Time constraints pushed the teachers to limit their instructions and the students' interactions with each other in the classes. Certainly, students needed more time to think about the subject matter, work on the tasks assigned by the teacher, and to share their ideas in the class. Romberg & Shafer (2003) assert that the instructional experiences affect students' learning mathematics with understanding (p.245). In addition, the vast majority of the students were from low income families. Therefore, these findings should not be assumed to automatically generalize to students from other socio-economic backgrounds.

Future Research

The current study investigated the effectiveness of the reform-based curricula on students' motivation in learning geometry at the sixth grade level in a few particular topics. Learning is a very complex process affected by many factors. This study examined one of the important factors, namely method of instruction in sixth grade geometry. The effects of many of the other independent variables on students' learning of geometry may be investigated and their interactions could be examined in order to get an in-depth information and help students enhance their knowledge of geometry. Also, it would be interesting to examine if similar results are obtained with different topics and at different grade levels.

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Effects of Mastery Learning Approach on Secondary School Students' Physics Achievement

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This study aimed at finding out the effects of Mastery Learning Approach (MLA) on students' achievement in Physics. The study was Quasi-experimental and Solomon Four Non-equivalent Control Group Design was used. The target population comprised of secondary school students in Kieni East Division of Nyeri District. The accessible population was Form Two students in district co-educational schools in the division. Purposive sampling was used to obtain a sample of four co-educational secondary schools. Each school provided one Form Two class for the study hence a total of 161 students were involved. The students were taught the same Physics topic of Equilibrium and Centre of Gravity. In the experimental groups MLA teaching method was used while the Regular Teaching Method (RTM) was used in the control groups. The experimental groups were exposed to MLA for a period of three weeks. The researchers trained the teachers in the experimental groups on the technique of MLA before the treatment. Pre-test was administered before treatment and a post-test after three weeks treatment. The instrument used in the study was Physics Achievement Test (PAT) to measure students' achievement. The instrument was pilot tested to ascertain the reliability. The reliability coefficient α was 0.76. Experts ascertained their validity before being used for data collection. Data was analysed using t-test, ANOVA and ANCOVA. Hypotheses were accepted or rejected at significant level of 0.05. The results of the study show that MLA teaching method resulted in higher achievement but gender had no significant influence on their achievement. The researchers concludes that MLA is an effective teaching method, which physics teachers should be encouraged to use and should be implemented in all teacher education programmes in Kenya.

Keywords: Mastery Learning, Kenya, Physics Achievement, Secondary School

INTRODUCTION

Science is recognized widely as being of great importance internationally both for economic well being of nations and because of the need for scientifically literate citizenry (Fraser & Walberg, 1995). Knowledge of science and technology is therefore a requirement in all countries and all people globally due to the many challenges that are facing them. These challenges include emergences of new drug resistant diseases, effects of genetic experimentation and engineering, ecological impact of modern technology, dangers of nuclear war and explosions and global warming among others (Alsop & Hicks, 2001;Minishi,Muni,Okumu, Mutai, Mwangasha, Omolo & Munyeke, 2004). As a result there are rapid changes taking place in industry, communication, agriculture, and medicine. Science as an instrument of development plays a dominant role in bringing about these changes by advancing technological development, promoting national wealth, improving health and industrialization (Republic of Kenya, 1999; Validya, 2003). Weham, Dorlin, Snell and Taylor (1984) emphasized that Physics is and will remain the fundamental science. This suggests that

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other sciences depend upon the knowledge obtained through the study of Physics. Physics is therefore an important base in science and technology since it studies the essence of natural phenomena and helps people understand the increasingly technological changing society (Zhaoyao, 2002). Physics as a branch of Science has many applications for example in medicine; where throughout this century advances in Physics and medicine have gone hand in hand. The most fundamental discoveries in Physics have rapidly been exploited by medical community to devise new techniques for diagnosing and treating a variety of illness. Even in the continuing research necessitated by the challenges posed by diseases as Ebola and HIV/AIDS, the development of high precision equipment employing principles of Physics remain necessary (Minishi et.al, 2004).

In information technology, which has reduced the world into a global village through use of satellites and computers the use of principles of Physics has, been very useful. A wide range of application of Physics is used in industrial development for improvement of materials useful to the well being of human race. Furthermore in the entertainment industry Physics has contributed to the refinement of sound and colour mixing to create special effects in stage presentations. The study of Physics involves the pursuit of truth, hence it inculcates intellectual honesty, diligence, perseverance and observation in the learners (Das, 1985). Physics education therefore enables the learner to acquire problem-solving and decision-making skills that provides ways of thinking and inquiry which help them to respond to widespread and radical changes in industry, health, climatic changes, information technology and economic development. These changes are demanding knowledge of scientific principles in order to tackle them (Kleeves &Ai kenhead, 1995; Mohanty, 2003). The teaching of Physics provides the learners with understanding, skills and scientific knowledge needed for scientific research, fostering technological and economic growth in the society, where they live thus improving the standards of living (Kenya.Institute of Education K.I.E., 2002; Minishi et.al, 2004). Physics education therefore should be a lifelong and recurrent, and not restricted to the stages of secondary school because issues will undoubtedly emerge during the coming decade.

Kenya needs to develop through science and technology education, a human resource capacity for rapid industrialization, which will ensure economic growth and sustainable development (Changeiywo, 2001). Therefore if the Kenya government is to meet her goal of industrialization by the year 2020 (Republic of Kenya, 1996), she should expand science and technology education in order to produce the required human resource. Although science is essential for industrialization, there has been a decline in academic achievement scores of secondary school students as well as low enrolment in the subjects in Kenya (Kenya National Examination Council KNEC, 2003). Students shun Sciences particularly Physics when given an option and this especially applies to girls (Aduda, 2003). That is, given a choice a student would rather drop Physics in favour of other Science subjects.

For a long time, Physics has been mystified as difficult and hence, some schools have not offered it in the last two years of secondary school education. Recent findings show that students who hold negative stereotype images of scientists, science and technology in society are easily discouraged from pursuing scientific disciplines and usually performed poorly in science subjects (Changeiywo, 2000). This situation does not favour Kenya's move towards developing a scientific and technological nation. The concern is that the performance in Physics is poor and the subject is less popular among students in Kenyan secondary schools as compared to other science subjects. The recurrent complain aired every time the National examinations are released is that performance in science is low. Since 2003 the government has been implementing a new curriculum in both primary and secondary schools, and has a new examination format (KNEC, 2005). This new format makes a deliberate attempt to lure students to take physics (Orende & Chesos, 2005). Although the government has done its part the role of the teacher in the classroom is important. The teaching approach that a teacher adopts is one factor that may affect students achievement (Mills, 1991). Therefore use of appropriate teaching method is critical to the successful teaching and learning of Physics.

In an attempt to achieve the objectives of secondary school education and improve on performance various strategies of teaching have been researched in Kenya though in other subjects. Wachanga and Mwangi (2004) found out that cooperative class experiment teaching method facilitated students' chemistry learning. This method also increased student' motivation to learn. The cooperative concept mapping approach teaching method enhanced the teaching of secondary school biology in Gucha district (Orora, Wachanga & Keraro, 2005). A research done in the teaching of agriculture by Kibett and Kathuri (2005) revealed that students who were taught using project based learning out performed their counterparts in regular teaching approach. This study aimed at finding the effects of mastery learning approach (MLA) on achievement in physics.

Mastery Learning Approach (MLA) is an instructional method, where students are allowed unlimited opportunities to demonstrate mastery of content taught (Kibler, Cegala, Watson, Barker & Miler, 1981). MLA involves breaking down the subject matter to be learned into units of learning, each with its own objectives.

The strategy allows students to study material unit after unit until they master it (Dembo, 1994). Mastery of each unit is shown when the student acquires the set pass mark of a diagnostic test. MLA helps the student to acquire prerequisite skills to move to the next unit. The teacher also is required to do task analysis and state the objectives before designating the activities. MLA can help the teacher to know students area of weakness and correct it thus breaking the cycle of failure. Results from research studies carried out on MLA suggest that MLA yields better retention and transfer of material, yields greater interest and more positive attitudes in various subjects than non Mastery Learning Approaches (Kibler et al, 1981). Other research studies report similar findings (Hon, 1990; Ngesa, 2002; Wachanga & Gamba, 2004).

This method of teaching had not been tried out in Physics teaching and learning in Kieni East Division where performance in the subject has continued to decline. This study aimed at finding out the effects of Mastery Learning Approach teaching method in the teaching of Physics in the division. The study was meant to contribute in the understanding of effects of MLA on academic achievement in Physics in this division of Nyeri District in Kenya.

Despite the fact that Physics is an important subject in economic, scientific and technological development most schools have made it optional in Forms Three and Four and others do not offer it at all due to students' poor performance in the subject. The mean at KCSE has continued to be low over the years. Often the teacher is blamed for the poor performance among other factors such as availability of teaching facilities and the attitude of the students towards the subject. Teaching methods therefore are a crucial factor that affects the academic achievement of students (Mills, 1991).

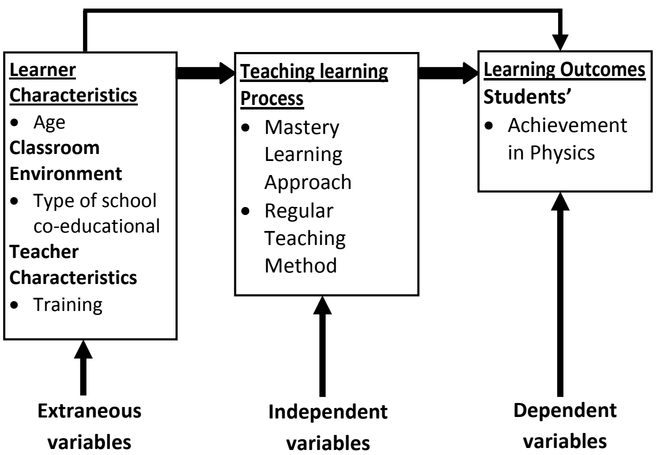

Figure 1. The conceptual framework

MLA has the unique quality of enabling mastery of content by the student through supplementary instruction and corrective activities of small units of the subject matter. MLA also requires the teacher to do task analysis, thereby becoming better prepared to teach the units. The use of MLA in teaching Physics in secondary schools is likely to help improve their academic achievement. The available research does not indicate any research on the effectiveness of Mastery Learning Approach in secondary school Physics in Kieni East Division . This research study was therefore intended to fill this gap in the body of knowledge. The study provides empirical evidence on the effects of MLA on students achievement in secondary school Physics.

Purpose of the Study

The purpose of the study was designed to investigate the effect of using MLA on students' achievement in secondary school Physics.

Objective of the Study

The e specific objective of the study was to compare the achievement of students' taught Physics through MLA with that of students taught through regular teaching methods

Hypothesis of the Study

The following null hypothesis was tested in this study at significance alpha level of 0.05.

$H_0 1$ There is no statistically significant difference in achievement in Physics between students who are exposed to MLA and those who are not exposed to it.

The Conceptual framework

The Conceptual framework to guide the study was based on the Systems Approach (Joyce & Weil, 1980), which holds that the teaching and learning process has inputs and outputs. To achieve good results then the inputs must have suitable materials. The study was also based on the assumption that the blame for a students' failure rests with the quality of instruction and not lack of student's ability to learn. (Bloom, 1981; Levine, 1985). The framework is represented diagrammatically in figure 1. Figure 1 shows the relationship of variables for determining the effects of using MLA on secondary school students' achievement in Physics. Learning outcomes are influenced by various factors. These include: learner characteristics, classroom environment and teacher characteristics as shown in Figure1. These are extraneous variables which needed to be controlled. Teacher training determine the teaching approach a teacher uses and how effective the teacher will use the approach. The learners' age and hence their class determine what they are taught. The type of school as a teaching environment affects the learning outcomes. The study involved trained Physics teachers to control the teacher variable. The type of school used was co-educational to control the effect of the classroom environment. Form Two students who are approximately of the same age were involved in the study. In this study therefore the teaching method used influenced the learning outcomes.

METHODOLOGY

Research design

Quasi-experimental research involving the Solomon's four Non-Equivalent Control Group Design was used. This is because there was non-random selection of students to the groups. Secondary school classes exist as intact groups and school authorities do not normally allow the classes to be dismantled and reconstituted for research purposes. (Borg & Gall, 1989; Fraenkel & Wallen, 2000). This design has advantage over others since it controls the major threats to internal validity except those associated with interaction and history, maturity and instrumentation (Cook &Campbell, 1979). In this study no major event observed in the sample schools to introduce the threat of history and interaction. The conditions under which the instruments were administered were kept as similar as possible across the schools in order to control instrumentation and selection. The schools were randomly assigned to the control and treatment groups to control for selection maturation and interaction (Ary, Jacobs & Razavien, 1979).

Where O_1 and O_3 were pre-test; O_2, O_4, 0_5, 0_6 were the post-test; X was the treatment where students were taught using MLA. The dotted line implies involvement of intact groups. Group I was the experimental group which received the pre-test, the treatment X and the post-test. Group II was the control group, which received a pre-test followed by the control condition and then the post-test. Group III received the treatment X and post-test but did not receive the pre-test. Group IV received the post-test only since it was a control group. Group I and III were taught using MLA while Group II and IV were taught using RTM.

The Research design may be represented as shown in Figure 2.

Group I	O_1	X	O_2
Group II	O_3	-	O_4
Group III		X	O_5
Group IV		-	O_6

Figure 2. Solomon Four Non-Equivalent Control Group Research Design. Source: Fraenkel and Wallen (2000 p.291)

Sampling Procedures.

The unit of Sampling was the secondary school rather than individual learners because secondary schools operate as intact groups (Borg & Gall, 1989). This means therefore that each school was considered as one group. The list of the co-educational schools in the division was the sampling frame. The researcher visited the schools to ascertain that they were suitable for research. During the visit the researcher established that there were trained teachers in the schools and also obtained information on class composition and learner characteristics from schools records. Purposive sampling technique was used to select four schools that formed the sample of the study. The four schools sampled provided the four groups. Purposive sampling was used so as to minimize experimental contamination (Fraenkel & Wallen, 2000). The four schools were randomly assigned to the treatment and control groups. For schools that had more than one Form Two streams, all the streams were taught using similar method of teaching because of ethical reasons and then simple random sampling was used to pick one stream for the study.

Sample Size

The sample of four selected co-educational schools in the division were obtained. The schools in each group are shown below.

Group 1 (Experimental group) N= 35
Group 2 (Control group) N=37
Group 3 (Experimental group) N=45
Group 4 (Control group) N=44

Therefore, the sample size in the research was 161 Form Two students. Fraenkel and Wallen (2000) recommend at least 30 subjects per group. Hence this number was adequate for the study.

Instrumentation

A Physics Achievement Test (PAT) adapted from Kenya National examination council past examination papers and modified was used to measure the students' achievement. It contained twenty structured questions with a maximum score of 29. The instrument was given to four experts in science education for validation. The test was pilot tested using a school in a Division that was not included in the study but had similar characteristics as the sample schools. This ascertained the test reliability. The reliability coefficient was calculated using Kuder-Richardson formula 21 (Gronlund, 1981). This method is suitable when test items can be scored correct or incorrect.The reliability coefficient of PAT instrument was 0.7570 which rounds of to $\alpha=0.76$. According to Fraenkel and Wallen (2000), an alpha value of 0.7 and above is considered suitable to make group inferences that are accurate enough.

The Development and use of Instructional Materials

The content used in the class instruction was developed based on the revised KIE 2002 physics syllabus. A guiding manual was constructed for the teachers involved in administering Mastery Learning Approach that was used throughout the treatment period. The teachers of the experimental groups were trained by the researcher on how to use the manual. These teachers taught using MLA on a different topic other than Equilibrium and Centre of Gravity for one week to enable them to master the skills. After this period the pre-test were administered to Group I and Group II. Treatment period was Three weeks as recommended in the syllabus (KIE, 2002). At the end of the treatment period a post-test was administered to all the groups.

Data Collection

For this study PAT was used to collect data. The pre-test was administered to the two schools in group 1 and group 2. Then treatment took three weeks and was given to the two experimental groups after which post-tests were administered to all the groups. The researchers scored the pre-tests and post-tests and generated quantitative data, which were analysed.

Data Analysis

The ANOVA was used to analyse differences in the four means of the post-test scores. It was used to determine whether the differences were significant. ANCOVA was used to establish whether there were initial differences in the treatment and control groups. It reduces experimental error by statistical rather than by experimental procedure (Borg &Gall, 1989; Coolican, 1994). A t-test was used when dealing with two means because of its superior power to detect differences between two means. Significance level of 0.05 was used to test the null Hypotheses.

Table 1. PAT Post-test Means

Group	N	Mean
1	35	15.57
2	37	7.078
3	45	16.04
4	44	7.81
Total	161	11.78

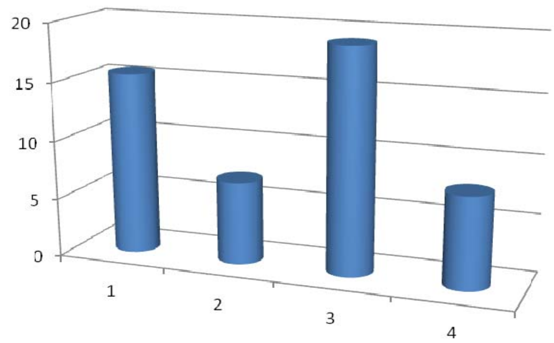

Figure 2. PAT Mean by Groups

RESULTS

The Solomon four-group design used in this study enabled the researchers to have two groups sit for pre-tests as recommended by Borg and Gall (1989). This enabled the researchers to assess the effects of the pre-test relative to no pre-test and assess if there was an interaction between the pre-test and the treatment conditions.

The results of the pre-test scores on PAT for groups 1and 2 showed a statistically significant difference $t(70)=0.056$, $p > 0.05$. This means that the p value was large, and therefore the obtained difference between the sample means is regarded as not significant. This indicated that the groups used in the study exhibited comparable characteristics. The groups were therefore suitable for the study when comparing the effects of Mastery Learning Approach with the Regular Teaching Method on achievement in Physics.

Effects of MLA on Students' Achievement in Physics.

To determine the relative effects of MLA teaching method on student's achievement in Physics, an analysis of Students' Post-test PAT was carried out. Hypothesis

Table 2. Analysis of Variance (ANOVA) of the Post-test scores on the PAT

Group	Sums of Squares	df	Means Square	F	P-value
Between groups	2602.94	3	867.65	68.55	0.005 (S)
Within groups	1987.30	157	12.66		
Total	4590.24	160			

* (P < 0.05, df=3, F=68.55)

Table 3. Scheffe's Comparisons of the PAT Post- Test means

	I Group	J Group	Mean Difference (I-J)	P-value
Scheffe's	1	2	7.79*	0.00
		3	-0.47	0.56
		4	7.75*	0.00
	2	1	-7.79*	0.00
		3	-8.26*	0.00
		4	-3.44 E-02	0.00
	3	1	0.47	0.97
		2	8.26*	0.56
		4	8.23*	0.00
	4	1	-7.75*	0.00
		2	-3.44 E-02	0.79
		3	-8.23*	0.00

*p < 0.05. Note. Values enclosed in the parentheses represent a statistical significant difference

Table 4. Analysis of Covariance (ANCOVA) of the Post-test score with KCPE as covariate

	Sum of Squares	Df	Mean Square	F	P-value
KCPE	486.97	1	486.97	50.63	0.00
GROUP	2456.024	3	818.68	85.12	0.00
ERROR	1500.33	156	9.62		

* (F=85.12, df=3, p<0.05)

Table 5. ANCOVA of the PAT Pre-test Score

	Sum of Squares	df	Mean Square	F	P-value
PAT (Pretest)	5671.40	1	5671.40	444.53	0.00
GROUP	1092.06	1	1092.06	85.60	0.00
ERROR	880.32	69	12.76		

* (F=85.12, df=1, p<0.05)

$H_0$1 of the study sought to find out whether there was any statistically significant difference in achievement scores between students exposed to MLA teaching method and those who were not exposed to it.

Table 1 shows the post-test mean score for PAT on a maximum of 29 obtained by the students in the four groups. An examination of the table 1 shows that the mean scores for Groups 1and 3, the experimental groups, were higher than those of Groups 2 and 4. This shows that Mastery Learning Approach had an effect of improving performance as compared to the Regular Teaching Method. Although a conclusion of whether to reject or accept the hypothesis cannot be made based on these results. The results can further be illustrated by a graph as shown in Figure 2.

The graph in Figure 3 shows the PAT mean scores for the four groups. The graph further confirms that the mean of the experimental groups 1 and 3 which were taught using Mastery Learning Approach teaching method were higher than the means of the control groups 2 and 4, which were taught using Regular Teaching Method. A further analysis on an ANOVA was done as shown on Table 4.

Table 2 shows the results of the ANOVA post-test scores on PAT. The table shows that there was a statistically significant difference between the means F (3,157)=68.55, p <0.05. This means that the F factor is significant at p <0.05 level and between means square is statistically significantly greater than within means square. This shows that there is a highly significant overall treatment effect. That is, the null hypothesis could be rejected and can also conclude that there is probably at least one significant difference among possible comparisons of two means in the four groups. There was therefore, need to find out where this experimental effect was located. This made it necessary to carry out Scheffe's test of significance for a difference between any two means. The results are shown in table 3.

Table 3 shows the results of Scheffe's test of significance for a difference between any two means. The results in Table 3 show that the pairs of PAT mean of groups 1 and 2, groups 1 and 4, groups 2 and 3 and groups 3and 4 were statistically significant different at the 0.05α-level. However there was no statistically significant difference in the mean between Groups 1 and 3 and Groups 2 and 4. This study involved non-equivalent control group design there was therefore, need to confirm these results by performing analysis of covariance (ANCOVA) using the students' Kenya Certificate of Primary Education (KCPE) scores as covariate. KCPE scores correlate closely with the scores used in this study.

Table 4 shows the ANCOVA of the post-test PAT scores with KCPE scores as covariate. Table 4 shows that there is a statistically significant difference in the PAT mean scores of the four groups F (3,156) =85.12, p< 0.05. This confirms that the differences between the means are statistically significant at 0.05α-level. And therefore the differences were as result of the treatment effect. This could be further confirmed by using ANCOVA with pre-test as covariate as shown in table 7.

An examination of Table 5 shows that the difference between groups 1 and 2 is highly statistically significant F (1,69)= 85.60, P<<0.05. This implies that the treatment condition affected Group 1 only. Since Group 1 was taught using MLA while Group 2 was the control; therefore the MLA teaching method gave higher achievement than the Regular Teaching Method. This confirms the results of the ANOVA and ANCOVA with KCPE as covariate, therefore $H_0$1 was rejected.

DISCUSSIONS

The Effect of MLA on Students' Achievement in Physics.

The researcher found out that the students who were taught through the MLA teaching method achieved statistically significantly higher scores in the PAT compared to those were taught through the RTM. This implies that MLA teaching method is more effective in enhancing students' achievement. A study conducted by Block (1971) showed that students with minimal prior knowledge of material had higher achievement when taught MLA teaching method than those taught through regular teaching method. The findings of the current study at 0.05 α-level, showed a statistically significant difference in scores even when the students had no prior knowledge on the topic to be taught when MLA was used as compared to RTM, therefore concurs with the findings of previous research.

Bloom (1984) in his research on group instruction showed scores of students taught through MLA were around the ninety-eighth percentile, or approximately two standard deviations above the mean. He argued that students taught through Mastery Learning needed more time to master more advanced material. Bloom through his many empirical studies on MLA suggests that Mastery Learning procedures are likely to enhance achievement mainly in mathematics and Sciences since learning in these subjects' areas is ordered and sequential (Guskey & Gates, 1986). Physics as a science subjects fits in this category. The physics syllabus as recommended by the Kenya Institute of Education is ordered and sequential. This makes MLA an effective method of teaching it in Kenyan secondary schools. The findings of the current study shows that MLA covers small units of study which students show mastery as they proceed to the next. In this study there was improved performance for the students who were taught using MLA. Kulik, Kulik and Bangert-Downs (1990) conducting a meta-analysis involving 108 evaluations of Mastery Learning programmes found out that performance on examinations at the end of instruction showed positive effects on students achievement although these effects were higher on locally prepared examinations than on nationally standardized test. Their results concur with the findings of this study where the achievement of students taught through MLA was higher.

Also Kulik et al (1990) found out that the effects of MLA were not uniform on all students in a class low aptitude students were found to have higher gains than high aptitude students. They found out that MLA produces more gains in achievements than other teaching methods. The results of the current study agree with this because they show that students in co-educational district schools who are normally selected after national and provincial have done their selection, did better when they were taught using MLA.

Lazarowitz, Baird, Bowlden and Lazarowitz (1996) studied the effects of using Group Mastery Learning on the achievement of high school biology students. They found that in Group Mastery Learning students did better in some topics as compared to individualize

Mastery Learning, although their method stressed more on students co-operative skills than mastery of the content. MLA used in this study stressed more of mastery of content, through corrective feedback and remediation rather cooperative skills but the results showed that MLA is superior than RTM in terms of achieving higher scores.

Research conducted on comparing effects of Mastery Learning alone, and regular teaching methods on student achievement (Mevarech, 1985) showed that Mastery Learning was the indicator that significantly increased achievement Wentling (1973) when comparing Mastery Learning and non Mastery Learning as to how feedback relates to achievement found that students who received feedback in MLA had higher achievement scores for both immediate achievement and long-term retention. However, time spent toward instruction showed no significant difference. The findings of this study concur with these results.

Apart from feedback the other aspect of MLA that receives attention is time. Mastery Learning theorist especially Bloom (1984) contend that MLA reduces the amount of time needed to achieve Mastery. A research conducted by Arlin and Webster (1983) on achievement, time and learning rate found out that use of MLA significantly raises achievement levels but the time needed for this increase is considerable. Wachanga and Gamba (2004), in their study on effects of using MLA on secondary school students' achievement in Chemistry found that MLA facilitates students learning Chemistry better than the regular teaching method. This agrees with Ngesa (2002) who reported that MLA resulted in higher student achievement in Agriculture than the regular teaching method. He argued that the results were significant with regard to classroom Instruction and Teacher Education in Agriculture.

The current study was carried out with these issues in mind and also that the students' performance in Physics at KCSE examination has been less than fifty percent. In the nutshell the results have shown that the use of MLA in Physics results in better students achievement than the regular teaching method. This agrees with previous studies done by other researchers. One of the factors influencing the quality of education is the quality of the teacher and the instruction carried out in the classroom. In the present study the teachers were carefully trained into the use of MLA teaching method. Learning materials were prepared to ensure that after teaching testing was done followed by remedial and retesting. Continued interaction with the teacher, helped the teacher to discover the area of weakness and.therefore assisted the students to reach the expected area of competence. MLA helped the students to have a deeper understanding of the concepts.

MLA allows students to have enough time to master the prerequisites before making progress. However, Arlin and Webster (1983) raised an important issue regarding the use of instructional time in Mastery Learning. He argued that low achievers in grouped Mastery Learning do better because of corrective instruction, but faster students may be slowed down waiting for the other students. This would require the Physics teacher to be willing to use the time outside the normal school timetable for corrective procedures and retesting. The results also show that MLA is beneficial to both boys and girls. If secondary school Physics teachers enhance in the use of this method, they might be able to overcome the disparity between boys and girls achievement in KCSE examination.

In this study, peer tutoring was encouraged in, out of class time where the students checked each other for mastery. They tutored one another and verified that everyone mastered the subtopic and was ready for the test. Since Mastery Learning stresses need for formative assessment and feedback for each unit a variety of remediation materials were prepared. This was done by using a variety of the recommended books by the ministry of education as sources of information. These books included Comprehensive Physics, Secondary School Physics, and Foundation Physics for form 2. All the tests were prepared before the teaching and the remedial ones were prepared according to the numbers, who failed to reach the required pass mark. The teachers were encouraged to avoid objective test, since they could easily lead to memorizing and learning specifics rather than higher levels of learning.Mastery Learning Approach assumes that virtually all students can learn what is taught in school if their instruction is approached systematically and students are helped when and where they have learning difficulties (Bloom, 1984).

The most important feature of Mastery Learning Approach is that it accommodates the natural diversity of ability with any group of students. With careful preparation and greater flexibility all students can be appropriately accommodated according to their respective levels of understanding and they can progress at their own rate (Kibler et. al, 1981).

CONCLUSIONS

Based on the results of this study it can be concluded that MLA facilitates students learning in Physics better as compared to regular teaching method.

Implications of the study

This study offers evidence that Mastery Learning Approach can increase achievement. Since achievement is important in the student learning process, physics teachers should be encouraged to use MLA in order to improve performance in physics. Generally the performance in KCSE Physics examination over the years has been below average. The achievement of students taught through MLA teaching method at form two were able to get higher scores compared to those taught using regular teaching method. This means therefore that there is a likelihood of improvement in performance at KCSE if this method is implemented in the four years of the secondary school cycle.

Many of the professional courses in the Kenyan universities and other tertiary institutions have Physics as a requirement (Siringi, 2005). Therefore if MLA teaching method is introduced in secondary schools more students will opt to do Physics and access these courses. The features of Mastery Learning Approach teaching method suggests that it can be easily implemented in the existing school setting. However it should be realized that time needed to develop the materials is considerable and that the development of learning objectives along with corresponding formative tests and corrective activities is an enormous burden on the teachers. Nonetheless, experience in the United States (Guskey & Pigott, 1988) indicates that teams of teachers working cooperatively can develop materials. The best developing time is during the school holidays and the full days away from school. The practice of teamwork can generate teacher enthusiasm and commitment to Mastery Learning Approach teaching method.

RECOMMENDATIONS

This study has provided data on the effectiveness of MLA teaching method in enhancing academic achievement. This means that the use of MLA in the teaching of Physics at secondary school level can address the poor performance and the low enrolment in the subject. Therefore supplement the government's efforts to improve Physics education in Kenya's secondary schools.

Curriculum developers will find the study helpful in designing appropriate instructional strategies involving Mastery Learning, which would enhance the learning of Physics.

Physics teachers and education inspectors will identify this as an effective teaching method that would be suitable, to provide favourable learning conditions for all students rather than just for the top fraction of the class. The revised (2002) secondary school syllabus would accommodate this method since the time allocated for each topic is adequate to enable the learner to acquire mastery of concepts in the subject (K.I.E, 2002). And teacher educators will find the study useful in developing programs aimed at producing teachers capable of structuring learning environment that can equalize their interaction with learners enabling greater learner participation, satisfaction and further academic aspirations.

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Pre-Service and In-Service Physics Teachers' Ideas about Simple Electric Circuits

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The aim of the study is to determine pre-service and high school physics teachers' ideas about simple electric circuits. In this study, a test contains eight questions related to simple electric circuits was used to the pre-service physics teachers (32 subjects) graduated from Balıkesir University, Necatibey Faculty of Education, the department of physics education and working as physics teachers (25 subjects) in various High Schools in Turkey to determine their ideas about in the same subjects. As a result, it is found that, in partial, while the physics teachers have alternate conceptions about "sequential reasoning", "source of stationary current", and "current usage", the pre-service of physics teachers have unscientific ideas about "source of stationary current", "The concept of current, energy and potential differences are used one another by mistaken", "current usage" and "sequential reasoning".

Keywords: Electric Circuits, Physics Education, Pre-Service Physics Teacher, In-Service Physics Teacher

INTRODUCTION

In the last 20-25 years, many researches, especially research in Europe and the United States; have found that students in every levels have some preconceived ideas about their world that contradict with scientific one. Many different names are used for these kinds of ideas. Well known and frequently used names for these ideas are: "alternate conceptions", "misconceptions", "children science", "conceptual misunderstanding", "spontaneous ideas", "intuitive 'law' or spontaneous reasoning", "conceptual framework, students' unscientific beliefs or students' conceptual categories", "spontaneous models" (Gilbert and Watts, 1983; Marin et. all 2000).

Many researches (Kärrqvist 1985; Lee and Law 2001; McDermott and Shaffer 1992; Shipstone at all. 1988; Osborne 1983; Tiberghien 1983; Küçüközer 2003) have been done to determine (primary, secondary and university) students' ideas about simple electric circuits. From those studies, in general, students have the following unscientific ideas about simple electric circuits:

- Current have been consumed by its closed circuits components (like bulb, resistance, etc.).Therefore, the current diminishes when it returns to battery.
- Current as collisions. The current comes both polar of the battery, when they collide on the bulb, the bulb gives the light.
- One polar current model. The only need is one connection between battery and bulb. Second connection to the other polar of the battery is not necessary for giving the light.
- Battery to be seen as stationary source of current.
- The more battery in the circuits, the more brightness of the bulb.
- Using the concept of current, energy, and potential difference for one another.
- The thought of brightness of the bulb to bee seen as "sequential reasoning" model. (when it consider the path of the current is one way in the series circuits), according to this current path, some changes before or in front of the bulb,

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affect the brightness of the bulb, but some changes after or backward of bulb does not affect the brightness of the bulb.
- When bulbs are connected each other with parallel, the current splits as equally to bulbs no matter bulb's value of the resistance is low or high.

There are few researches (Pardhan and Bano, 2001; Webb 1992; McDermott et al., 2000; Stocklmayer and Treagust, 1996) have been done about similarity of science and physics teachers' ideas on simple electric circuits that those of students have. The following results are found based on teachers' concept of simple electric circuits.

- The source-consumer model (battery is source of electrons/energy; whereas the bulb is a consumer)
- Current is not conserved.
- Clashing current and; the current comes both polar of the battery, and than they collide on the bulb, as a result of this, the light gets on.
- Current as unipolar model; the only need is one connection between battery and bulb. Second connection to the other polar of the battery to bulb is not necessary for getting the light on.
- Current as equally sharing model; in the series circuits, the current is shared equally by the bulbs
- Sequential reasoning or "attenuation" model; in the series circuits, some changes before or in front of the bulb, affect the brightness of the bulb, but some changes after or backward of bulb does not affect the brightness of the bulb
- Mechanical model; in this model, it is seen that electrons moves as a mechanical particle in the wire; and this is the cause of the current.

The main aim of the study is to determine pre-service and high school physics teachers' ideas about simple electric circuits. In this purpose, the following question is going to be answered:

What kinds of ideas do in-service and pre-service high school physics teachers have about simple electric circuits?

METHODOLOGIES

Sampling

The sample was chosen sample of convenience from 25 High school in-service physics teachers held by Ministry of Education. Also 32 pre-service physics teachers (12 of them were male, 17 of them were female) in the last semester before graduation from physics education department at Balikesir University, Necatibey Faculty of Education. In the study there were 25 in-service physics teachers (3 of them were female and 22 of them were male) came from 25 different High Schools in various regions in Turkey (participated teachers in service course was chosen randomly from applicants of physics teachers) ranging their age between 26 to 49 years old and experience in their teaching between 5 to 24 years.

Collecting and Analyzing Data

In the study there was one instrument, the concept test about simple electric circuits, to collect data. This concept test which consists of eight partly open ended questions, was developed to determine in-service physics teachers' and pre-service physics teachers' ideas about simple electric circuits. The test had high reliability (r=0.75) coefficient (the multiple choice question part) and was developed to use as a part of Küçüközer's (2004) doctoral dissertation (the test is given in the appendix). Then this test was adopted to use in this study. To analyze the data the following procedures was followed:

- First, participants' correct answer was determined for each question.
- Then, these correct answers, according to their open ended explanations, divided into two parts as being scientifically correct or wrong.
- Then, explanations of the scientifically correct answers were classified into two parts as being exact correct answer or partly correct answer.
- Next, explanations of the wrong answers were similarly classified into categories among the answers.
- Finally, after analyzing the correct and wrong answer and explanations, results were summarized into tables for each question.

RESULTS

In this part, only four questions are analyzed (out of eight) and their results are given:

Stationary Current Sources

In the following question, in the first part, it is aimed to determine participants' ideas about "batteries as stationary current source". In the second part (part b), participants' opinion about "battery's run out time" was asked to be tested. This question is given in appendix (question 3) and results about first part are given in Table 1.

It can bee seen in Table 1 that 88 % of the physics teachers and 69 % of the pre-service of physics teachers marked the correct answer. Only 8% of the physics teachers gave the exact correct answer with relating the brightness of the bulb with power of the bulb. 64 % of

Table 1. Participants' results about the first part of third question.

Question No	Number (Freq. in %)	
3-a	In-service Physics Teacher	Pre-service Physics Teacher
The Correct Answer is: A = D = E > B = C		
Scientifically Acceptable Correct Answers		
a) Exactly Correct answer		
- The brightness of the bulbs is proportional to power of the bulb ($P=V^2/R$)	2 (8)	5 (16)
- The brightness of the bulbs is proportional to power of the bulbs." ($P=I^2R$)	-	1 (3)
b) Partly Correct answer		
- In this answer, participants did not mention any of bulbs' power but used to compare brightness according to bulbs' potential differences.	16 (64)	15 (47)
- In this answer, participants did not mention any of bulbs' power but used to compare brightness according to bulbs' current.	-	1 (3)
c) the correct answer but no explanation is given	4 (16)	-
Wrong Answers		
1) A > B = C > D = E		
- In this answer participant focus on effective resistance and gave this answer: *"Because of the total resistance, B and C less bright than A. Also the bulb of D and E less bright than the others."*	1 (4)	-
- wrong answer but no explanation is given	1 (4)	1 (3)
2) A = B = C > D = E		
- In this choice participants have seen batteries as stationary current sources.	1 (4)	8 (25)
- The bulbs that parallel with the battery share same potential differences; therefore brightness differentiates according to this.	-	1(3)

Table 2. Participants' results about the first part of second question.

Question No	Number (Frequency in %)	
2a	In-ser. Phy. T.	Pre-ser. Phy.T.
Correct Answer: increases		
Scientifically Acceptable Correct Answers		
a) exact correct answer		
- The brightness of the bulbs is proportional to power of the bulb (decreasing resistance causes increase of current according to ohm law; increase of the current is proportional to power and brightness of bulb ($P= I^2 R$) therefore the bulb's brightness is going to increase*)*.	5 (20)	7 (22)
b) Partially correct		
- Some compared brightness of bulb only bulbs' current they did not mention bulbs' power. Other words, the current and brightness are proportional to each other.	17 (68)	12 (37)
- The brightness of the bulbs is proportional to potential differences of the bulbs. (R_1 decreases the potential difference of bulb and R_2 increase; then potential difference is proportional to brightness of the bulb).	-	6 (19)
c) Wrong Explanations		
- Sequential Reasoning	3 (12)	6 (19)
Wrong Choice: Remain the same		
- Increase of resistance of system causes decrease of current then this does not affect the brightness of the bulb.	-	1 (3)

the physics teachers just related the potential differences with the brightness of the bulb.

Of the given correct answers, only 19 % of the pre-service of physics teachers used power concept to explain the brightness of the bulb.

There were two approaches to explain the answer. One approach was current, and the other was potential difference. For example, one teacher and one student explained the exact correct answer like this "the brightness is proportional to power of the bulbs. The power is proportional to square of current ($P=I^2R$). When one battery and bulb are in the circuit, if the main current was I, then when added the second bulb to circuit in series, the main current becomes I/2; when added the second bulb to circuit in parallel, the main current become 2I, but each bulb shares the current of I. According to given formula; therefore, the correct answer becomes B=C < A=D=E". Another student approached the correct answer with potential differences, and stated: "the potential differences of A, D, and E are the same and the potential differences of these bulbs twice as than bulb of B and C. The power of the bulbs is given P=V2/R, therefore the correct answer becomes B=C < A=D=E." Most of the teachers and students gave the correct answer but stated their partially correct answer that the brightness was proportional to current or potential differences of the bulbs, and they did not mention the power of the bulbs. For example, one teacher and one student stated as: "the more potential differences, the more brightness. A, D, E have potential of V, and B and C have a potential of V/2; therefore the correct answer is B=C < A=D=E." 12 % of the physics teachers and 31% of the pre-service physics teachers have marked the wrong

Table 3. Participants' results about the first part of second question

Question No	Number (Frequency in %)	
2-b	In-ser. Phy. T.	In-ser. Phy. T.
Correct Answer: increases		
Scientifically Acceptable Correct Answers		
a) exact correct answer		
- The brightness of the bulbs is proportional to power of the bulb (increasing resistance causes decrease of current according to ohm law; decrease of the current is proportional to power and brightness of bulb ($P= I^2 R$), therefore the bulb's brightness is going to decrease).	4 (16)	6 (19)
b) Partially correct		
- Some compared brightness of bulb only bulbs' current they did not mention bulbs' power. Other words, the current and brightness are proportional to each other. The decrease of current, the decrease of brightness of the bulb.	18 (72)	13 (40)
- The brightness of the bulbs is proportional to potential differences of the bulbs. (R_2 increases the potential difference of bulb and R_1 increase; then potential difference is proportional to brightness of the bulb).	-	6 (19)
No explanation given	3 (12)	-
Wrong choice: remain the same		
- Sequential Reasoning	-	6 (19)
- no explanation given	-	1 (3)

answers. When analyzing the wrong answer, it can be seen that 4 % of the physics teachers and 25 % of the pre-service physics teachers have chosen the wrong answer that related the unscientific ideas about "battery is stationary current source." For example, one teacher and one student stated their reasoning like this: "In series circuits the same current flow over the circuits, but in parallel circuits current are divided into two parts; therefore the more current gives the more brightness".

Sequential Reasoning

In the following question, it is aimed to determine participants' ideas about "sequential reasoning". This question is given in appendix (question 2) and related results are given in Table 2 and 3, respectively. It can bee seen in Table 3 (part b) that 100 % of the physics teachers and 78 % of the pre-service of physics teachers marked the correct answer. Only 16 % of the physics teachers and 19 % of the pre-service of physics teachers gave the exact correct answer with relating the brightness of the bulb with power of the bulb. 72 % of the physics teachers and 40 % of the pre-service of physics teachers just related the current with the brightness of the bulb. 19 % of the pre-service of physics teachers just related the potential difference with the brightness of the bulb. 19 % of the pre-service

Table 4. Participants' results about the second part of fifth question

Question No	Number (Frequency in %)	
5-b	In-ser. Phy. T.	In-ser. Phy. T.
The correct answer is: 0, 3, 3 Volts, respectively		
Scientifically Acceptable Correct Answers		
a) exact correct answer		
- The explanation of the correct answer is given: *"The resistance of the wire is almost "zero" and the potential difference between the given two points is zero. Also the series connection of the bulbs share equally of the battery's potentials."*	18 (72)	18 (56)
b) Scientifically not Acceptable explanations		
- *"there is a short cut between 1 and 2 points and the potentials of the points are zero. Between 2 and 3; and 3 and 4 are connected to each other in series, therefore the potential differences of those points should equal to battery's potentials."*	-	1 (3)
- *"Because of the series connection of the bulb's resistance, there should not be any change of the current. The current of each bulb shares equally of 3 Volts."*	-	1 (3)
No explanation is given	4 (16)	8 (25)
Wrong choices		
1) 6, 6, 6 Volt		
- No explanation is given	1 (4)	-
2) 0, 3, 0 Volt		
- No explanation is given	1 (4)	-
2) 0, 6, 6 Volt		
"the series connection between the two points does not affect the results the potential differences should be 6 Volts"	-	1 (3)
3) 6, 3, 3 Volt		
- "the bulbs are connected in series; therefore, the potential differences of the battery is divided halves into bulbs" .	-	1 (3)
- no explanation is given	-	2 (6)
No answer is given	1 (4)	-

physics teachers have given incorrect explanation and that is also related the unscientific ideas about "sequential reasoning". For example, one student stated their reasoning like this: "Because the resistance of R_2 is in next to the bulb, decreasing the value of resistance causes increase of bulb's current; but, the brightness of bulb *remains the same"*.

It can be seen in Table 2 (part a) that 100 % of the physics teachers and 97 % of the pre-service of physics teachers marked the correct answer. Only 20 % of the physics teachers and 22 % of the pre-service of physics teachers gave the exact correct answer with relating the brightness of the bulb with power of the bulb. 68 % of the physics teachers and 37 % of the pre-service of physics teachers just related the current with the brightness of the bulb. 19 % of the pre-service of physics teachers just related the potential difference with the brightness of the bulb. 12 % of the physics teachers and 19 % of the pre-service physics teachers have given the wrong explanation and that is related the

Table 5. Participants' results about sixth question

Question No	Number (Frequency in %)	
6	In-ser. Phy. T.	In-ser. Phy. T.
The correct answer is: 1 = 2		
Exact correct answer		
- Conservation of the current (in series circuits the current is the same all over of the circuits. The current does not change when it passes through the bulbs)	17 (68)	24 (75)
No explanation is given	7 (28)	6 (19)
Wrong Choice: 1 < 2		
- Consume of the current	1 (4)	1 (3)
No answer is given	-	1 (3)

unscientific ideas about "sequential reasoning". For example, one teacher and one student stated their reasoning like this: "Because the resistance of R_1 is in front of bulb, decreasing value of the resistance causes increase of bulb's current; however, the brightness of bulb *is not going to be changed".*

To determine participants' responses about potential difference the fifth question has been asked. The

question is shown in appendix (question 5) and the results are given in Table 4. It can be seen that in question 5, the question consists of two parts. Similarity of the results, it is given only second part of the question in Table 4.

It can be seen in Table 4 that 88% of the physics teachers and 62 % of the pre-service physics teachers have marked the correct answer of b section of the question five. Of the given correct answer, 72 % of the physics teachers gave the exact explanation while 16 % of them did not give any explanation. On the other hand, 9 % of the pre-service physics teachers gave the exact explanation while 47 % of them gave the partially correct explanation and 9% of them explained incorrectly. Also 8% of the physics teachers and 13 % of the pre-service physics teachers have marked the incorrect answer. The teacher that gave the incorrect answer also did not give any explanation of the reasoning of the question, but when we look at the explanation of the candidate physics teachers' responses, it can be said that they are confused about potential differences and current concepts.

Consume of current by circuit components

To determine participants unscientific ideas about the concept of "circuits component consumes the current", sixth question have been asked. This question and its results are given in appendix (question 6), and Table 5.

Table 6. The summary of the participants' misconceptions about electric circuits

Unscientific Conceptions	Number (Freq. in %)	
	In-ser. Phy. T.	In-ser. Phy. T.
- The more battery, the more brightness of the bulbs (the first question).	-	1 (3)
- Current is consumed by its component. (4 and 6th question).	1 (4)	1 (3)
- Batteries are seen as stationary current sources (the third question).	1 (4)	8 (25)
- The concept of current, energy and potential differences are used one another by mistake (the fifth question).	-	4(13)
-"sequential reasoning"; in the series circuits, some changes before the bulb, affect the brightness of the bulb, but some changes after do not affect the brightness of the bulb (second question)	-	6 (19)
-"sequential reasoning"; in the series circuits, affect the brightness of the bulb, (second question)	4 (16)	6 (19)
- Using ammeter and voltmeter in circuits incorrectly (7th question).	3 (12)	4 (13)
- 8th question.	-	-

Potential Differences

It can be seen in Table 5 that 96% of the physics teachers and % 94 of the pre-service physics teachers have marked the correct answer. Of the given correct answer, 68 % of the physics teachers gave the exact explanation of "conservation of the current" while 28 % of them did not give any explanation. On the other hand, 75% of the pre-service physics teacher gave the exact explanation while 19 % explained incorrectly. 4% of the physics teachers and 6% of the pre-service physics teachers have marked the incorrect answer. As the explanation of choosing the answer of (1<2), the one teacher and one student gave the similar explanation, they said "the current has a big value when it closes the negative pole of the battery. Because, when the current passes through the bulb, the current is lessened"

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The main aim of the study is to determine pre-service and high school physics teachers' ideas about simple electric circuits. In this purpose a test, contains eight questions related to simple electric circuits, was used to determine the high school physics teachers' and pre-service physics teachers' ideas about same subjects. The summary of the high school physics and pre-service physics teachers' unscientific conceptions is given in Table 6. In this last session, we are going to answer the research question:

What kind of ideas do high school pre-service and in-service physics teachers have about simple electric circuits?" It can be said from Table 6 that even though the high school physics teachers have very low percentage of unscientific ideas about simple electric circuits than those of pre-service physics teachers have, however, the high school physics teachers have alternative conceptions about simple electric circuits. Those are: "Current is consumed by its component" (4 %), "Using ammeter and voltmeter in circuits incorrectly" (12 %), "Batteries are seen as stationary current sources" (4 %), and "sequential reasoning" (16%).

It can be seen in Table 6 that pre-service physics teacher have unscientific ideas about seven out of eight questions. These are: "The more battery, the more brightness of the bulbs" (3%), "Current is consumed by its component" (3%), "The concept of current, energy and potential differences are used one another by mistake" (13%), "Using ammeter and voltmeter in circuits incorrectly" (13 %), "sequential reasoning" (19 %), "In the series circuits, some changes before the bulb, affect the brightness of the bulb, but some changes after do not affect the brightness of the bulb" (12 %) and "Batteries are seen as stationary current sources" (25%).

As a result, high school and pre-service physics teacher have many unscientific ideas or alternative conceptions about simple electric circuits. Finding of this study results have similarities those researches from the literature (Pardhan and Bano, 2001; Webb 1992; Engelhart and Beichner 2004), and those kinds of conceptual ideas are not depend on any culture or nation (Driver and Erickson, 1983; Shipstone et al 1988; Küçüközer 2003).

Recommendations

From this study results and experience, the following recommendations can be made:

- From the most percentage of pre-service physics teachers' unscientific ideas, those kinds of alternative conceptions have to be considered in graduate level and pay attention by university lecturers or professors to overcome these ideas (like, activities about conceptual change, preparing the new syllabus, hands-on and mind-on experiences, etc.).
- A number of definitions and statements about the concept of brightness of the bulb in the physics textbooks are relating only bulb's current or potential difference but power of the bulb. The publishers and authors of physics textbooks have many responsibilities when stating and/or emphasizing some unscientific concepts or alternate concepts
- After determining students' and/or teachers' alternate conceptions about simple electric circuits, teachers should be informed and have to aware of and overcome those kinds of ideas with arranging in service courses by ministry of education department as frequently as possible.
- Students should not avoid asking any kinds of questions and/or participating classrooms activities when they do not understand or their thoughts or concepts contradict with anything different than those of teachers have.
- The physics teachers, instructors, or professors have to follow educational researches about their related topics or current physical issues or alternate conceptions to get up-to-date scientific information with using magazines, research papers, internet or what so ever any medium.

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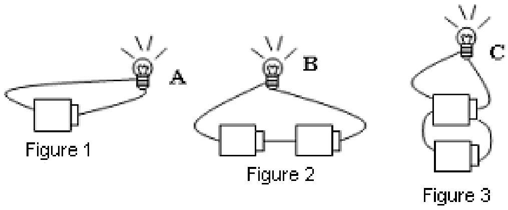
APPENDIX

Basic Circuit Conceptual Survey

The following test consists of eight questions to survey your conceptual response about basic circuits. Please answer all questions and explain your reasoning provided spaces for each question. Your responses are very important to us. Thank you your cooperation.

Questions

1.



Each bulb in the given figures is identical. In figure 2, the second battery is added as serie; in figure 3, the second battery is added as parallell to first battery.

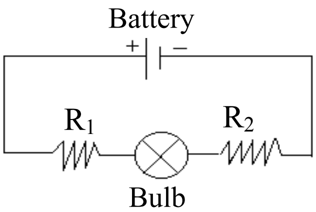
After adding the scond battery, how do you list the brightness of the bulb? Please choose(x mark) one of the following and than explain your reasoning.

❑ A>B>C ❑ B>A>C ❑ B>A=C
❑ A=B=C ❑ B=C>A ❑ ....

Explain your reasoning

----

2. The following basic circuit is given. After making given changes, please choose one of the given answer and than explain your reasoning.



a) If the value of R_1 decreases, the brightness of bulb will
❑ Increase ❑ Decrease ❑ Remain the same

Explain your reasoning

----

b) If the value of R_2 increases, the brightness of bulb will
❑ Increase ❑ Decrease ❑ Remain the same

Explain your reasoning

----

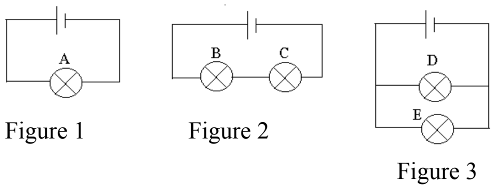
c) If the value of R_1 increases, the brightness of bulb will
❑ Increase ❑ Decrease ❑ Remain the same

Explain your reasoning

----

d) If the value of R_2 decreases, the brightness of bulb will
❑ Increase ❑ Decrease ❑ Remain the same

Explain your reasoning



3. In the figures above, the bulbs and batteries are identical.

a) In the above figures the bulbs are connected as shown. Please choose one answer about the brightness of the bulbs and then explain your reasoning.

❑ A>B=C=D=E ❑ A=B=C>D=E ❑ A>B=C>D=E
❑ A=D=E>B=C ❑ A=B>C>D>E ❑ ....

Explain your reasoning:

----

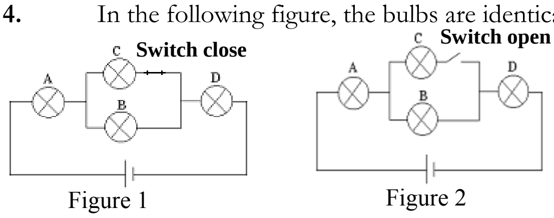
b) If the battery of figure 1 is run out exactly in one hour, ow many does it take to run out of the batteries of igure 2 and figure 3

The battery of figure 2 …… hour (s) The battery of figure 3 …… hour (s)

Explain your reasoning:

----

4. In the following figure, the bulbs are identical.



a) In figure 1 the switch is closed. Please rank the brightness of the bulbs, choose one answer and then explain your reasoning.

❑ A=D>B=C ❑ A>B=C>D ❑ C>A=D>B ❑ A=B=C=D
❑ when the switch is closed, no bulbs give light ❑ ....

Explain your reasoning

----

b) In figure 2, when the switch is opened. Please rank the brightness of the bulbs, choose one answer and then explain your reasoning.

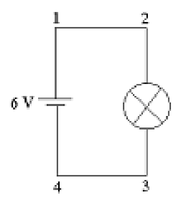
❑ A>B=C>D ❑ A>B=D, C gives no light ❑ A=B= C=D
❑ A=D>B=C ❑ A>B>D, C gives no light
❑ when the switch is opened, no bulbs give light ❑....................

Explain your reasoning

----

5. In the following given both circuits the bulbs are identical. What are the potential differences between given two points? Please mark the correct answer and then explain your reasoning.

a)

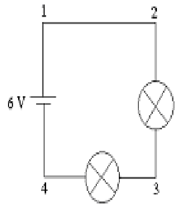


❑ Between 1 and 2 = **6** Volt, 2 and 3 = **6** Volt, 3 and 4 = **6** Volt
❑ Between 1 and 2 = **6** Volt, 2 and 3 = **3** Volt, 3 and 4 = **3** Volt
❑ Between 1 and 2 = **0** Volt, 2 and 3 = **6** Volt, 3 and 4 = **0** Volt
❑ Between 1 and 2 = **2** Volt, 2 and 3 = **2** Volt, 3 and 4 = **2** Volt
❑ ....

Explain your reasoning:

----

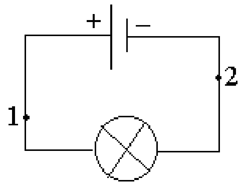
b)



- ❑ Between 1 and 2 = **6** Volt, 2 and 3 = **6** Volt, 3 and 4 = **6** Volt
- ❑ Between 1 and 2 = **6** Volt, 2 and 3 = **3** Volt, 3 and 4 = **0** Volt
- ❑ Between 1 and 2 = **0** Volt, 2 and 3 = **3** Volt, 3 and 4 = **0** Volt
- ❑ Between 1 and 2 = **2** Volt, 2 and 3 = **2** Volt, 3 and 4 = **2** Volt
- ❑ Between 1 and 2 = **0** Volt, 2 and 3 = **3** Volt, 3 and 4 = **3** Volt
- ❑ ....

Explain your reasoning:

6.



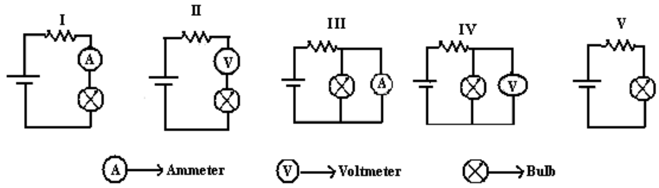
❑ 1>2
❑ 1=2
❑ 1<2

In the figure, what is the current between given 1 and 2 points? Mark the correct the answer and then explain your reasoning.

Explain your reasoning:

----

7. In the following figures; the bulbs, resistances, and batteries are identical.



Please rank the brightness of the bulbs, choose one answer and then explain your reasoning.

❑ I=II=V>III=IV ❑ I=II=V>III=IV ❑ V>I=II>III=IV
❑ I=IV=V, II and III do not give light
❑ I=II=III=IV=V ❑ ....

Explain your reasoning:

----

8. a)

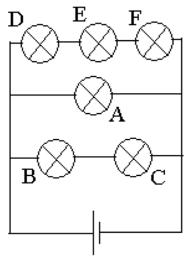


Figure1

In the left figure, the bulbs are identical Please rank the brightness of the bulbs, choose one answer and then explain your reasoning.

❑ A=B=C=D=E=F ❑ A>B=C>D=E=F
❑ B=C>A>D=E=F ❑ A>B>C>D>E>F ❑ B=C>A>D=E=F
❑ ....

Explain your reasoning

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b) When bulb B and C are taking off from circuit in Figure 1, how effect this change the brightness of the other bulbs of A, D, E and F; and then explain your reasoning.

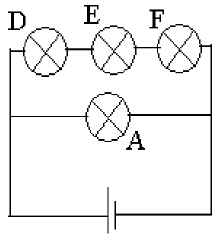


Figure2

Bulb A: ❑ increases ❑ remain the same ❑ decreases
Bulb D: ❑ increases ❑ remain the same ❑ decreases
Bulb E: ❑ increases ❑ remain the same ❑ decreases
Bulb F: ❑ increases ❑ remain the same ❑ decreases

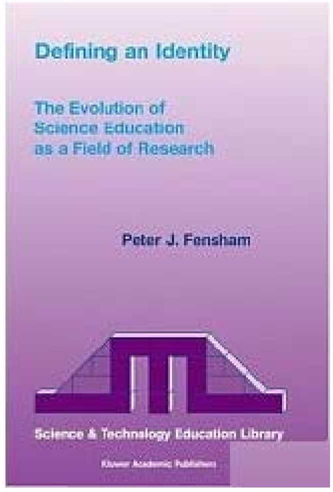
Explain your reasoning

Eurasia Journal of Mathematics, Science & Technology Education, 2008, **4**(3), 313-314

Book Reviews

DEFINING AN IDENTITY – THE EVOLUTION OF SCIENCE EDUCATION AS A FIELD OF RESEARCH.

By Peter F. Fensham
2004
Kluwer Academic, Netherlands
xi+ 264 pp.
ISBN 978-1402014673 (hard cover)



Science education research has developed significantly over the past four decades. This domain has steadily grown – the number of science education researchers has increased, for instance, rather nicely. The membership of the National Association for Research in Science Teaching (NARST), for instance, increased from some 600 in the early 1990s to more than 1800 today. It seems that this by now mature discipline feels the need to look back into its own history – surely in order to gain orientation for further successful work.

An early attempt of such a historical analysis was carried out by DeBoer (1991). More recently, a number of books appeared. There are basically two different approaches of historical analyses. The "classical" approach includes a scholarly review from the personal view of the authors (DeBoer, 1991; Atkin & Black, 2003). The "history in person" approach (Tobin & Roth, 2007; Liu, 2007) illustrates the historical development by discussing the development of individual researcher. Tobin and Roth (2007), for instance, invited a couple of colleagues to write personal views on their own development and commented these "stories". Liu (2007) asked students in a seminar to outline the work of a set of "noted" science educators.

In the book under review here Peter Fensham (2004) draws on personal interviews with 79 science education researchers from many countries "all over the world". He uses this data set to reconstruct the evolution of science education as a field of research in order to provide orientation for future developments.

I would like to point out that I am personally involved in this book. When I was driving on a busy road between Santiago de Chile and La Serena just behind a huge stinking truck Peter, who was sitting in the other front seat, asked me: Tell me about two of your publications in the field that you regard as significant. I did not understand that question properly but told him about publications by other colleagues that had been significant for me. That was the birth of the second question Peter later used in his interviews. I also carried out a couple of interviews and was interviewed by Peter. Hence, also my voice is in the book reviewed here.

In the interview the following two questions were asked:

- ✓ Tell me about two of your publications in the field that you regard as significant.
- ✓ Tell me about up to three publications by others that have had a major influence on your research work in the field.

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These two questions provided the frame for a somewhat "open-ended" interview. The 79 colleagues interviewed stemmed from sixteen countries – mainly from North American, Europe, and Australia. It is a "convenience" sample – however including "noted" science educators from various parts of the world.

A formal analysis of the interviews in terms of qualitative content analysis or grounded theory framework may not be expected from this book – and this actually is the very advantage of the work. Peter Fensham uses the interviews in two ways. First, as an additional source to supplement his deep insight into the state and the development of science education as a research domain. Second, the views of the interviewed colleagues are used to illustrate the points Peter makes.

The first chapter *"Science Education: What defines a field of research?"* provides the following criteria for the subsequent analyses:

Structural Criteria: (S1) Academic recognition; (S2) Research journals; (S 3) Professional associations; (S4) Research conferences; (S5) Research centres; (S6) Research training.

Intra-Research Criteria: (R 1) Scientific knowledge; (R 2) Asking questions; (R 3) Conceptual and theoretical development; (R 4) Research methodologies; (R 5) Progression; (R 6) Model publications; (R 7) Seminal publications.

Outcome Criteria: (O 1) Implications for practice.

Here are the themes of the subsequent chapters:

- ✓ Origins
- ✓ The Researcher as Person
- ✓ Major Influence on Research
- ✓ Asking Questions
- ✓ The Role of Theory
- ✓ Methodology
- ✓ Evidence of Progression
- ✓ Focus on Content
- ✓ Research to Practice
- ✓ Gender and Science Education
- ✓ Politics and Science Education
- ✓ Science Education, Technology and IT
- ✓ Conclusions: Language and Science Education

The reader may expect a deep insight into the state and development of science education as a research domain from studying these chapters. Peter Fensham makes the reader familiar with key publications, major researchers working in the various fields as well as with significant theoretical views, ideas, findings, and implications for instructional practice. These chapters are rather skilfully designed and illustrated with examples from the interviews. However, they do not allow "easy reading". Full attention is needed to follow the many fine details and thoughts provided.

It seems to be quite characteristic for the intention of the book that the concluding chapter has the title "Conclusion: Language and Science Education". This chapter, namely, does not include a conclusion of the arguments presented in the previous chapters but provides insight into an additional more recent research field. Throughout the book conclusions do not come in the dress of summaries condensing issues discussed into few bold statements. Further, there is no paragraph on discussing consequences explicitly for the further development of science education. Peter Fensham provides a wealth of information on the state and origin of major ideas in science education research. Of course, also Peter's own views become apparent. But he does not superimpose his views on the reader. It appears that he intends to provide the reader with the best food of thought for the further development of science education available. But he seems to leave drawing conclusions for future development to the reader.

It is for this reason that I refrain from summarizing the message of the book in a few sentences. The only message I have for the readership of this journal is to read this book. If there is a set of books in science education that must be read – Peter Fensham's book discussed here is one of them.

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The book consists of fourteen chapters, an introduction, acknowledgments, an epilogue, references, name index and a subject index. Thematically it is organized in four sections. In the first section, the authors set out their philosophical position about the nature of knowledge and its relation to education. In the second section, they summarise some theories of method as examples of critical inquiry in science. The third section develops a case against sociological and postmodernist approaches to knowledge and science. In the fourth section, the authors concentrate on issues of culture and politics in science with a sizable discussion on various versions of multiculturalism. The overall argument underlying the book is that the recent debates around constructivism, multiculturalism and postmodernism have promoted a version of science that have imparted negative influences on how science and science education are conceptualized. The authors want to place critical inquiry at the core of education in general and science education in particular. In promoting critical inquiry, the authors draw from Plato's views on knowledge and Socratic method. In a similar vein in emphasis on logic, the authors propose logical analyses to illustrate self- refutation of relativism (pp.125-126). In short, the authors question the abandonment of ideas such as universalism, trans-cultural rationality, scientific method and objective truth.

Overall the book provides a good review of some key concepts from philosophy of science. The emphasis on recovering the rationality of science and cautioning science educators of the perils of relativism are particularly important ideas to promote. A key strength of the book is the range of useful conceptual distinctions it provides. For example, in relation to constructivism, the authors review the cognitive, semantical, epistemic and ontological constructivism in Chapter 5. The discussion on the culture and politics of science provide some interesting insights into how multiculturalism is contextualized in different country case studies such as India and Turkey (pp. 446-459). However, the link made to the applications of philosophy of science in science education tend to be mainly on the basis of criticism and thus the book is limited in its framing of science educators' work in this area. The authors do state that "the book is about philosophical theories of knowledge and science that impinge on science education. Empathetically it is not about techniques for the classroom teaching of science nor is it an empirical study concerning science teaching and learning." (p.3). However, even at the level of review of the theoretical discussions stemming from

science education, the relation of the authors discussion of science education literature to philosophy of science remains restricted and unsubstantiated as a balanced argument. For example, the authors state: "It is fair to say that the most definitions (of science) in the literature are either too narrow or too wide. Instead of trying to substantiate our impression, we will simply provide our own definition and then let each science educator to compare it with his or her favorite characterization" (pp. 201-202). The authors then proceed to confine their definition of science in terms of six aspects: Activity, Aim, Product, Method, M-Rule and Attitude. It is difficult to understand the authors' criticism of how some science educators' definitions could be different from these aspects – their definition-of science given they do not cite particular references to

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science educators in this respect. Considering the substantial body of literature on the nature of science in science education and the wide range of researchers in this area, the work appealed to is rather limited. The work cited (e.g. articles by Michael Matthews, William McComas, Rosalind Driver) while useful, does not represent an even wider range of perspectives on how history and philosophy of science can be applied in science education. For example, there is no citation of some key contributors such as Richard Duschl and Norm Lederman.

The tone of the text in relation to issues of education appears rather naïve from a science educators' perspective. For example, in the section titled "Applying the Hypothetico-Deductive Method in the Classroom" (pp.253-258), there is surprisingly no insight into how this method could indeed be applied in the classroom. The recommendations are minimal -e.g. "ask them to give an explanation for this" (p.254) - which is not useful for any educator (researcher or teacher alike) who would need to know exactly how this sentence needs to be translated into classroom actions, resources and timings of events. Indeed, the overall tone of the educational aspects of this book would benefit from some incorporation and reflection on teaching and teacher education literature (e.g. Shulman, 1992) in order to warrant a more substantial criticism of science educators' work. A further example of short-sightedness about educational issues appears in Chapter 1 where the authors distinguish between different sense of learning: learning how to, learning why and learning that. In a similar vein, the second chapter clarifies different senses of knowledge and knowing. The authors thereby criticize the work of some science education researchers in being vague about some of the distinctions that lie among these key concepts (pp.86-88). While such clarifications are useful and provide important distinctions for science education, they do not capture the more complex meanings of various terms such as learning and knowing from a pedagogical point of view.

The overemphasis of the authors' take on educational issues from a logical angle is, in this respect, both a strength and a weakness of the book. It is a strength in terms of providing science educators with logical and philosophical insights into some concepts that form the basis of their endeavour although then reverting the logical emphasis to criticize the way in which science educators mean these concepts seems unfounded. The inflation in logical analysis is limiting in usefulness to application in real life science learning environments or indeed their theoretical study from a science education disciplinary perspective. For instance, the notion of learning does not seem to encapsulate a real learner, how this learner's idiosyncratic learning process might feed into the way in which learning is perceived. In short, from the authors' perspective, the learner is not a real person but a decontextualised and hypothetical entity.

The authors' interpretation of some concepts such as disunity of science, thus, takes on a unidimensional interpretation which does not acknowledge the multitude of senses of the philosophical concepts that can be applied in science education. In tackling with the disunity of the sciences issue, the authors conclude: "We think that the claims for disunity in the sciences are overplayed to no clear end." (p.409). In one sense the disunity of the sciences relates to the reaction against the positivist characterizations of the unity of the sciences and the role of reductionism in defining physics as the paradigmatic science. In another sense, the "disunity of science" argument need not be at odds with the rational and objectivist accounts of science. For instance, the disciplinary ways of reasoning might indeed pose domain-specific features of science that are important to capture to represent in the classroom (Erduran, 2007).

Despite its limitations in its usefulness for science education researchers, overall the book is a good contribution to the literature in raising awareness of some fundamental philosophical issues and particularly in guarding the rational, evidential and critical nature of science. The book would be a useful resource for researchers in philosophy of education, philosophy of science as well as science education.

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