JESEH

VOLUME
2
ISSUE
1

YEAR
2016

Journal of Education in

Science, Environment and Health

e-ISSN 2149-214X

EDITORIAL BOARD

Journal of Education in Science, Environment and Health (JESEH)

The Journal of Education in Science, Environment and Health (JESEH) is a peer-reviewed and online free journal. The JESEH is published quarterly in January, April, July and October.The language of the journal is English only. As an open access journal, Journal of Education in Science, Environment and Health (JESEH) does not charge article submission or processing fees. JESEH is a non-profit journal and publication is completely free of charge.

The JESEH welcomes any research papers on education in science, environment and health using techniques from and applications in any technical knowledge domain: original theoretical works, literature reviews, research reports, social issues, psychological issues, curricula, learning environments, book reviews, and review articles. The articles should be original, unpublished, and not in consideration for publication elsewhere at the time of submission to the JESEH.

Abstracting/ Indexing

Journal of Education in Science, Environment and Health (JESEH) is indexed by following abstracting and indexing services: SOBIAD, Scientific Indexing Service (SIS), Education Resources Information Center (ERIC).

Submissions

All submissions should be in electronic (.Doc or .Docx) format. Submissions in PDF and other non-editable formats are not acceptable. Manuscripts can be submitted through the journal website. All manuscripts should use the latest APA style. The manuscript template for formatting is available on the journal website.

Contact Info

Journal of Education in Science, Environment and Health (JESEH)
Email: jesehoffice@gmail.com
Web : www.jeseh.net

Journal of Education in Science, Environment and Health
Volume 2, Issue 1, 2016
e-ISSN:2149-214X

CONTENTS

Journal of Education in Science, Environment and Health
Volume 2, Issue 1, 2016 ISSN: 2149-214X

New Science Curriculum Based on Inquiry Based Learning- A Model of Modern Educational System in Republic of Macedonia

Natalija Aceska*
Bureau for development of education, Republic of Macedonia

Abstract

The process of globalization, more progressive development of the scientific findings, new technology and the way of communicating with the new forms of literacy in which the most secure spot has been taken by the development of natural sciences in the spirit of *sustainable development* have been the reasons that make science and sustainable development an educational imperative. The development of *natural sciences* in the educational processes in Republic of Macedonia has become an essential process which is being permanently improved with the goal to find the best solutions for its improvement. Currently, all of the elementary grade teachers have to face this process. One of the most recent changes is the study of natural sciences according to the adapted educational *curriculum* from the Cambridge International Examination Center. The goal of this reform is to lead the students on the right way of becoming future "scientists". The programs include research that encourages students to ask questions and derive the answers themselves with the support from their teachers. This is a proven method with which natural science classes will become more interesting for the students and the findings will remain learned. The educational curriculum also allows the students to develop their critical thinking and to think and use the proofs. Students will easily learn that natural sciences are important and can help them in solving everyday life's problems according to the principles of education for sustainable development. A very important part in the adaptation and realization of the adapted educational curriculum from the Cambridge International Examination Center is being played by the *information and communication technology (ICT)* that is a very useful resource for the development of the knowledge, skills and understanding among students. ICT needs to improve the quality of the teaching. The teachers will have the opportunity to choose and use the most appropriate and effective ICT resources.

Key words: New science curriculum, Inquiry based learning, ICT, Education for sustainable development

Introduction

Few years ago, according to the results of PISA (a triennial international survey which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students), Macedonian government decide to find a way to improve the given results. Cambridge International Examinations was approached in January 2013 by the Ministry of Education and Science (MoES) of the Republic of Macedonia in the context of MoES's ambition to raise school-level educational standards. As part of the Republic of Macedonia's plans for educational reform, the Bureau for Development of Education (BDE) is working in partnership with Cambridge and started implementing an adapted form of Cambridge primary science curricula at Grades 1-9 from September 2014. Implementation of educational reform requires a balance of speed and sustainability. It is essential that the changes required do not exceed the capacity to deliver them effectively. This may relate to the ability of teachers to familiarize them with new content and implement new approaches to teaching and to the evolution of professional support systems and the alteration of operational practice by schools and education agencies. Financial and resource constraints also have an impact on successful implementation in terms of the reform's educational impact for learners. The first year of new science curriculum implementation is at the end. The BDE and Cambridge International Examinations teams monitored more than 50 schools until now in term to collect more data about the ongoing curriculum realization. The first results given by the surveys and interviews provide to BDE and MoES the first impressions about the success of the process of new science reforms.

* Corresponding Author: *Natalija Aceska, aceska.bro@gmail.com*

Correlation between Inquiry Based Learning and New Science Curriculum

Inquiry-based learning or inquiry-based science describes a range of philosophical, curricular and pedagogical approaches to teaching. Its core premises include the requirement that learning should be based around student questions. Pedagogy and curriculum requires students to work independently to solve problems rather than receiving direct instructions on what to do from the teacher. Teachers are viewed as facilitators of learning rather than vessels of knowledge. The teacher's job in an inquiry learning environment is therefore not to provide knowledge, but instead to help students along the process of discovering knowledge themselves. Its core premises include the requirement that learning should be based around student questions. Pedagogy and curriculum requires students to work independently to solve problems rather than receiving direct instructions on what to do from the teacher. Teachers are viewed as facilitators of learning rather than vessels of knowledge. The teachers job in an inquiry learning environment is therefore not to provide knowledge, but instead to help students along the process of discovering knowledge themselves. Inquiry-based learning is a concept which underlines the importance of students engaging into meaningful hands-on science experiences (Louca, Santis & Tzialli, 2010). Inquiry can't be separated from the world of science and as National Science Educations Standards states: "Inquiry is central to science learning" (NRC, 1996 p2).

Inquiry learning cause beyond memorizing information and aims to give students an understanding and reasoning of the knowledge which they develop. Inquiry-based learning is active and provides opportunities for students to engage themselves with scientific activities (Edelson, Gording and Pea, 1999). This self-engaging into activities should lead to a less guided situation in which students design their learning by exploring. Exploring is the essence of inquiry learning, students design their own question and hypothesis in order to engage in hands-on activities which are aligned by exploration. Hakkarainen (2002) shows that inquiry learning leads to students who design their own intuitive theories by explaining answers on their research question. Kirschner, Sweller and Clark (2006) strongly oppose to the concept minimal or non- guidance, cause it places a huge burden on working memory. Guided instruction is seen to lead to vastly more learning, IBL can't be seen as a fully guided instruction (Kirschner et al. 2006). Hmelo-Silver, Duncan and Chinn (2007 p 99) wrote an article specially in response to Kirschner et al. (2006) and state that IBL isn't minimally guided but could use "extensive scaffolding to facilitate student learning".

Inquiry-based learning or inquiry-based science describes a range of philosophical, curricular and pedagogical approaches to teaching. A distinction has to be made between teaching and doing science in IBL (Colburn, 2000). Doing science refers to the student who enact with IBL and teaching refers to the way IBL is instructed to students and the way of guiding students into science inquiry. Teaching inquiry science might evoke more discussion and different opinions. In order to address this distinction first will be looked at teaching inquiry-based science and next doing inquiry-based science. Inquiry-based science is an approach to science education that is student constructed as opposed to teacher-transmitted, hands-on as opposed to lecture-based. Students learn science by using methods, adopting attitudes, and applying skills as scientists do when conducting scientific research. Students are able to find their own problems and generate their own questions, formulate their own hypotheses, design and implement their own methods for testing their hypothesis, and use their own data to answer their original questions.

There is a progression from teacher-guided inquiry to completely student-directed inquiry. Even though students direct the course of study, the teacher still assesses progress and introduces critical skills and concepts. An inquiry-based classroom enables students to actively construct meaningful knowledge rather than passively acquire facts. Because students learn by connecting information to their own experiences, inquiry-based learning allows students to have experiences with germinating seeds, maintaining an aquarium, and working with circuits to light bulbs. After engaging in such activities, students are able to apply the information from the experience to new science concepts and life in general. Inquiry-based learning environments are such environments. Inquiry-based learning refers to a learning process in which students are engaged (Anderson, 2002) and is defined as an active learning process: *"something that students do, not something that is done to them"* (National Science Education Standards, NRC, 1996, p. 21). Inquiry and constructivist teaching approaches therefore, share many educational objectives, such as emphasizing student construction of concepts and the relationship between student acquisition of concepts and the concepts' development in the history of science (Abd El Khalick et al., 2004) and promise the fostering of motivation for students in terms of self-regulated learning.

Teaching Inquiry-Based Learning

Which role the facilitator or teacher should play during science inquiry is widely recognized and answers aren't always equivocal. This question is very legit and importance for the success of IBL, How should you support the students? Overall there is a confusion about the definition of inquiry and what inquiry implies for the teacher (Colburn, 2000). The reform from traditional education to a more inquiry-based learning asks for a paradigm shift. Teachers need to shift their emphasis from textbooks to exploring questions (Crawford, 1999). This might sound easy to implement, but is far from easy. This new paradigm on education ask for specific new actions and teachers shouldn't 'simply' provide hands-on activities for students. Teachers should provide students with inquiry activities that build on prerequisite knowledge and elaborates understanding (Crawford, 1999). This asks for a new approach in teaching which 'forces' teachers to change their current form of teaching. Learning in IBL should come from experiments and inquiry activities which should be conducted by collaboration and interaction with other students and teachers. The current situation of science education and the importance of a scientifically literate society is in the course of international comparative studies such as PISA and TIMSS increasingly discussed. With respect to the discussion about deficiencies, shortcomings and inadequateness in the field of science education and the regarding educational mandate of general school education, science education researchers express wide consensus about scientific literacy being the central aim of science education (Gräber & Bolte,1997; Gräber, Nentwig, Koballa & Evans, 2002). Although there is no single right answer as to what defines inquiry-based science, educators have outlined what it looks like. In simple terms it is a learning process or strategy rather than any specific set of lessons. This process aims to enhance learning based on increased student involvement. Through hands-on investigations, knowledge becomes more relevant and easier to comprehend. Inquiry-based science leads to active construction of meaningful knowledge, rather than passive acquisition of facts provided by a teacher. The old Chinese proverb, "Tell me and I forget, show me and I remember, involve me and I understand" is the essence of what inquiry-based science is all about.

Advantages of Inquiry-Based Science

Unfortunately, our traditional educational system has evolved in a way that discourages the natural process of inquiry-learning. The current system is teacher-focused and revolves around giving out information about what is known. The emphasis is on student's ability to recall facts and master the chosen material so that they may proceed to the next grade level. However, memorizing facts and information is not the most important skill in today's world. Facts are constantly changing and thanks to our digital age, we are overwhelmed with information. The skill needed for this new age of information is the ability to examine and make sense of this avalanche of data. Students who actively make observations, collect, analyze, and synthesize information and draw conclusions are developing the critical skills that they will encounter both at school and in the future workforce. Students need to develop inquiry skills so that they can cope with future situations and become lifelong learners. Ultimately, the significance of inquiry learning is that students learn how to continue learning, something they will use and rely upon throughout their lives.

The science curriculum emphasizes inquiry-based teaching and learning. A balanced and engaging approach to teaching will typically involve context, exploration, explanation and application. This requires a context or point of relevance through which students can make sense of the ideas they are learning. Opportunities for student-led open inquiry should also be provided within each phase of schooling. The new Macedonian science curriculum provides opportunities for students to develop an understanding of important science concepts and processes, the practices used to develop scientific knowledge, of science's contribution to our culture and society, and its applications in our lives. The curriculum supports students to develop the scientific knowledge, understandings and skills to make informed decisions about local, national and global issues and to participate, if they so wish, in science-related careers. In addition to its practical applications, learning science is a valuable pursuit in its own right. Students can experience the joy of scientific discovery and nurture their natural curiosity about the world around them. In doing this, they develop critical and creative thinking skills and challenge themselves to identify questions and draw evidence-based conclusions using scientific methods. The wider benefits of this "scientific literacy" are well established, including giving students the capability to investigate the natural world and changes made to it through human activity. Science understanding is evident when a person selects and integrates appropriate science knowledge to explain and predict phenomena, and applies that knowledge to new situations. Science knowledge refers to facts, concepts, principles, laws, theories and models that have been established by scientists over time.

Science Inquiry Skills

Science inquiry involves identifying and posing questions; planning, conducting and reflecting on investigations; processing, analyzing and interpreting evidence; and communicating findings. This strand is concerned with evaluating claims, investigating ideas, solving problems, drawing valid conclusions and developing evidence-based arguments. Science investigations are activities in which ideas, predictions or hypotheses are tested and conclusions are drawn in response to a question or problem. Investigations can involve a range of activities, including experimental testing, field work, locating and using information sources, conducting surveys, and using modeling and simulations. The choice of the approach taken will depend on the context and subject of the investigation.

In science investigations, collection and analysis of data and evidence play a major role. This can involve collecting or extracting information and reorganizing data in the form of tables, graphs, flow charts, diagrams, prose, keys, spreadsheets and databases. There are five sub-strands of *Science Inquiry Skills*. These are:

- **Questioning and predicting**: Identifying and constructing questions, proposing hypotheses and suggesting possible outcomes.
- **Planning and conducting**: Making decisions regarding how to investigate or solve a problem and carrying out an investigation, including the collection of data.
- **Processing and analyzing data and information**: Representing data in meaningful and useful ways; identifying trends, patterns and relationships in data, and using this evidence to justify conclusions.
- **Evaluating**: Considering the quality of available evidence and the merit or significance of a claim, proposition or conclusion with reference to that evidence.
- **Communicating**: Conveying information or ideas to others through appropriate representations, text types and modes.

The curriculum will be divided in three developing periods:

- ***Grade 1-3 – first developing period***
- ***Grade 4-6 – second developing period***
- ***Grade 7-9 – third developing period***

Grade 1-3 – first developing period-Young children have an intrinsic curiosity about their immediate world. Asking questions leads to speculation and the testing of ideas. Exploratory, purposeful play is a central feature of their investigations. They use the senses to observe and gather information, describing, making comparisons, sorting and classifying to create an order that is meaningful. They observe and explore changes that vary in their rate and magnitude and begin to describe relationships in the world around them. Students' questions and ideas about the world become increasingly purposeful. They are encouraged to develop explanatory ideas and test them through further exploration. During these years students can develop ideas about science that relate to their lives, answer questions, and solve mysteries of particular interest to their age group. In this stage of schooling students tend to use a trial-and-error approach to their science investigations. As they progress, they begin to work in a more systematic way. The notion of a 'fair test' and the idea of variables are developed, as well as other forms of science inquiry. Understanding the importance of measurement in quantifying changes in systems is also fostered.

Through observation, students can detect similarities among objects, living things and events and these similarities can form patterns. By identifying these patterns, students develop explanations about the reasons for them. Students' understanding of the complex natural or built world can be enhanced by considering aspects of the world as systems, and how components, or parts, within systems relate to each other. From evidence derived from observation, explanations about phenomena can be developed and tested. With new evidence, explanations may be refined or changed. By examining living structures, Earth, changes of solids to liquids and features of light, students begin to recognize patterns in the world. The observation of aspects of astronomy, living things, heat, light and electrical circuits helps students develop the concept of a system and its interacting components, and understand the relationships, including the notion of cause and effect, between variables.

Grade 4-6 – second developing period - during these years, students continue to develop their understanding of important science concepts across the major science disciplines. It is important to include contemporary contexts in which a richer understanding of science can be enhanced. Current science research and its human application motivates and engages students. Within the outlined curriculum, students should undertake some open investigations that will help them refine their science inquiry skills. The quantitative aspects of students' inquiry skills are further developed to incorporate consideration of uncertainty in measurement. In teaching the outlined curriculum, it is important to provide time to build the more abstract science ideas that underpin understanding.

Students further develop their understanding of systems and how the idea of equilibrium is important in dynamic systems. They consider how a change in one of the components can affect all components of the system because of the interrelationships between the parts. They consider the idea of form and function at a range of scales in both living and non-living systems. Students move from an experiential appreciation of the effects of energy to a more abstract understanding of the nature of energy. As students investigate the science phenomena outlined in these years, they begin to learn about major theories that underpin science, including the particle theory, atomic theory, the theory of evolution, plate tectonic theory and the Big Bang theory.

Grade 7-9 – third developing period - the senior secondary courses for physics, chemistry, biology, and Earth and environmental science build on prior learning across these areas. The implementation of this part of new science curricula will be realized in upcoming school year.

General Capabilities

In the Macedonian Curriculum, the general capabilities encompass the knowledge, skills, behaviors and dispositions that, together with curriculum content in each learning area and the cross-curriculum priorities, will assist students to live and work successfully in the twenty-first century. There are seven general capabilities:

- Literacy
- Numeracy
- Information and communication technology (ICT) capability
- Critical and creative thinking
- Personal and social capability
- Ethical understanding
- Intercultural understanding.

In the Macedonian curriculum of science, general capabilities are identified wherever they are developed or applied in content descriptions. They are also identified where they offer opportunities to add depth and richness to student learning through content elaborations.

Sustainability in Macedonian Science Curriculum

Across the Macedonian science curriculum, sustainability will allow all young Macedonian to develop the knowledge, skills, values and world views necessary for them to act in ways that contribute to more sustainable patterns of living. It will enable individuals and communities to reflect on ways of interpreting and engaging with the world. The sustainability priority is futures-oriented, focusing on protecting environments and creating a more ecologically and socially just world through informed action. Actions that support more sustainable patterns of living require consideration of environmental, social, cultural and economic systems and their interdependence. In the Macedonian Curriculum of science the priority of sustainability provides authentic contexts for exploring, investigating and understanding chemical, biological, physical and Earth and space systems.

Science explores a wide range of systems that operate at different time and spatial scales. By investigating the relationships between systems and system components and how systems respond to change, students develop an appreciation for the interconnectedness of Earth's biosphere, geosphere, hydrosphere and atmosphere. Relationships including cycles and cause and effect are explored, and students develop observation and analysis skills to examine these relationships in the world around them. In this learning area, students appreciate that science provides the basis for decision making in many areas of society and that these decisions can impact on the Earth system. They understand the importance of using science to predict possible effects of human and other activity and to develop management plans or alternative technologies that minimize these effects.

Monitoring Process of Implementation Process in 1-3 Grade

The school year 2014/2015 was the first year with implementation of new science curricula in 1-3 grade. Prior to the arrival of Cambridge consultants, staff from the BDE visited over 50 schools, observing lessons and interviewing learners, teachers and head teachers. In the period of 3 November to 7 November 2014, a team of BDE and Cambridge advisors visited 7 schools, where the surveys, interviews and students impressions of science class trough drawing were monitored. On the following period the Cambridge consultants accompanied BDE staff and interpreters to the following schools in urban and rural areas:

• Bratstvo (Skopje)
• Draga Stojanonva (Skopje)
• Kirli Pejcinovic (Skopje)
• Zilko Brajkovski (Skopje)
• 7 Marsi (Chelopek)
• Kosta Racin (Brvenica)
• Bratvo Ligieni (Migjeni)

Survey Responses

There were delivered two surveys: for principals and for the teachers. After removing duplicates and other invalid entries, the principal survey received 160 valid responses (132 on the Macedonian version; 28 on the Albanian version; 22 responses discarded). The teacher survey received 1036 valid responses (902 on the Macedonian version; 134 on the Albanian version; 294 responses discarded). The information gathered here indicates the perceptions of the respondents. It should be interpreted as what they would like to tell us about their school, their teaching and their learners. It provides a greater sense of the variety of contexts in which the new curriculum is being applied.

The key findings of principal survey results are:
• There is large variation in the size and social context of schools.
• Schools are well established with experienced teachers.
• Most schools have a clear majority language but in some regions over 30% of schools have notable numbers of learners who have a different first language.

The principal survey provides contextual information that supports the interpretation of information collected by other methods. Responses to the principal survey came from all regions of Macedonia. The Northeastern region was the least represented (n=12). Skopje was the most represented (n=34). Average number of teachers (from 9 in Southwestern to 14 in Polog) and the number of Grade 1–3 classes (from 9 in eastern to 13 in Polog). These class averages hide significant variation within regions which all had a mixture of small (2–6 classes) and large (13–23 classes) schools. Some basic arithmetic suggests that on average there is one teacher per 10 children across the three grades and the average class size is 11. These ratios are lower in Northeastern (6 learners per teacher) and higher in Polog and Southeastern (13 learners per teacher). It should be noted that there is tremendous variation in these figures within regions. Teachers are generally very experienced with all regions reporting that the average teacher has between 17 and 19 years teaching experience (standard deviation across all regions is eight years). Schools are generally well established and even the region with the youngest schools on average had an average school age of 46 years. Macedonian (79%) and Albanian (17%) are the most commonly- used languages in the 116 schools that responded to the question about languages. There was, unsurprisingly, significant variation between regions. Eastern and Vardar were predominately Macedonian speaking while Polog had more Albanian speakers.

Other regions were largely Macedonian speaking but with significant (10-25%) speakers of other languages. Turkish was most commonly spoken in the Southeastern region while Serbian is only spoken by 5% in the Northeastern region, where it is most common. However, there are two schools where Serbian is the first language of more than a quarter of learners. 20 schools reported having Turkish-speaking learners. In half of these, Turkish speakers make up more than 20% of learners, in a quarter of them they make up more than 80% of the school population. These schools are in a diverse range of regions (Eastern, Pelagonia, Skopje, Southwestern, Southeastern). In total, 27 schools reported that more than 10% of their learners do not share a first language with the majority of the school. Such schools accounted for 30% (i.e. 5–6 schools) of those that responded from Pelagonia, Polog and Southwestern regions. By contrast Eastern region only has one such school. The responses to the survey suggest that learners predominantly come from ‘middle- income’ families in all regions except Polog (where 53% learners are from low-income families). In all regions an average of 6–10% of learners are reported as coming from high-income families. Most schools reported that learners tend to leave at the end of compulsory schooling (50 of 116). Only Vardar and Southeastern regions had the majority of schools sending the majority of their learners to further education. A diverse range of employment sector for learners leaving Macedonian schools was reported (minimum of five different sectors reported within each region). However, the most common sector was reported as being agriculture and the food industry (n=66). The only regions for which agriculture was not the primary employment sector were Skopje.

The key findings from teacher survey are:

• Teachers are familiar with the new curriculum with some regional variation.
• Teachers are using the textbooks but are less familiar with them.
• Some of the issues with textbooks reported by teachers reflect the changes in pedagogy required by the new curriculum and the partial nature of the curriculum reform.
• Lack of language learning (particularly reading and writing) is a potential barrier to successful implementation of the new curriculum.

The responses to the Teacher survey came from all regions of Macedonia. Polog (n=66) and Vardar (n=69) were the least represented regions. All other regions registered over 100 responses and Skopje was the most represented region with 204 responses. Questions about teachers' prior experience were in line with the findings of the Principal survey with teachers from all regions reporting an average of 13-17 years' experience of teaching primary mathematics. Teachers reported having less experience teaching primary science (7 years less on average). The majority of teachers (88%) described their own level of learning as higher education. Teachers responding to the survey had been teaching all three grades of the new curriculum but in Eastern and Southeastern it was noticeable that fewer teachers had been teaching Grade 2 than had been teaching Grades 1 and 3. Teachers' initial responses to reform are always affected by their relative uncertainty with the new material they are being asked to teach and this is reflected in teachers' responses to questions about the new curriculum. There were ambiguous levels of satisfaction reported. Scaled from 0-1 (disagree to agree) teachers reported uncertainty about whether the new curriculum is interesting enough (0.48 down from 0.71 in May), whether it enabled progression (0.39 from 0.67), whether it is pitched at the right level (0.42 from 0.62), whether it is equally accessible in all languages (0.53 from 0.66) and whether it is easy to teach (0.44 from 0.65). It will be important to monitor these attitudes again after a period of time to see if opinion is shifting and whether a change to the implementation plan is necessary.

There was some regional variation. Teachers from the Eastern and Polog regions were generally more positive than others but still not rate any aspect higher than 0.58. Eastern and Vardar regions were notably less concerned about accessibility in all languages (these regions do not have the same diversity of languages as other regions). Most teachers thought that the curriculum provides a balance of skills and content (58%); fewer teachers thought it emphasized only content (18% compare to 27% when asked about the old curriculum) or skills (24% compared to 3%). Teachers reported being uncertain about finding resources to support the new curriculum (0.41; scaled from 0-1, not confident to very confident). As with the previous survey, teachers reported being happy using different types of resources but were less likely to use video material (down to 41%) compared to others (textbooks – 76%, practical equipment – 82%). Many teachers use ICT (61%) and a significant proportion use it 'often' or 'always' (56%). Only twenty teachers reported that they never use ICT (including at least one teacher from each region). It should be noted that these results are in conflict with the observations of the monitoring team who did not report ICT being used regularly. Teachers reported using the new textbooks and workbooks in equal measure (355-390 responding that they had used each subject/grade combination). There was more variation in the language versions that teachers had used. Most teachers (83%) had used the Macedonian versions and many (14%) had used the Albanian version. Only 28 teachers had used the Turkish version and five had used the Serbian versions. Whichever language version they had used, they saw the textbooks and schemes of work as important (scaled 0-1, not important to very important). The range was 0.61-0.76. The only document to fall outside this was the Albanian version of the schemes of work which only scored 0.40.

This is in conflict with other data that suggests that learners have responded more positively to the Albanian workbooks and textbooks (0.78, scaled 0-1) than others (Macedonian 0.53, Turkish 0.46 and Serbian 0.55). Also, most teachers (including those who have used the Albanian documents) report preferring the schemes of work to the textbooks and workbooks. The most common uses of the textbooks are to provide ideas for lessons (55%), to support the whole class as part of a lesson (52%) or for homework (53%). Only 5% of teachers said that they had not used the textbooks or workbooks at all. A particular challenge of implementing a new curriculum in a small number of subjects is that they may not immediately align with learning in other subjects. When teachers were asked what they would like to change about the new textbooks the majority of teachers commented on the appropriateness of providing textbooks to learners without the language skills to read or write and therefore access the content. This comment was particularly directed at Grade 1 textbooks but was also mentioned in terms of Grade 2 where teachers note the significant challenge for learners who have made the transition from Grade 1 of the previous curriculum to Grade 2 of the new curriculum.

European Science Education Projects that Supports New Science Curriculum in Macedonia

In Macedonian educational system are present lots of international project. One of the project that has a strong correlation with new science curriculum is EU portal, named as Scientix. Year after year, hundreds of science education projects are funded by the European Commission but apart from the persons directly involved in these projects (teachers, project managers, etc.) not many people hear about the results obtained, especially when the projects are over. The objective of the Scientix portal is to ensure that the knowledge and results of the projects reach a larger audience. In other words, Scientix was created to facilitate regular dissemination and sharing of know-how and best practices in science education across the European Union. The portal collects and disseminates teaching materials and research reports from European science education projects financed by the European Union. Launched in May 2010, the portal is targeted especially at teachers and schools, but also at other science educators, curriculum developers, policy-makers, researchers and EU stakeholders. It is a free-to-access and free-to-use portal, so that anyone interested in science education in Europe can join the Scientix community. Most of the content on the portal is accessible for all users, without registration. However, after registration, users are able to access some additional content, such as their personal pages, and use additional services, such as the forum and the chat tool, and request translations of the existing teaching materials. All users are encouraged to give feedback on the portal through the feedback tool, and thus to take part in developing the portal further. The philosophy of the portal can be summarized in the following keywords: “search, find, engage”. This motto emphasizes the shift from a central portal where information is disseminated to end users (who act in this case as passive users) towards a more dynamic and user-centered platform. Scientix thus should not be seen as an information transmission mechanism, but rather as a knowledge building platform. Scientix is managed by European Schoolnet (EUN) on behalf of the European Commission. European Schoolnet is a key player at EU level in education, representing a network of 31 Ministries of Education in the EU Member States and beyond. EUN provides major European education portals for teaching, learning and collaboration and leads the way in bringing about change in schooling through the use of new technology.

Science Project of EU that can be found on Scientix Platform

As previously mentioned Scientix collects and distributes information about past and present science education projects carried out in Europe. Priority is given to projects funded by the European Commission, but other publicly funded projects are accepted as well. Projects accepted for Scientix must provide accurate information on the project goals, research and results, and preferably also links to the public reports and resources developed in the project. These are displayed on the Scientix portal, in both the Projects and Resources sections. Project authors are also invited to promote their events and news (e.g. new publications and calls for conference speakers) through the Scientix portal. Examples of currently active projects which are included in the Scientix portal can be found below. As most of them had just started at the time of this publication, their final results or achievements are not available yet. However, these will be updated on the Scientix portal at a later stage.

Projects on Scientix Portal

Places

Developing the concept of the European City of Scientific Culture, the PLACES project facilitates cooperation between science communication institutions and local authorities. The project focuses on developing and strengthening City Partnerships, bringing together 67 science centres, museums and festivals (each partnering with local authorities) and ten European regional networks. The partnerships provide a basis to foster interactions between science centers / museums, science festival / events and universities on one side and cities / local authorities on the other. PLACES puts emphasis on topics and issues with social relevance (e.g. environmental sustainability, ageing populations, healthcare, social security, drinking water, agriculture, biodiversity, transportation, clean energy, education policies, innovation for economic growth) which allow citizens to engage in dialogue with researchers and local authorities.

Temi

The project (2013-2016) introduces inquiry-based learning (IBS) into the science and mathematics classroom using magic tricks, myths and mysteries. TEMI is a teacher training project, working with teacher training institutions and teacher networks across Europe to implement innovative training programmes – inquiry labs.

The Enquiry labs are based around the core scientific concepts, but use local myths and mysteries to explain them. The labs are supported by scientists and communication experts to guide teachers through the transition to use inquiry in science teaching. The TEMI Central hub coordinates the activities of the local training centers and provides a platform to share best practice across all aspects of the project.

Cyber-Mentor

CyberMentor is an e-mentoring programme for girls and young women ages 12–18 in Germany designed to foster their participation in science, technology, engineering, and mathematics (STEM). Each female student (mentee) is paired with a professional woman in STEM, i.e. a researcher, a professor, or an engineer, (mentor) who informs and advises her. CyberMentor offers an online platform which provides communication possibilities and helpful suggestions for STEM activities and information on STEM courses of study and professions. Community members can introduce themselves through personal pages and interact regularly via e-mail, chat, or discussion forum for the period of one year with their mentoring partner and with all programme participants. Discussion topics range from specific scientific questions about the mentors' work to private matters. Each year, at least 800 girls and 800 women take part in the programme. Having so many other students and mentors as contact persons offers a great possibility for information exchange. In order to encourage engagement within the platform, the CyberMentor management team regularly makes suggestions for STEM-related experiments, activities, and competitions that participants can work on together. CyberMentor edits a monthly journal, CyberNews, which offers reports on interesting STEM articles, quizzes, and interviews with professionals in the STEM-Field.

Inspiring Science Education

Inspiring Science Education is a project aimed at providing resources and opportunities for teachers to make science more attractive to their students. The project includes:

- an online portal that provides an interactive inventory of e-learning tools and resources from research centers and other facilities;
- communities of practice as the place where the collaboration between teachers and students will take place.

The project will be implemented through pilot activities that will take place in 5.000 primary and secondary schools in 15 European countries. The schools will be selected to participate in piloting the project tools and resources through case studies developed in cooperation with the local teachers.

Science on Stage Europe

Science on Stage is a European initiative designed to encourage teachers from across Europe to share good practice in science teaching. Innovative and inspirational science teaching is seen as a key factor in attracting young people to deal with scientific issues, whether or not they finally choose a career in science. Hence, Science on Stage aims to stimulate the interest of young people through their school teachers, who can play a key role in reversing the trend of falling interest in science and current scientific research. Ultimately, the aim of Science on Stage is to enable teachers to deliver science in a more creative and engaging way.

e-Twinning

The eTwinning community for schools provides teachers across Europe with the opportunity and the tools for collaboration in math, science and technology education projects. eTwinning promotes collaboration between schools in Europe through the use of Information and Communication Technologies (ICT). The community provides support, tools and services to make it easy for schools to form short- or longterm partnerships in any subject area, and thus to improve and develop teachers' practices and education in Europe. Additionally, eTwinning provides Professional Development Workshops and Learning Events where teachers can learn more about eTwinning and develop their skills in using ICT in teaching.

Go-Lab

Go-Lab (2012-2016) has created an infrastructure (the Go-Lab Portal) to provide access to online laboratories run by research centers and universities worldwide. These online labs can be used by universities, schools, instructors, students and lifelong learners to extend regular learning activities with scientific experiments, giving students a real experience of research work. The Go-Lab Project offers a federation of remote laboratories, virtual experiments, and data-sets (together referred to as “online labs“), as well as facilities for teachers to embed these online labs in pedagogically structured learning spaces.

E-Bug

e-Bug is a free educational resource repository that makes learning about micro-organisms, antibiotics and hygiene fun and easy. e-Bug helps to teach children about the different types of microbes, the activity of antibiotics against them, and the increasing problems of antibiotic resistance with unnecessary use, and thus to raise awareness of wise antibiotic use. The e-Bug project aims to • Reduce the incidence of antibiotic resistance across Europe by educating future prescribers and users on prudent antibiotic use;

- Complement national antibiotic and hygiene educational campaigns;
- Exchange information and experience of good practice in the educational curriculum with European partner countries, and
- Translate and implement the e-Bug resources across Europe in close collaboration with local Ministries of Health and Education.

Profiles

PROFILES promotes Inquiry-Based Science Education by raising teachers’ awareness of more effective ways of teaching, with the support of various science education actors. The project aims to work towards a better understanding of the changing purpose of teaching science in schools and the value of science education stakeholders’ networking. PROFILES is based on “teacher partnerships” aiming to implement existing inquiry-based science teaching materials. Long-term teacher training courses reflecting challenges relevant to the participants raise their skills in developing creative, scientific problem-solving and socio-scientific related learning environments, which enhance students’ intrinsic motivation to learn science and their individual competences such as decision-making abilities and abilities in scientific inquiry. The intended outcome of PROFILES is that science education becomes more meaningful for students and more strongly related to 21st century science and Inquiry-Based Science Education (IBSE), and thus fosters students’ scientific literacy.

Science: It’s a Girl Thing

A pan-European awareness campaign to encourage girls to develop an interest in science and engage young women in scientific research careers. This reflected Commissioner Geoghegan-Quinn’s commitment to promote gender equality and the gender dimension in research and innovation. With the slogan “Science: it’s a girl thing!”, the first phase of the campaign targeted girls aged 13 to 18, aiming to challenge stereotypes around science and show girls that science can be a great opportunity for their future.

Responsible Research and Innovation

Responsible (RRI) implies that societal actors (researchers, citizens, policy makers, business, third sector organizations, etc.) work together during the whole research and innovation process to better align both the process and its outcomes with the values, needs and expectations of society. In practice, RRI is implemented as a package that includes multi-actor and public engagement in research and innovation, enabling easier access to scientific results, the take-up of gender and ethics in the research and innovation content and process, and formal and informal science education.

Conclusion

Macedonian new science curriculum is in the process of implementation of the second developing period, based on proposed reforms suggested by Cambridge international examination center, approved by Ministry of education and science and Bureau for developing of education. The BDE advisers and Cambridge consultants conduct monitoring process through interviews, surveys and conversations on the field after first year of new curricula implementation. Based on monitoring and observations process, were noted positive attitudes, work ethic and recognition of need for change. But, still, the teachers do not seem to have the necessary level of subject and pedagogical knowledge for learners to benefit fully from the new curriculum. There is no evidence so far of a shift away from content-focused to skills-focused lessons or any shift in the level of expectation. As many principals have not attended the training events they are not aware of the challenges presented by the new curriculum. During the visit the monitoring team from BDE and Cambridge team made the following observations of the changes needed in respect of pedagogy, attainment and attitudes:

- A greater variety of teaching styles are needed where the focus is more on the children learning than the teachers teaching. Learners should have more autonomy to complete work themselves.
- Practical work should focus on exploratory and investigative work that will develop skills e.g. accuracy of measurement or planning an investigation.
- There should be more group work. Learners often sit in groups but continue to work individually on tasks. This does not encourage them to discuss how to approach the task or solve the problems presented to them.
- Teachers should be encouraged to reflect on their teaching practice. This will help them to review their teaching in the light of how well the children have progressed in their learning.
- Learners are positive about science and are well-behaved and focused on their work. However, they need to be given more autonomy within the tasks they carry out to develop a resilience and commitment to problem solving. Learners need exposure to a range of strategies to enable them to start developing the decision making process needed for higher order thinking.

As additional support to the new science curriculum is the EU Scientix portal that was launched in May 2010. Since then, it has proven to be a very successful portal, which attracts users to search for science education projects and studies, browse and download reports, resources and tools, and use the communication and translation services provided. Most teachers are looking for project information, news and teaching materials, and they are generally happy with the content and resources that they found. Scientix is gradually growing as more and more projects join the community and share their resources and materials through the portal, which is also constantly updated and developed to display the current status and latest results of the projects, and to fulfill the needs and wishes of the users. Scientix is all the time looking for new educational initiatives to join its community to demonstrate new ideas and good practices for science education in Europe and Macedonia as well.

References

Ацеска, Н. & Вучиќ, В. (2007). *Иднината е во сегашноста*, прирачник за еколошко образование и одржлив развој, Универзитетска библиотека Св. Климент Охридски, Битола

American Association for the Advancement of Science. (2003). *Middle Grades Science Textbooks*: A Benchmarks-Based Evaluation.http://www.project2061.org/publications/textbook/default.htm

Christian M.S. (2013), *Learning Innovation and Quality: The future of Digital Resources, Proceedings of the European and International Conference LINQ 2013*, Rome, Italy, 19-17 p. 43-51.

Duschl, R., Schweingruber, H., & Shouse A. (2007). *Taking Science to School: Learning and TeachingScience in Grades K–8*. Washington, DC: The National Academies Press.

Foley, B.J. & McPhee, C. (2008). *Students' attitudes towards science in classes using hands-on or textbook based curriculum*. Paper presented at the 2008 Annual Meeting of the American Educational Research Association, New York, NY3 Franklins, Wilfred *A. Inquiry Based Approaches to Science Education: Theory and Practice*. http://brynmawr.edu/biology/franklin/InquiryBasedScience.html

Gras-Velázquez, À., Schwarzenbacher, B., Tasiopoulou, E., Debry, M., Bargoin, M., Kudenko, I. & Hernández, M. (2013). *The Scientix Observatory*: Online Communication Channels with Teachers and Students – Benefits, Problems and Recommendations

Gérard, E. & Snellmann, J. (2011). *Scientix - the Community for science education in Europe, Directorate-General for Research and Innovation, Capacities Specific programme*.

Harlen, W. (2001). *Primary Science: Taking the Plunge - 2nd edition.* 160 pp Heinemann, UK,

Harlen, W. (2004). *Enseigner les sciences: comment faire?* Collection *La main à la pâte,* Le Pommier Eds, 220 pp.

Концепција за деветгодишно основно воспитание и образование, (2007). Министерство за образование и наука и Биро за развој на образованието, Скопје

Извештај за образование за одржлив развој во Република Македонија, (2011). Македонски центар за граѓанско образование, Скопје

Llewellyn, D. (2002). *Inquire Within: Implementing Inquiry-Based Science Standards*, CorwinPress.

Linn, M., Davis, E., & Bell, P. (2004). Internet Environments for Science Education. Mahwah, NJ: Lawrence Erlbaum Associates.

National Academies Press (2007). *On Evaluating Curricular Effectiveness*: Judging the Quality of K-12 Mathematics Evaluations.http://www.nap.edu/openbook/0309092426/html/index.html

National Assessment of Educational Progress (2005). *Average Scores in 2005 Higher at Grade 4, Unchanged at Grade 8, and Lower at Grade 12 Since 1996.* ttp://nationsreportcard.gov/science_2005/s0102.asp?printver=

O'Donnell, C. (2007). *Research on the Effectiveness of Inquiry-based Science Programs: Changing the Course of Science Education*: National Leadership Development Symposium. Based on data from the NAEP Data Explorer.

O'Sullivan, C.Y. & Weiss, A.R. (1999). *Student Work and Teacher Practices in Science. Education Statistics Quarterly*.1.2 http://nces.ed.gov/programs/quarterly/vol_1/1_2/3-esq12-f.asp

O'Donnell, C. (2007). *Research on the Effectiveness of Inquiry-based Science Programs: Changing the Course of Science Education: National Leadership Development Symposium*. Based on data from the NAEP Data Explorer.

Velek, P. & Perez Rubio, V.J. (2013**)**. Sharing Open Educational Resources in Multilanguage Repositories - the Learning Resource Exchange and Scientix.

Journal of Education in Science, Environment and Health
Volume 2, Issue 1, 2016 ISSN: 2149-214X

Science Education: Beyond a Liminal Understanding of Knowledge Production and Dissemination

Sandra Abegglen*, Jessie Bustillos
London Metropolitan University

Abstract

The present paper is a case study based on a first year BA Hons Education Studies module that explores a number of important questions about the relationship between technology, knowledge and society and begins to think about how our ideas about each of these contribute to an understanding of what education means. Following a Foucauldian perspective on discourse, truth and power, we look with our students at science – and science education – to explore the production of knowledge in a context where many initiatives promote scientific literacy for children and young people as an important factor in their educational upbringing. The paper argues that it is important to reflect with students on these forms of knowledge production and dissemination and so to avoid seeing and teaching science purely from a consumerist perspective; rather we embrace and develop the idea of science education as a discourse that shapes our understanding of the world and ourselves.

Key words: Science education, Knowledge production, Discourse, Power, Foucault

Introduction

Science and Science Education

Science, in one form or another and intermittently, has been “a subject” at school level in many countries for centuries. However, this has not always been the case. In the past, science education was confined to a few seriously devoted people. As Das (1985) argues, this might have been the case because in the past science was considered as an inferior subject to study. In addition, ‘[n]ew ideas or inventions in science were not immediately accepted in the society and were looked upon with suspicion’ (Das, 1985, p. 3). For example, the idea that the sun was the centre of the Solar System advanced by Copernicus and developed by Galileo and Newton was, for a long time, regarded as controversial, especially by the Roman Catholic Church. This led to the idea that science, and especially scientists, were not to be trusted. Hence, science education, for a long time, was not considered relevant for “the masses”.

Now, we cannot think of a world without science. Science has become an integral part of our life and living. ‘There’s no aspect of man’s life today which has not been influenced by science one way or the other’ (Das, 1995, p. 2). Hence, in recent years, science education has become increasingly important, with the subject forming an essential part of school curricula. ‘Teaching of everyday science for everybody has become an unavoidable part of general education’ (Das, 1985, p. 2). As a result, new guidance has been developed that encourages schools to put science education at the centre of their attention. For example, in England the revision of in the ‘National Curriculum’ has put science as a subject in the foreground. The changes resulting from this revision come into effect for all Key Stage 1 and Key Stage 2 pupils from September 2015, and for pupils in Year 11 from September 2016 (Department for Education, July 2013).

The new ‘National curriculum in England: Science programmes of study’ states that ‘...all pupils should be taught essential aspects of the knowledge, methods, processes and uses of science‘ (Department for Education, December 2014). This means, pupils should learn to understand the world through the specific disciplines of biology, chemistry and physics. ‘They should be encouraged to understand how science can be used to explain what is occurring, predict how things will behave, and analyse causes’ (Department for Education, December 2014). The aim is to ensure that all pupils:

- ‘develop scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics;

* Corresponding Author: *Sandra Abegglen, s.abegglen@londonmet.ac.uk*

- develop understanding of the nature, processes and methods of science through different types of science enquiries that help them to answer scientific questions about the world around them;
- are equipped with the scientific knowledge required to understand the uses and implications of science, today and for the future' (Department for Education, December 2014).

For children in Key Stage 1 – the two years of schooling in maintained schools in England normally known as Year 1 and Year 2, when pupils are aged between 5 and 7 – this means to experience and observe phenomena by looking more closely at the natural and humanly constructed world around them. They are encouraged 'to be curious and ask questions about what they notice' (Department for Education, December 2014). Older children – upper Key Stage 2, Year 5 and 6 – are encouraged to develop a deeper understanding of scientific ideas: '...they should encounter more abstract ideas and begin to recognise how these ideas help them to understand and predict how the world operates' (Department for Education, December 2014). In Key Stage 3 – the three years of schooling in maintained schools in England normally known as Year 7, Year 8 and Year 9, when pupils are aged between 11 and 14 – pupils are encouraged 'to relate scientific explanations to phenomena in the world around them and start to use modelling and abstract ideas to develop and evaluate explanations' (Department for Education, December 2014). They should learn to pay attention to objectivity and develop concern for accuracy, precision and repeatability.

Although the UK Government – with the new curriculum – envisages schools and teachers taking greater control over what is taught in schools and how it is taught, using their professional skills and experience to provide the best educational experience for all their pupils, the new 'National curriculum in England: Science programmes of study' provides quite detailed guidance on the topics to be covered by schools. For example, in the Year 1 programme of study children should learn to:

- 'identify and name a variety of common animals including fish, amphibians, reptiles, birds and mammals;
- identify and name a variety of common animals that are carnivores, herbivores and omnivores;
- describe and compare the structure of a variety of common animals (fish, amphibians, reptiles, birds and mammals including pets)' (Department for Education, December 2014).

Hence, many feel that with the new science curriculum there is 'a shift towards hard facts and "scientific knowledge"' (BBC News, September 2014). Others argue that the new science curriculum is 'a "two-tier curriculum" favouring the core subjects of English and Maths at the expense of the arts and humanities' (The Independent, September 2013). However, in general it seems as if the new curriculum follows what Hodson (1993) has pointed out as the three main purposes of science education, that is, to come 'to understand the major achievements of science', the concepts, the models and the theories, 'to learn about science', to develop an understanding of the nature and methods of science, and 'to learn to do science', involving modelling and model testing – although some argue that the main purpose of science education in schools should be 'to increase the flow of specialist scientists, technologists and engineers' (The Association for Science Education, The Economic & Social Research Council & The Teaching and Learning Research Programme, 2006): a sort of sensitization and pre-professional training.

The purpose of this paper is to reflect critically on current science education with the help of a case study example in order to develop a more critical understanding of what science education might mean for "future educators". The paper argues that – in the light of the new English National Curriculum – the teaching of scientific knowledge should be more than the presentation of facts and figures, following Millar and Osborne (1999, para 4.2), who argue that '[t]he science curriculum from 5 to 16 [years] should be seen primarily as a course to enhance general "scientific literacy"'. This means that educators need to be able not only to teach scientific facts and figures, but also to raise questions of truth and power in relation to the subject itself in order for their pupils to recognize that scientific ideas change and develop over time. In our module, we use the Foucauldian theoretical position which focuses on discourse and its power to produce "truths"; we use this as a heuristic tool that future educators can use to diversify the teaching, learning and public understanding of scientific knowledges. We argue that it is therefore important not only to introduce prospective educators to science as a discrete subject area, but also to make them aware of the importance of discourse in shaping our understanding of the world and ourselves within it.
Here we follow Foucault, who argued that social processes are shaped (or constructed) in and by discourse, and in modern societies scientific discourse is highly valued and authoritative, which in turn points to existing power relations.

Foucault: Discourse, Truth and Power

In our teaching we follow a Foucauldian perspective to explore the aims and objectives – and also implications – of science education with our students. We chose this approach because the concept of discourse allows us to re-pose questions about science education, and to explore the implicit and explicit power relationships at work when speaking about science as a subject. As Foucault (1981, p. 52) argues:

> 'In every society the production of discourse is at once controlled, selected, organised and redistributed by a certain number of procedures whose role is to ward off its powers and dangers, to gain mastery over its chance events, to evade its ponderous, awesome materiality'.

Following from this, it is noticeable how knowledge should not be taken for granted and how through discourse we can elicit some of the pre-conditions to knowledge acquisition, validation and distribution in particular space-time continuums. Consequently, through atomising the notion of discourse, we can encourage our students to problematise scientific discourse-pervaded knowledges and to become more epistemologically relativistic about the subject of science and what the effects of those knowledges might be.

Theoretically, discourse, as argued by Foucault, transcends desire and institutions. Desire in relation to discourse is then understood as that subjective (circumstantial and often contextualised) position that we might find ourselves in; in any given moment we are juxtaposed and immersed with discourse(s). The institution, as Foucault (1981, p. 52) points out, is ontologically dependent on the production of a particular discourse; it replies to the individual by saying:

> '…we are all here in order to show you that discourse belongs to the order of laws, that we have long been looking after its appearances; that a place has been made ready for it … and that if discourse may sometimes have power … it is from us and us alone that it gets it'.

Significantly, the institution's very own sense of existence is permeated by discourse production; the institution then tries to control discourse, and its production and distribution (or dissemination), yet, discourse has a more subversive and insidious power, which permeates desire (subjectivity) and institution (objectivity). Discourse in itself could then be understood as symbolically, representationally, semantically and concretely forming and constructing the objects of which it speaks and in doing so it finds itself outside subjective and objective positions. This means the study of discourse, as explored by Foucault, is linked to the historical institutions that embrace it, give it a voice, silence it or disregard it; discourse then forms not only the objects of a particular reality, but also determines how that reality is formed. Discourse creates knowledges and "truth"; it creates "a world" that is both palpable and also transformative.

For instance, if we take Foucault's example of the historical opposition between reason and madness as represented by the 'madman' and his speech, we can appreciate how the scientific knowledges of psychiatry and psychoanalysis have emerged as a result of the continuous decoding of the evolving discourses around madness. But in this decoding there is still a very definite oppositional production of the conditions and characteristics associated with states of reason and madness. Foucault (1981, p.53) states:

> 'Since the depths of the Middle Ages the madman has been one whose discourse cannot have the same currency as others. His word may be considered null and void, having neither truth nor importance … It was through his words that his madness was recognised, they were the place where the division between reason and madness was exercised, but they were never recorded or listened to. No doctor before the end of the eighteenth century had ever thought of finding out what was said, or how and why it was said … He [the madman] was only symbolically allowed to speak, in the theatre, because there he played the role of truth in a mask'.

This extract is pointing to how, although the madman's speech was discredited, it still held a credited position within the institution of the theatre; there on the stage, was the madman's place of worth, where his madness became mysticism and curse but still in its most rational form. Yet, it could be argued that this discourse is understood and decoded very differently now that the madman's speech is no longer sitting easily on one side of the divide between reason and madness. This is because this discourse is now decoded by other modern knowledge-institutions which no longer immediately discredit the madman's speech; rather it has significance in '...that it puts us on the alert; that we now look for a meaning in it...' (Foucault, 1981, p. 53). The extract is further referring to the development of a whole system of knowledge, knowledge-institutions and knowing-subjects (people) who are now responsible not only for articulating the 'madman's speech' but also for diagnosing and treating it. Of these knowledge frameworks we only need to think '...of the whole network of institutions which permit someone – a doctor or a psychoanalyst – to listen to it, and which at the same time permit the patient to bring along his poor words or, in desperation, to withhold them' (Foucault, 1981, p. 53).

Following this example, it is argued that the madman's speech is the iconic representation which allows the institution to present possibilities for decoding it, it is not the subject, in this case the madman, per se, neither just the institution itself. Instead all these elements are interwoven and harnessed together by discourse; it is discourse which forms, transforms, validates and configures the institution, leading to the arrangements of "the subject". These arrangements and designs in subjects are particularly infused by scientific discourses, and by the institutions which are seen as responsible for actualising these discourses, as the example explored above explains.

In our teaching we use this Foucauldian understanding of discourse to analyse critically and re-pose questions about specific parts of scientific knowledge, and what the acquisition of these knowledges have allowed us to make of ourselves as part of a changing society, underpinned by varying and changing discourses. The problem that we present to students is not to do with drawing the line between truth and something else; in fact, the notion of discourse is pointing beyond this long-standing true-false opposition. Foucault (1994, p. 119) asserts that:

> '...the problem does not consist in drawing the line between that which, in a discourse, falls under the category of scientificity or truth, and that which comes under some other category; rather it consists in seeing historically how effects of truth are produced within discourses that, in themselves, are neither true nor false'.

Within this understanding we can open up possibilities to discuss scientific knowledge as discourse that is pervaded by power relations.

We, the authors of this paper, believe that conceptions of discourse and power relations are important theoretical tools which can help students to understand how we are in a state of flux – societally and culturally – and that the analysis of discourses can give a powerful indication as to how societal and cultural change is created and effected. Therefore, in the module 'Culture, Curriculum and Technics', we are moving students beyond what is normally covered in a first year undergraduate course by introducing them to evaluative, theoretical tools that help them understand that all systems of knowledge are subject to debate. These systems of knowledge are, as Foucault (1994, p.131) states, neither outside of power nor 'lacking in power'. Following this view, we argue that systems of knowledge are systems of power because of the types of discourses that they are formed by and these discourses operate in exclusionary ways. Consequently, science education needs to have a strong and discernible criticality looking at the very

> '…mechanisms and instances that enable one to distinguish true and false statements; the means by which each is sanctioned; the techniques and procedures accorded value in the acquisition of truth; and the status of those who are charged with saying what counts as true' (Foucault, 1994, p. 131).

In the light of this, science education can be regarded as a particular discourse of science and its truths, but ultimately, and following a Foucauldian perspective, is neither true nor static; it is infused with economic, political, social and ideological traits of our time. Conceivably, science education and education in itself are manifestations of discourses and knowledge systems.

Case Study: Education Studies

For the purpose of this paper and to interject science education with a social science perspective we, the authors of this paper, decided to illustrate the contribution of discourse through this selected case study. Both of us teach on the BA Hons Education Studies at London Metropolitan University (UK). The BA Hons Education Studies takes education as a study object. This means, the course tackles philosophical questions concerning the place of education in the modern world as well as the detail of everyday professional practice in schools and other educational institutions. Hence, it addresses philosophical, sociological, epistemological and historical aspects of learning and teaching against the backdrop of education as part of changing societies. Through that, it prepares students for a range of socially responsible professional roles in a variety of settings – including primary, secondary and adult education, youth and community work and health and social care.

Students on the course traditionally come from a broad range of backgrounds, with many students choosing the course as a second pathway into professional teaching. As Blagburn and Cloutterbuck (April 2011) point out, London Metropolitan University (UK) is made up of almost 50 per cent non-traditional students. This is confirmed by internal statistics that show that the majority of students on the course come from a working-class and/or ethnic minority background. This means, students on the course have mixed abilities and interests – with many being unfamiliar with the theoretical frameworks used in academia – and science. They are 'outsiders' compared with ‘those who know how the system works’ (Pratt-Adams et al., 2010). Despite this, we like to challenge and develop their personal learning and understanding.

One of the first modules students on the course need to undertake is ‘Culture, Curriculum and Technics’ – a 30 Credit Level 4 core module that runs over 30 weeks, from September until May. The module was introduced in 2012 as part of a broader restructuring of the BA Hons Education Studies. The aim of the module is to present a range of theoretical perspectives and tools to students, which they can use to analyze a curriculum as a socio-cultural construction – and which also enable them to identify ways in which knowledge is produced, reproduced and transmitted. It is hoped that this enables students to move beyond a simplistic understanding of a curriculum as a set of subjects that need to be covered in a certain period of time towards a critical appreciation of knowledge and knowledge production in educational settings – including schools.

The module content is organised in blocks, six in total, which all address a specific question. These blocks are as follows:

- Block 1: What do we mean by culture?
- Block 2: What counts as knowledge and why do we educate?
- Block 3: How does representation construct knowledge?
- Block 4: How will new media technologies transform knowledge and education?
- Block 5: workshop project (Wiki workshop)
- Block 6: Does the Anthropocene have a future?

This means that the module does not introduce students to educational subjects as such, but rather encourages students to think critically about records and information: objects, evidence and interpretation: and stories, narratives and meaning. Students – in the sense set out by Vivianne Burr (2003) – are encouraged to ‘take a critical stance toward our taken-for-granted ways of understanding the world, including ourselves’. This means, students are encouraged to see science as a ‘set of practices’ – following Stuart Hall’s (1997) approach to culture. As Hall (1997, p. 2) in relation to culture states: ‘Primarily, culture is concerned with the production and exchange of meanings - the “giving and taking of meaning” – between the members of a society or group’. Equally science – and science education – could be seen as a driving force for the creation and representation of our knowledge about the world we live in and ourselves.

It is in this context that students are introduced to the notion of discourse, which we define in a Foucauldian sense as ‘…a group of statements which provide the language for talking – a way of representing the knowledge about – a particular topic at a particular historical moment*’* (Hall 1992 cited in Hall 2004, p. 72). This leads to the argument that knowledge might not be absolute but rather provisional and that what is presented in a curriculum represents selections from the knowledge available in any particular culture at a given point in time. The module therefore moves beyond seeing science as a pure subject to be mastered by prospective educators; rather, it focuses on the subject of science itself to open up questions encouraging students to think more holistically about knowledge creation and dissemination. Crucially, this approach envisages science education as needing to be creative and innovative – and challenging current perceptions and approaches of students as well as teachers.

Teaching Practice: Introducing the Notion of Discourse

Introducing students to Foucault’s work and the notion of discourse carries its challenges, especially as most students on the module are unfamiliar with the work of social theorists – and theoretical concepts such as power and knowledge. We tackle this problem by using a constructivist approach to getting students to think about the world they are living in. First, we encourage students to think about the world around them: ‘How do humans shape the world around them? And how are they shaped the world around them?’. By doing that we hope to move them from an objectivist viewpoint to a positioning whereby they realize that culture is not a set of things, but ‘… concerned with the production and exchange of meaning – “the giving and taking of meaning” – between the members of a society or a group’ (Hall, 1997, p. 2).

However, early on we try move our students beyond a “simple reflection” on their experiences and worldview by asking them: ‘Why is it important to think about these things?’, a kind of meta-reflection on our sessions. We argue with our students that it is important to think about the world they are living in and their perception because it consists of concepts and ideas that shape what they “believe” and how they interact with the world around them. In this context we argue that '… language is the privileged medium in which we "make sense" of things, in which meaning is produced and exchanged' (Hall, 1997, p. 1). This leads us to the idea that language acts as a representational system; it stands for or represents to other people our ideas and feelings. This means, following a constructivist tradition, we do not simply perceive the world as it is, but we are "making sense" of our perceptions with the help of language.

To bridge the gap between the idea of language as a means to interpret and re-present our lived experience, and discourse as a theoretical tool to reflect on science education, we use the idea of 'knowledge technologies'. Knowledge technologies, as we use and understand them in our teaching, are assemblages in the sense of Deleuze and Guattari (1987), which can extend our understanding of the world and how we come to learn about the world. Some of these, which are explored and developed in the module, are: time, mathematics, the printed word and maps and cartography – and also digital technologies, including social media, and scientific ways of looking at the world such as biology, chemistry and physics. In reference to science, we invite a science communicator into our classroom to illustrate to students how scientific ideas and their perception change over time – and also how these ideas shape our worldview.

Further, we look with our students at how scientific ideas and discoveries are communicated to the general public at a particular point in time. In this context, we also explore how schools tackle scientific ideas and discoveries. As an example we look at the idea of evolution and its representation in educational policies. For example, the new UK National Curriculum (Department for Education, December 2014) states:

> 'Pupils should be taught to:
> - recognise that living things have changed over time and that fossils provide information about living things that inhabited the Earth millions of years ago
> - recognise that living things produce offspring of the same kind, but normally offspring vary and are not identical to their parents
> - identify how animals and plants are adapted to suit their environment in different ways and that adaptation may lead to evolution'.

With the help of these examples we introduce our students to the notion of discourse, the idea that '…a group of statements which provide the language for talking a way of representing the knowledge about a particular topic at a particular historical moment' (Hall, 1992, p. 291). We argue that discourse, in the sense of Foucault, is not purely a mode of speech that presupposes a founding subject. It provides the very '…space of emergence determined the possibilities for speech and speaking subjects' (Clifford, 2001, p. 182); in doing this discourse surpasses the individual and the structures but instead infiltrates itself, becoming structured and structuring. In this context science and science education can be seen as systems of representation that generate "knowledge" and "truth" – fluid and versatile, but nevertheless bound to existing systems of knowledge and their underlying power relations. Hence, we tell our students, it is important that we do not base science education on the teaching of facts and figures, but rather embrace the idea of science as a discourse that shapes our understanding of the world and ourselves.

Conclusion and Recommendations

In this paper, by looking at science in the context of an Education Studies module, we, the authors of this paper, have evaluated practically the objectives and some of the new developments in science education curricula, and theoretically explored the possible contributions of using the concept of discourse to approach the emergence and prevalence of scientific systems of knowledge. We have argued that these scientific knowledge-systems are producers of reality and do not occur disentangled from power relations. Following a Foucauldian perspective we have also alluded to how these discourse-based producers of reality are not inherently producing truths, but rather, effects of truths. As a result of these explorations we argued that the education of prospective educators needs to move beyond fact-bounded pedagogy and approximate towards a more constructivist understanding of the subject area of science.

In practice this means to encouraging students to de-essentialize curricula in order to become holistic pedagogues: to "provisionalize" knowledge in order to be critically aware of its effects: and to understand the changeable, shifting, fluctuating and dynamic nature of societies. These myriad effects, changes and moves – discussed within the module – occur as part of a wider culturally, technologically and ideologically changing paradigm. The approach we have taken with our students is to question critically traditional concepts and pedagogies, by presenting to them conceptual tools such as discourse, power relations and constructivism that afford them the opportunity to reflect on these macro and micro level topics.

Consequently, as Wellington (2005, p. 107) states: 'The essential bridge that needs to be built [is] between the world of experiences (the phenomenal) and the world of explanation (the conceptual or theoretical)…'. We propose that to bridge this gap students need to be given the opportunity to deal with metaphor, theory and the abstract but at the same time the concrete, experiential and practical, not in an atomized and disjointed manner but rather by understanding them as an interconnected, inseparable and unfolding continuum.

Acknowledgment

The authors thank David Blundell who is Course Leader for the BA Hons Education Studies and has played a vital role in the development of the module Culture, Curriculum and Technics – and still is an important contributor to its delivery.

Paper based on a presentation given at the International Conference on Education in Mathematics, Science & Technology (ICEMST2015).

References

BBC News (September 2014). *How is the national curriculum changing?*. Retrieved April 20, 2015 from http://www.bbc.co.uk/news/education-28989714.

Blagburn, P. & Cloutterbuck, S. (April 2011). A multi-disciplinary approach to retention and drop out: A response to institutional concerns. In: University of Lower Silesia (Eds.) *Access and retention: Experiences of non-traditional learners in Higher Education*. Retrieved April 20, 2015 from http://www.dsw.edu.pl/fileadmin/www-ranlhe/files/Blagburn_et_al.pdf.

Burr, V. (2003, 2nd Edition). *Social constructionism*, London: Routledge.

Clifford, M. (2001). *Political genealogy after Foucault: Savage identities*. New York: Routledge.

Das, R. C. (1985). *Science teaching in schools*. New Delhi: Sterling Publishers.

Deleuze, G. & Guattari, F. (1987). *A thousand plateaus: Capitalism and schizophrenia*. Minneapolis: University of Minnesota Press.

Department for Education (December 2014). *Statutory guidance. National curriculum in England: Science programmes of study*. Retrieved April 20, 2015 from https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study/national-curriculum-in-england-science-programmes-of-study.

Department for Education (July 2013). *The national curriculum in England: Framework document*. Retrieved April 20, 2015 from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210969/NC_framework_document_-_FINAL.pdf

Foucault, M. (1994). Truth and power. In: Faubion, J. D. (Eds.) *Michel Foucault power: Essential works of Foucault 1954 - 1984*. London: Penguin, pp. 111-133.

Foucault, M. (1981). The order of discourse. In: Young, R. (Eds.) *Untying the text: A post-structuralist reader.* London: Routledge and Kegan Paul, pp. 51-78.

Hall, S. (2004). Foucault: Power, knowledge and discourse. In: Wheterell, M., Taylor, S. & Yates, S. (Eds.) *Discourse, theory and practice: A reader*. London: Sage, pp.72-81.

Hall, S. (1997). *Representation: Cultural representations and signifying practices*. London: Sage.

Hall, S. (1992). The West and the rest. In: Hall, S. & Gieben, B. (Eds.). *Formations of Modernity*. Cambridge: Polity Press/The Open University.

Hodson, D. (1993). Re-thinking old ways: Towards a more critical approach to practical work in school science. *Studies in Science Education*, 22, pp. 85-142.

Miller, R. & Osborne, J. (1998). *Beyond 2000: Science education for the future*. London: King's College London, School of Education. Retrieved April 20, 2015 from http://www.nuffieldfoundation.org/sites/default/files/Beyond%202000.pdf

Pratt-Adams, S., Burn, E., Adams, M. M. & Race, R. (2010). *Changing urban education*, London: Continuum.

The Association for Science Education, The Economic and Social Research Council & The Teaching and Learning Research Programme (2006). *Science education in schools: A commentary by the Teaching* *and Learning Research Programme*. London: TLRP, Institute of Education. Retrieved April 20, 2015 from http://www.tlrp.org/pub/documents/TLRP_Science_Commentary_FINAL.pdf

The Independent (September 2013). *Michael Gove creating "neo Victorian" curriculum for primary schools, says professor who led massive review into sector.* Retrieved April 20, 2015 from http://www.independent.co.uk/news/education/education-news/michael-gove-creating-neo-victorian-curriculum-for-primary-schools-says-professor-who-led-massive-review-into-sector-8837223.html

Wellington, J. (2005). Practical work and the affective domain: What do we know, what should we ask, and what is worth exploring further?. In: Alsop, S. (Eds.) *Beyond Cartesian dualism: Encountering affect in the teaching and learning of science*. Dordrecht: Springer, pp. 99-110.

JESEH
Journal of Education in Science, Environment and Health
Volume 2, Issue 1, 2016 ISSN: 2149-214X

Development of Teacher Beliefs through Online Instruction: A One-Year Study of Middle School Science and Mathematics Teachers' Beliefs About Teaching and Learning

Sissy S. Wong[*]
University of Houston

Abstract

Understanding teachers' beliefs is important because beliefs influence teacher decisions. In science, teacher beliefs have an impact on how science curriculum is interpreted and implemented in the classroom. With the push for science, technology, engineering, and mathematics (STEM) education in the United States, it is also critical to examine the beliefs of teachers who integrate science in the classroom. This study of 21 U.S. middle school science and mathematics teachers found that teachers' participation in the first year of a two-year graduate online program that emphasised inquiry-based instruction and student-centred frames of mind influenced participants' beliefs. Overall, participants moved toward holding more student-centred beliefs. When types of beliefs were disaggregated, participants' beliefs about teaching and about learning both moved toward a more student-centred position. Further, teachers' beliefs significantly changed regardless of their years of teaching experience. One surprising finding was that science teachers' beliefs changed significantly, while those of mathematics teachers did not. The findings from this study support the notion that formal knowledge has an impact on teacher beliefs.

Key words: Mathematics teacher beliefs, Middle school, Online instruction, Science teacher beliefs

Introduction

In the United States, certain national documents advocate for science teachers to engage students in inquiry-based lessons to foster students' scientific literacy (National Research Council [NRC], 1996; NGSS Lead States, 2013). Inquiry-based instruction has been found to foster student learning of concepts (Lott, 1983; NRC, 1996) and is a more accurate and authentic representation of how scientists do science (NRC, 1996). Even though inquiry is well supported for elevating K–12 students' learning of science, teachers have consistently struggled with implementing inquiry in their classrooms (Crawford, 2007; Luft, Wong, Ortega, Adams, & Bang, 2011). Further, inquiry instruction is hampered by a lack of time, limits set by district curricula, and teachers' perceived lack of classroom control (Costenson & Lawson, 1986) as well as teachers' beliefs about teaching and learning.

Considerable research has shown that teacher beliefs have an impact on their decisions (Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Haney, Czerniak, & Lumpe, 1996; Nespor, 1987; Simmons et al., 1999), including what to teach and how to teach. For example, Brickhouse found that teachers' beliefs affected how they interpreted the nature of science curriculum and how they implemented it in the classroom. Cronin-Jones' study of two middle-grade science teachers showed how teachers' beliefs about how students learn, the teacher's role in the classroom, and the ability level of the students influenced the ways that teachers modified packaged curriculum. Overall, teachers' beliefs about how students learn have an impact on what teachers do in the classroom.

Beliefs are influenced by both personal and school experiences as well as by formal knowledge (Apostolou & Koulaidis, 2010; Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Jones & Leagon, 2014; Pajares, 1992; Richardson, 1996). Luft and Patterson (2002) developed a one-year science-specific induction program to connect theory with practice for beginning science teachers. They found that "75% of the participating teachers [felt that] the program [had] significantly challenged their ideologies about teaching science" (p. 278). Luft et al. (2011), in a two-year study, found that science-specific induction and mentoring that emphasised student-centred frames of mind, which is important for inquiry-based instruction, led to teachers' developing more student-centred beliefs about teaching and learning. In contrast, teachers who did not receive science-specific induction and mentoring did not experience change in their beliefs.

[*] Corresponding Author: *Sissy S. Wong*, *sissywong@uh.edu*

Studies on teacher professional development have examined the changes in beliefs of beginning and practicing teachers. Luft (2001) found that beginning science teachers were more likely to change their beliefs about teaching science as compared to their more experienced peers, whose beliefs were found to be more static over time. Luft's findings are in keeping with those of Simmons et al. (1999), who, in a study of 114 science teachers, found that novice teachers' beliefs were more malleable when compared to those of more experienced teachers. Teachers in the beginning phase of their career are still negotiating, within the school context, their role as a science or mathematics teacher (Henry, Bastian, & Fortner, 2012; Luft, 2001).

Studying science teachers' beliefs is critical because teachers are the negotiator of content and curriculum in the classroom (Ramsey & Howe, 1969). This content and curriculum, however, also are influenced by the current push for science, technology, engineering, and mathematics (STEM) education. The call to increase those in the STEM workforce is in response to the desire to keep the United States competitive in the evolving global market (Bybee, 2010; Gerlach, 2012). Thus, educators and certain U.S. agencies have advocated for the integration of STEM classes in K–12 classrooms. For example, the *National Science and Education Standards* (NRC, 1996) support the integration of science and mathematics because they increase students' understanding and applications of both subjects. The *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000) also advocates for the integration of science and mathematics because "process and content of science can inspire an approach to solving problems that applies to the study of mathematics" (p. 66). The *Next Generation Science Standards* (NGSS) promotes practices that integrate science and engineering applications (NGSS Lead States, 2013). With the call for integration of science and mathematics subject areas, it is important for science teachers and teachers who integrate science into their curriculums to hold beliefs that foster the implementation of student-centred inquiry-based instruction.

Research Questions

This study examined middle school science and mathematics teachers' beliefs over a one-year period. The questions that guided this study are:

1. To what extent do middle school science and mathematics teachers' beliefs change based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?
2. To what extent do middle school science and mathematics teachers' beliefs about teaching and learning change based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?
3. To what extent are there differences between middle school science teachers' and middle school mathematics teachers' beliefs based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?
4. To what extent are there differences between beginning (0-5 years) middle school science and mathematics teachers' beliefs and experienced (6 or more years) middle school science and mathematics teachers' beliefs based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?

The above distinction, in regard to years of teaching experience, between beginning and experienced teachers is drawn from the research of Luft et al. (2011).

Relevant Literature

Belief Systems

Belief systems encompass such areas as self-efficacy, epistemologies, and expectations (Jones & Carter, 2007). Nespor (1987) defined belief systems as "loosely-bound systems with highly variable and uncertain linkages to events, situations, and knowledge systems" (p. 321). Thompson (1992) stated that beliefs systems are an organization of a person's beliefs, with central beliefs' being difficult to change and peripheral beliefs' being more susceptible to change. In an essence, belief systems are like hubs in which core or central beliefs are more static and less apt to change, while exterior beliefs that radiate from the hubs are more susceptible to change, particularly as related to environmental factors (Jones & Carter, 2007).

Beliefs influence how individuals view the world and the decisions that they make. Nespor (1987) stated that beliefs "are important influences on the ways [individuals] conceptualize tasks and learn from experiences" (p. 317), and "play a major role in defining teaching tasks and organizing the knowledge and information relevant to those tasks" (p. 324). Specific to the teaching field, Kagan (1992) stated that beliefs are "a particularly provocative form of personal knowledge that is generally defined as pre- or in-service teachers' implicit assumptions about students" (p. 65). Crawford (2007) noted that a teacher's beliefs about learning and content knowledge are interwoven, which supports the notion that a teacher's beliefs about inquiry influence curricular and instructional decisions.

Challenges in Changing Beliefs

Scholars have called for teacher education and professional development to purposefully elicit and challenge teacher beliefs as a means to influence decisions and practice (Brousseau & Freeman, 1998; Horak & Lunetta, 1979; Kagan, 1992). This may be difficult to do with teachers who already have extensive personal experiences in the classroom as both students and teachers (Pajares, 1992). These personal experiences have a large impact on teachers' beliefs and actions (Richardson, 1996; Tsai, 2002). Tsai found such effects amongst beginning teachers; those who experienced teacher-centred practices as students tended to implement teacher-centred practices as teachers. As related to our understanding of belief systems, it becomes clear that beliefs formed through years of personal experiences in the classroom may be difficult to change.

There are other challenges to changing beliefs, including accessing and assessing them. According to Rokeach (as cited by Pajares, 1992), beliefs are difficult to understand because "beliefs cannot be directly observed or measured but must be inferred from what people say, intend, and do—fundamental prerequisites that educational researchers have seldom followed" (p. 314). Further, Kagan (1992) found that university leaders provide mainly supportive and positive feedback instead of challenging instructors' beliefs about teaching and learning. Moreover, teacher education programs seldom elicit or address beliefs. Teachers need to be given opportunities to reflect on beliefs that were formed before entering the profession (Brownlee, Boulton-Lewis, & Purdie, 2002). Cronin-Jones (1991) found that beliefs are often unchallenged because teacher education program instructors assume that preservice teachers hold beliefs similar to their own. In addition, those who teach in teacher education programs often have not had their own beliefs challenged.

From a research perspective, understanding teacher beliefs is especially challenging because beliefs "cannot be inferred directly from teacher behaviour, because teachers can follow similar practices for very different reasons" (Kagan, 1992, p. 66). Using interviews to collect information on teachers' beliefs allows researchers to elicit details, but teachers may not be able to reflect on their beliefs. Teachers also may not be able to communicate their beliefs to another person or may not want to reveal their beliefs for a variety of reasons. In addition, Kagan stated that teachers' knowledge and beliefs about their area of expertise often is implicit. "[T]eachers are often unaware of their own beliefs, they do not always possess language with which to describe and label their beliefs, and they may be reluctant to espouse them publicly" (p. 66). Although there are limitations to interviews and observations as avenues to elicit teacher beliefs, these methods remain the most reliable ways to collect teacher beliefs data.

Inquiry-Based Instruction

Inquiry includes interconnected processes that scientists and students use to ask questions and to investigate the natural world (Crawford, 2007). It also includes science concepts, science skills, the nature of science, and an inquisitive frame of mind (NRC, as cited by Crawford, 2007). Inquiry-based lessons may be foreign to students who are used to step-by-step instructions in scientific investigations. Therefore, inquiry should be scaffolded over time so that students can adjust to the autonomy and student-driven decisions made during inquiry.

According to Bell, Smetana, and Binns (2005), although inquiry should be viewed as a continuum, inquiry may be scaffolded over time. First is confirmation inquiry, in which the teachers provide the question and methods and knows the conclusion in advance. Next is directed inquiry, in which the teacher has determined the question and methods. Then, guided inquiry starts with a teacher-driven question, but students decide on the methods and conclusion. Finally, open-ended inquiry occurs when students decide the question, methods, and conclusion. To maximize student learning, especially with students who have not previously experienced inquiry, scaffolding from confirmation toward open-ended inquiry is critical.

Theoretical Perspective

This study utilized a pragmatic perspective because it involves methods that best address the research questions (Creswell, 2013). Pragmatism is particularly applicable to this study because it honours the specific assumptions that education researchers hold about knowledge construction. This includes taking into account the role of subjective and objective points of view when investigating phenomena, recognizing that knowledge changes over time, and understanding the importance of implementing different approaches to investigate the natural world (Biesta, 2010; Johnson & Onwuegbuzie, 2004). In a pragmatic perspective, the design and methods used in research are relative to the resulting knowledge claims (Biesta, 2010).

Method

This study utilized qualitative and quantitative measures to understand the participants' conception of the nature of science over a one-year period. The following is a description of the methods used to address the research questions.

Description of iSMART

Integrated Science Mathematics and Reflective Teaching (iSMART) is a two-year cohort-based online master's program that emphasises theories and pedagogies of research-based science and mathematics teaching. iSMART also scaffolds the integration of both content areas over the two-year period. All students in iSMART are practicing middle school (Grades 4–8) science or mathematics teachers who teach in a state in the southern region of the United States. Although the majority of the program occurs online, iSMART begins with a one-week face-to-face summer conference. The conference addresses program expectations, instructions in the navigation of the online platform in which courses take place, technology tools pertinent to the program, and initial data collection. Students also are given the materials necessary for inquiry-based class activities.

All students took two courses per semester during the first academic year. For both semesters, students were enrolled in one science methods course and one mathematics methods course. The courses alternated weeks so that courses met every other week for a total of seven class sessions per semester. Each class session lasted three hours. The online courses occurred synchronously so that everyone in the course was online simultaneously and was able to interact via the Blackboard Collaborate platform. In Collaborate, all participants had access to video, audio, chat, and an interactive white board. The platform also provided access to course readings, assignments, and discussion boards asynchronously. Both science methods courses during fall and spring semesters emphasised the importance of a student-centred frame of mind and inquiry-based instruction. Course lessons were inquiry-based and promoted student-centred and student-driven interactions. After two semesters of online courses, all students met for another one-week summer face-to-face conference in which data were collected again. For a complete description of iSMART, please see Lee, Chauvot, Vowell, Culpepper, and Plankis (2013).

Research Participants

The participants (N = 21) in this study consisted of 12 science and 9 mathematics middle school teachers enrolled in the iSMART program. Of the teachers, 19 were female, and 2 were male; and 18 were Caucasian, 2 were Hispanic, and 1 was African American. The teachers had between 2 and 27 years of classroom experience at the start of the study. There were a total of 9 beginning teachers with between 2 and 5 years of experience, and 12 teachers with 6 to 27 years of experience. Of the participants, 18 worked in public schools, and 3 worked in private schools. All participants in this study gave consent for their relevant data to be included for the purpose of research and publication.

Inquiry-Based Instruction and Student-Centred Frames of Mind

During the one-year time frame of this study, participants engaged in explicit and reflective classroom activities, discussions, readings, and assignments. The author of this paper instructed the first science methods course, and another science education professor instructed the second science methods course. Both classes utilized inquiry-based student-centred lessons to teach the course objectives. In addition, both courses included discussions to highlight and reflect upon the inquiry-based, student-driven lessons that resulted in the co-construction of knowledge about the content objective.

The first course focused on (a) inquiry-based instruction in the middle school classroom, (b) integration of science and mathematics content in the middle school classroom, (c) deeper science content knowledge, and (d) a more sophisticated conception of the nature of science. Specifically for inquiry-based instruction and student-centred framing of teaching and learning, students were instructed via scaffolded inquiry lessons that followed Bell et al.'s (2005) model of inquiry. In all cases, classes began with a discussion about prior conceptions before readings were completed. After activities and readings, the class engaged in discussion to reflect on the entire experience. This was purposefully done to help participants to identify prior conceptions and to compare them with new knowledge developed via course activities, discussions, and readings. In this way, participants were able to explicitly consider how their prior beliefs about teaching and learning compared to research findings about effective instructional models and how students learn.

The second science methods course focused on (a) constructivism and student learning, (b) scientific evidence vs. pseudoscience, (c) greater understanding of the nature of science, and (d) the difference between the nature of science and the nature of mathematics. Beliefs that influence participants' views on scientific concepts were addressed in this course through explicit confrontation. Students engaged in activities that revealed how personal knowledge, beliefs, and experiences affected their acceptance, or non-acceptance, of global climate change and the theory of evolution.

Data Collection

Data were collected in this study via semi-structured annual interviews that were conducted by the author. During the interview, the researcher took notes and digitally audio recorded the interview. There were a total of two annual interviews conducted with each participant during the study. The first time (T0) occurred during the summer conference that took place prior to the start of the iSMART courses. The second time (T1) occurred after the first academic year or the subsequent summer when the participants were at the second summer conference.

The semi-structured interview had three parts (Seidman, 2013). The first part of the interview included general questions that probed for information on the participants' teacher preparation programs, teaching experiences, and types of teaching support. This portion of the interview took approximately 30 minutes. The second portion probed for participants' conception of the nature of science. This portion took approximately 20 minutes. The third portion of the interview was from which the data were drawn. This third portion utilized the Teacher Beliefs Interview (TBI; Luft & Roehrig, 2007).

The TBI is a semi-structured interview that consists of seven prompts that were developed based on beliefs research to reveal an interviewee's beliefs about teaching and learning. The TBI utilizes the semi-structured format because it allows researchers to probe for additional details when necessary (Fylan, 2005). The TBI's validity was established through multiple examinations of the protocol, which resulted in consistent depictions of beliefs (Luft & Roehrig, 2007). The TBI has a Cronbach's α coefficient of 0.77 for reliability (Luft & Roehrig, 2007). iSMART focuses on science and mathematics methods and the integration of both over time. This study examined the science and mathematics teachers' teaching beliefs over the one-year period.

Data Analysis

Completed interviews were coded by two independent researchers in accordance with the rubrics created by Luft and Roehrig (2007) for each TBI question. Each TBI question could be coded as one of five categories that are arranged in a continuum from teacher-centred to student-centred (Table 1). The individual researchers then cross-coded together to reach consensus on the responses for each participant. The final category was then quantitised for a numerical score (Miles, Huberman, & Saldana, 2014; Teddlie & Tashakkori, 2006) for quantitative analysis.

Paired t-tests were used to address the first two research questions. First, a paired t-test was conducted to explore whether the science and mathematics teacher participants' beliefs significantly changed between T0 and T1, i.e., before and after two semesters of online instruction that emphasised student-centred inquiry-based instruction. Paired t-tests also were conducted to examine whether beliefs about teaching and beliefs about learning were significantly different. This was done by separating TBI questions by whether they elicited information about the participants' beliefs about teaching or about beliefs about learning. (Please see Table 2 for TBI questions by beliefs on teaching versus learning.)

Table 1. TBI coding categories and example responses

Category	Orientation	Description	Examples
Traditional	Teacher-centred	Teacher provides information and resources in a structured manner and environment. Teacher decides what students need to do and learn.	• I decide what students need to know • All desks should face me
Instructive	Teacher-centred	Teacher decides experiences and uses subjective evaluation of student actions and performance	• I observe students to know they have learned
Transitional	Teacher considers students	Teacher emphasises teacher-student relationship that includes subjective and affective components. Does not focus on teaching or learning of science	• I use different types of activities for different learning styles • I build relationships with my students and get to know them
Responsive	Student-centred	Teacher focuses on opportunities and collaboration between students and teacher as well as between students as peers. Focus is on development of science learning and content knowledge	• I use small-group activities that provide opportunities to generate questions, create, collaborate, and question • Students have opportunities to engage in discussions
Reform-based	Student-centred	Teacher uses individualized and student-centred methods of learning that includes student interests and abilities. Provides a collaborative environment for students to apply knowledge to novel situations.	• I know that students learn in different ways and have different interests. I teach science so that students can use existing skills and develop new skills • Students to choose their own ways to learn the content

Paired t-tests and independent samples t-tests were conducted to address the third research question. Paired t-tests were run to determine whether science teacher participants' beliefs were statistically different at T1 vs. T0 and whether mathematics teacher participants' beliefs were statistically different at T1 vs. T0. In addition, independent samples t-tests were used to determine whether the science participants' beliefs differed significantly from those of the mathematics participants at T0 and T1.

Table 2. TBI questions by beliefs on teaching and beliefs on learning

	Beliefs about Teaching		Beliefs about Learning
1.	How do you maximize student learning in your classroom?	3.	How do you know when your students understand?
2.	How do you describe your role as a teacher?	6.	How do your students learn science best?
4.	In the public school setting, how do you decide what to teach or what not to teach?	7.	How do you know when learning is occurring in your classroom?
5.	How do you decide when to move on to a new topic in your class?		

Finally, paired t-tests and independent samples t-tests were conducted to address the fourth research question. Paired t-tests were run to determine whether the beginning teachers' beliefs were statistically different at T1 vs. T0 and whether those of experienced teacher participants were statistically different at T1 vs. T0. Independent samples t-tests also were conducted to determine whether the beginning teachers and experienced teachers differed significantly in their beliefs at T0 and at T1.

Results

As noted, a paired-samples t-test was conducted to address the first research question. The results indicated that there was a statistically significant difference amongst the participants in regard to their beliefs over the one-year period (Table 3).

Table 3. Paired-samples t-tests for beliefs of all teachers at T0 and T1

Variable	N	M	SD	t	p
Group					
T0 All Teachers Beliefs	21	17.38	1.88	$t(20) = -4.70$	0.00
T1 All Teachers Beliefs	21	19.57	2.27		

The results of two paired-samples t-tests conducted to address the second research question indicated that, for beliefs about teaching, there was a statistically significant difference between scores at T1 vs. T0. For beliefs about learning, the results indicated that there also was a statistically significant difference in scores at T1 vs. T0 (Table 4).

Table 4. Paired-samples t-tests for teaching beliefs vs. learning beliefs

Variable	N	M	SD	t	p
Group					
T0 Beliefs about Teaching	21	9.24	1.39	$t(20) = -3.64$	0.00
T1 Beliefs about Teaching	21	10.52	2.26		
Group					
T0 Beliefs about Learning	21	8.14	0.93	$t(20) = -3.10$	0.01
T1 Beliefs about Learning	21	9.05	1.75		

Paired-samples t-tests and independent samples t-tests were conducted to address the third research question. The paired-samples t-tests revealed a statistically significant difference amongst the science teacher participants at T1 vs. T0. Another set of paired-samples t-tests was conducted to determine whether there was a significant difference in the scores for mathematics teacher participants at T0 vs. T1. The results indicated that there was no statistically significant difference. Independent samples t-tests compared science and mathematics teachers' beliefs at T0 and at T1 and yielded no statistically significance differences at T0 or T1 (Table 5).

Table 5. Paired-samples t-tests and independent samples t-test for science vs. mathematics teachers' beliefs

Variable	N	M	SD	t	p
Group					
T0 Science Teacher Beliefs	12	17.46	3.44	$t(12) = -4.65$	0.00
T1 Science Teacher Beliefs	12	19.85	5.97		
Group					
T0 Mathematics Teacher Beliefs	9	17.25	4.21	$t(7) = -2.01$	0.08
T1 Mathematics Teacher Beliefs	9	19.13	4.13		
Group					
T0 Science Teacher Beliefs	12	17.46	3.44	$t(14) = -0.24$	0.82
T0 Mathematics Teacher Beliefs	9	17.25	4.21		
Group					
T1 Science Teacher Beliefs		19.85	5.97	$t(17) = -0.73$	0.48
T1 Mathematics Teacher Beliefs		19.13	4.13		

Paired-samples t-tests and independent samples t-tests were conducted to address the fourth research question. The results of paired-samples t-test conducted to determine whether there was a difference in the scores for novice teacher at T1 vs. T0 showed a statistically significant difference in their beliefs over the one-year period. The results of another paired-samples t-test revealed that there was a statistically significant difference in experienced teacher participants' beliefs at T1 vs. T0. Independent samples t-tests compared novice and experienced teachers' beliefs at T0 and again at T1, and both tests found no significance at T0 or T1 (Table 6).

Table 6. Paired-samples t-tests and independent samples t-test for novice vs. experienced teachers' beliefs

Variable	N	M	SD	t	p
Group					
T0 Novice Teacher Beliefs	9	2.78	3.44	*t*(8) = -4.43	0.00
T1 Novice Teacher Beliefs	9	19.99	1.86		
Group					
T0 Experienced Teacher Beliefs	12	17.25	4.39	*t*(11) = -2.84	0.02
T1 Experienced Teacher Beliefs	12	19.33	7.88		
Group					
T0 Novice Teacher Beliefs	9	17.56	2.78	*t*(19) = 0.37	0.71
T0 Experienced Teacher Beliefs	12	17.25	4.39		
Group					
T1 Novice Teacher Beliefs	9	19.99	1.86	*t*(17) = 0.60	0.56
T1 Experienced Teacher Beliefs	12	19.33	7.88		

Discussion

This study examined the beliefs of middle school science and mathematics teachers in the United States over a one-year period. In the following, results are addressed by research question.

Research Question 1: To what extent do middle school science and mathematics teachers' beliefs change based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?

The results show that the science and mathematics teacher participants significantly changed their beliefs over the one-year period. It appears that the iSMART courses had an impact on the teachers' beliefs, which moved toward more student-centred positions at T1. This finding supports previous studies that show teacher beliefs can be affected through personal experiences, prior knowledge, and formal education which include teacher education and professional development interventions (Apostolou & Koulaidis, 2010; Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Jones & Leagon, 2014; Pajares, 1992; Richardson, 1996).

This outcome was expected based on two main factors. First, both science methods instructors did not assume the teacher participants held similar beliefs about teaching and learning (Cronin-Jones, 1991). Second, based on this assumption, instructors included activities and assignments that were designed to elicit and challenge teacher beliefs (Brousseau & Freeman, 1998; Horak & Lunetta, 1979; Kagan, 1992). Specifically, both iSMART science methods courses were designed to elicit and challenge teacher beliefs by including explicit and reflective inquiry-based instruction, discussions, readings, and assignments. Activities were designed to challenge students' prior beliefs about science content, the nature of science, and science pedagogies.

Research Question 2: To what extent do middle school science and mathematics teachers' beliefs about teaching and learning change based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?

The results indicate that the science and mathematics teacher participants significantly changed both their beliefs about teaching and their beliefs about learning over the one-year period. The iSMART program provided multiple activities, discussions, and readings about research on the impact of pedagogy in the science classroom and about student learning. The science methods courses also helped participants to recognize the interconnectedness of teaching with learning. Both science methods courses encompassed the knowledge, beliefs, and skills necessary for effective teaching for the learning of science.

The science methods courses, in discussions and explorations of inquiry-based teaching, emphasised the connection between teaching science with inquiry and students' science learning. In fact, repeated discussions were held regarding how inquiry-based instruction and lecture-based methods affect student learning outcomes. The course also emphasised teaching science as inquiry to represent how scientists do science in the field. Numerous pieces of evidence to support the importance of inquiry were integrated through research-based articles, national documents (NGSS Lead States, 2013; NRC, 1996), and the participants' own personal experiences as they implemented inquiry in their classroom. The focus on the connection between teaching science with student-centred inquiry and students' science learning may have led to teachers' beliefs about teaching and about learning to move toward more student-centred positions.

Research Question 3: To what extent are there differences between middle school science teachers' and middle school mathematics teachers' beliefs based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?

The results demonstrate that the science teacher participants significantly changed their beliefs over the one-year period toward views that were more student-centred. The mathematics teachers, however, did not significantly change their beliefs over time. This was surprising because the science methods courses were designed to address the beliefs of both groups of teachers.

There are two potential reasons for this unexpected result. First, closer inspection of the data showed that there was one mathematics teacher whose beliefs scores moved from more student-centred to more teacher-centred over the one-year time frame. Out of curiosity, the researcher removed this outlier and found that the results then were significant at the .01 level. In other words, without the scores from this participant, the results would have indicated a significant change in the mathematics teachers' beliefs between T0 and T1.

The second reason is due to the TBI's design, which reveals beliefs about science teaching and learning. The mathematics teachers may not have developed sufficient formal knowledge to change beliefs about science. As noted, personal experiences, prior knowledge, and formal education have an impact on beliefs (Apostolou & Koulaidis, 2010; Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Jones & Leagon, 2014; Pajares, 1992; Richardson, 1996). The mathematics teacher participants had years of personal experiences as science students but did not teach science or engage in science teaching professional development. Their personal experiences as students may have been in teacher-centred science classrooms that did not implement inquiry-based instruction. The years spent in this environment may have strongly influenced the mathematics teacher participants' beliefs system, making it resistant to change, even though they participated in two semesters of science methods courses.

The results also indicated that, when science teacher beliefs were compared with mathematics teachers' beliefs, there were differences in beliefs at point T0 or T1. This was unexpected, as the results also indicated that science teachers significantly changed between T0 and T1, while the mathematics teachers did not significantly change during the same period. Overall, the science teachers' beliefs and the mathematics teachers' beliefs were not statistically different at the start of the study nor were the science teachers' scores significantly different at the end of the study. It appears that the scores for science and mathematics teachers differed to some degree but that science teachers moved toward student-centred beliefs more so than did their mathematics counterparts.

Research Question 4: To what extent are there differences between beginning (0-5 years) middle school science and mathematics teachers' beliefs and experienced (6 or more years) middle school science and mathematics teachers' beliefs based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?

This study found that both novice and experienced teachers experienced a shift in their beliefs toward more student-centred orientations. This appears to stand in contrast to research by Luft (2001) and Simmons et al. (1999). In both of these studies, however, the researchers found that experienced teachers were less likely to shift in beliefs when compared to their novice peers. Although experienced teachers' beliefs shift less, they do shift nonetheless. This study confirmed that both beginning teachers and experienced teachers' beliefs shifted toward more student-centred orientations. This is important to know when examining the connection between beliefs and practice and when designing teacher education and professional development interventions for a specific population of participants.

Although other researchers have found that experienced teachers' beliefs shift less than do their beginning counterparts', this study did not find that novice teachers' beliefs shifted more than those of the experienced teachers. The novice teachers' and experienced teachers' beliefs were not significantly different at T0 or T1. This appears to indicate that the novice and experienced teachers both experienced similar shifts in beliefs.

Implications

The results of this study support long-established research that teachers' beliefs are a critical area of study. Beliefs have an impact on teacher decisions, including what to teach and how to teach (Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Haney et al., 1996; Nespor, 1987; Simmons et al., 1999). With the strong support for inquiry-based instruction to occur in K–12 science classrooms, understanding how to foster beliefs that align with student-centred instruction is of the utmost importance.

This study also supports the notion that teacher education and professional development interventions can help to shift teachers' beliefs toward more student-centred frames of mind (Apostolou & Koulaidis, 2010; Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Jones & Leagon, 2014; Pajares, 1992; Richardson, 1996). The results indicate that both science and mathematics teachers' beliefs about science teaching and science learning are malleable through formal education that purposefully elicits and challenges beliefs. In addition, this study found that both novice and experienced teachers' beliefs can be influenced through formal education interventions. These are promising findings, as teacher beliefs affect what and how teachers teach.

In light of the current STEM movement, understanding teachers' beliefs has become increasingly important. It is not enough to understand science teachers' beliefs about science teaching and learning. We now also must understand the beliefs of teachers who integrate science into their curriculum as well as the ways to cultivate student-centred beliefs about science teaching and learning amongst non-science teachers. As Crawford (2007) stated, the beliefs and knowledge required for teaching are intertwined. As noted, in this study, the science teachers' beliefs were affected, while those of mathematics teachers were not. In light of the context of a program that purposefully integrated curricula to elicit and challenge science and mathematics teachers' beliefs, this finding is of concern. If mathematics teachers are to integrate science into their instruction, it is important that they develop student-centred beliefs that foster inquiry-based instruction. This study highlights the need for further study into ways to have an impact on the beliefs of non-science teachers who integrate science into their curricula.

Fundamentally, science teachers need to hold the student-centred beliefs that align with inquiry-based instruction. If teachers do not hold such beliefs about how to teach and how students learn, this will have an impact on classroom practices. Teachers are the negotiators of content and curriculum (Ramsey & Howe, 1969). Therefore, teacher beliefs are a much-needed area of further research. To build on this study, those who teach science, integrate science into their teaching, develop science curriculum, educate preservice and in-service teachers, and serve as education administrators should consider how to foster teachers' student-centred beliefs. Ultimately, working with teachers to develop student-centred beliefs about science and STEM education may increase the implementation of inquiry-based instruction that leads to students' development of scientific literacy.

Acknowledgements

The author would like to recognize Jennifer Chauvot, Imani Goffney, John Ramsey, and Lionnel Ronduen for their support during this research project. The iSMART program is funded by The Greater Texas Foundation. The findings, conclusions, and opinions herein represent the views of the authors and do not represent the views of personnel affiliated with the Greater Texas Foundation.

References

Apostolou, A., & Koulaidis, V. (2010). Epistemology and science education. A study of epistemological views of teachers. *Research in Science & Technological Education, 28*(2), 149-166.

Bell, R., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction. *The Science Teacher*, *72*(7), 30-33.

Biesta, G. (2010). Pragmatism and the philosophical foundations of mixed methods research. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social & behavioral research* (2nd ed., pp. 95-118). Thousand Oaks, CA: Sage.

Brickhouse, N. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41*(3), 53-62.

Brownlee, J., Boulton-Lewis, G., & Purdie, N. (2002). Core beliefs about knowing and peripheral beliefs about learning: Developing a holistic conceptualization of epistemological beliefs. *Australian Journal of Educational & Developmental Psychology, 2*, 1-16.

Brousseau, B. A., & Freeman, D. J. (1988). How do teacher education faculty members define desirable teacher beliefs? *Teaching & Teacher Education, 4*(3), 267-273.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology & Engineering Teacher, 70*(1), 30-35.

Costenson, K., & Lawson, A. E. (1986). Why isn't inquiry used in more classroom? *The American Biology Teacher*, *48*(3), 150-158.

Crawford, B. (2007). Learning to reach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Education, 44*(4), 613-642.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches.* Los Angeles, CA: Sage.

Cronin-Jones, L. L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28*(3), 235-250.

Fylan, F. (2005) Semi structured interviewing. In J. Miles & P. Gilbert (Eds.), *A handbook of research methods for clinical and health psychology* (pp. 65–78). Oxford, UK: Oxford University Press.

Gerlach, J. (2012, April 11). *STEM: Defying a simple definition* (NSTA Reports). Arlington, VA: National Science Teachers Association.

Haney, J. J., Czerniak, C. M., & Lumpe, A. T. (1996). Teacher beliefs and intentions regarding implementation of science education reform strands. *Journal of Research in Science Teaching, 33*(9), 971-993.

Henry, G. T., Fortner, C. K., & Bastian, K. C. (2012). The effects of experience and attrition for novice high-school science and mathematics teachers. *Science, 335*(6072), 1118-1121.

Horak, W. J., & Lunetta, V. N. (1979). Science teacher types: A study of beliefs about the importance of specific teaching behaviors. *Journal of Research in Science Teaching, 16*(3), 269-274.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher, 33*(7), 14-26.

Jones, M. G., & Carter, G. (2007). Science teacher attitudes and beliefs. In S. Abell. & N. Lederman (Eds.), *Handbook of research on science education* (pp. 1067-1104). Mahwah, NJ: Lawrence Erlbaum Associates.

Jones, M. G., & Leagon, M. (2014). Science teacher attitudes and beliefs. In N. Lederman & S. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 830-843). New York, NY: Routledge.

Kagan, D. M. (1992). Implication of research on teacher belief. *Educational Psychologist, 27*(1), 65-90.

Lee, M. M., Chauvot, J. B., Vowell, J., Culpepper, S. M., & Plankis, B. J. (2013). Stepping into iSMART: Understanding science-mathematics integration for middle school science and mathematics teachers. *School Science and Mathematics, 113*(4), 159-169.

Lott, G. W. (1983). The effect of inquiry teaching and advance organizers upon student outcomes in science education. *Journal of Research in Science Teaching, 20* (5), 437-451.

Luft, J. A. (2001). Changing inquiry practices and beliefs: The impact of inquiry-based professional development programme on beginning and experienced secondary science teachers. *International Journal of Science Education*, *23*(5), 517-534.

Luft, J. A., J., Wong, S. S., Ortega, I., Adams, K., & Bang, E. J. (2011). Beginning secondary science teacher induction: A two-year mixed methods study. *Journal of Research in Science Teaching, 49*(10), 1199-1224.

Luft, J. A., & Patterson, N. C., (2002). Bridging the gap: Supporting beginning science teachers. *Journal of Science Teacher Education*, *13*(4), 267-282.

Luft, J. A., & Roehrig, G. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education*. Retrieved from Electronic Journal of Science Education database.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook.* Los Angeles, CA: Sage.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: NCTM.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*(4), 317-328.

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: National Academies Press.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332.

Ramsey, G., & Howe, R. (1969). An analysis of research on instructional procedures in secondary school science. *The Science Teacher, 36*(3), 62-70.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), *Handbook of research on teacher education* (pp. 102-119). New York, NY: Macmillan.

Seidman, I. (2013). *Interviewing as qualitative research: A guide for researchers in education and the social sciences.* New York, NY: Teachers College Press.

Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D., . . . Labuda, K. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching, 36*(8), 930-954.

Teddlie, C., & Tashakkori, A. (2006). A general typology of research designs featuring mixed methods. *Research in the Schools, 13*(1), 12-28.

Thompson, A. G. (1992). Teachers' beliefs and conceptions: A synthesis of research. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 127-146). New York, NY: Macmillan.

Tsai, C. C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education, 24*(8), 771-783.

Journal of Education in Science, Environment and Health
Volume 2, Issue 1, 2016 ISSN: 2149-214X

Achievement Levels of Middle School Students in the Standardized Science and Technology Exam and Formative Assessment Probes: A Comparative Study

Nermin Bulunuz*[1], Mızrap Bulunuz[1], Funda Karagöz[2], Ömer Faruk Tavşanlı[1]
[1]Uludağ University
[2]Eskişehir Mehmet Gedik Secondary School

Abstract

The present study has two aims. Firstly, it aims to determine eighth grade students' conceptual understanding of floating and sinking through formative assessment probes. Secondly, it aims to determine whether or not there is a significant difference between students' performance in formative assessment probes and their achievement in the Standardized Science and Technology Exam (TEOG 1) exam. The sample of this research is 61 eighth grade students from a central middle school in Eskişehir. Data collection tools are four two-stage formative assessment probes and the scores of the student taken from the first TEOG 1 exam. The answers of the students to the two-stage probes were scored by use of a rubric. Findings indicated that most of the students either: a) both chose incorrect answer and did not write correct scientific explanation (%41); b) chose correct answer but did not write correct scientific explanation (%33); and c) chose correct answer but wrote partially correct explanation (%43). This result indicates the poorness of students' explanation and interpretation skills in formative assessment probes. In addition, the findings of the dependent sample t-test results also indicate that there is a significant difference between the scores of the students taken from the standardized science test (TEOG 1) and the formative assessment probes on the concepts of floating and sinking. This finding shows that the students are more successful on standardized science test than the formative assessment probes in general. These research findings, suggest that students should be exposed to teaching practices based on "formative assessment" that promotes the development of students' skills of explaining, interpreting, and reasoning rather than multiple-choice tests in science lessons.

Key words: Formative assessment, science teaching, TEOG 1

Introduction

When we hear the word 'assessment' in our education system, we first think of written and oral exams, marks obtained in the exams, ranking, stress, or failure. For most of the time, assessment is even used to mean written and oral exams and homework. Using the word assessment as if it was synonymous with summative assessment types simplifies the complex structure, stages and the aim of assessment (Atkin & Coffey, 2005). This is because the marks and points obtained actually constitute only the smallest part of the assessment. However, assessment is a fairly comprehensive concept ranking at the top of Bloom's taxonomy and a skill that requires an advanced performance. The basis of the assessment is to understand what a student has learnt, what he/she does not know well or to determine what kind of misconceptions he/she has in mind and to find qualitative and quantitative solutions.

Researches show that the assessment practices that are not integrated into teaching do not contribute to conceptual understanding of students (Black & William, 1998; Kavanagh & Sneider, 2007; Yin, Tomita, & Shavelson, 2013). The conventional evaluation and assessment methods such as "true-false", "matching", "fill in the gaps", and "multiple choice" questions that are applied at the end of a unit or semester lead to superficial learning and memorizing as they include fragmentary, discrete, and detailed information that students will forget in a short time (Butler, 1987; Butler & Neuman, 1995). Since these kinds of assessment methods which measure the level of learning by heart and low-degree gains focus on giving marks rather than teaching, the learning function of assessment becomes of secondary importance (Black, 1993; Black & William, 1998; Crooks, 1988). Conceptual learning requires such knowledge and skills as explanation, giving examples, interpretation, applying what has been learnt into new cases, and problem-solving rather than learning by heart. It is a known fact that "conceptual learning" is mostly not realized in science lessons where the information is given most of

* Corresponding Author: *Nermin Bulunuz, nermin.bulunuz@gmail.com*

the time without taking the prior knowledge that the students already have into consideration. To Angelo and Cross (1993), learning can be achieved without any teaching at all, too. However, teaching without ensuring conceptual understanding is a very ironic situation in educational practices.

Types of Assessment

When the related literature is examined, it is seen that there are 3 common types of assessment which are 1) diagnostic assessment (determining prior knowledge), 2) summative assessment, and 3) formative assessment (Keeley, Eberle & Farrin, 2005; Keeley, 2008).

Diagnostic Assessment

Diagnostic assessment is carried out in order to determine whether the prior knowledge that students have about a subject or field is correct and to determine the misconception that students might have about that subject or field (Keeley, Eberle & Farrin, 2005; Keeley, 2008; Tan, 2010). Such assessments are applied at the beginning of the educational process. The aim of this type of assessment is to recognize the student and to place him/her in the program or job that fits him/her. The placement tests that are applied at schools and private education centers as well as the university placement exams that only aim to classify students based on their achievement levels can be given as examples to diagnostic assessment. The data obtained in these exams do not contribute to the learning of students unless they are used to determine scope and methodology of the course in line with the needs of students. Nevertheless, the aim of the diagnostic assessment should be to determine the level of readiness of students by finding out their imperfect knowledge and what they know wrong before teaching.

Summative Assessment

Called shortly as the assessment of learning, this type of assessment is used mostly to determine academic achievement score and achievement order (Keeley, Eberle, & Farrin, 2005; Keeley, 2008). Being a study to make a judgement about the learning levels among students, this type of assessment measures and certifies whether the students have reached the intended gains in lessons with a certain mark. For example, the mid-term and final exams in universities, the written and oral exams applied in primary and middle schools, high school entrance exams, and international exams such as PISA and TIMMS can be given as examples to summative assessment (Tan, 2010). In this regard, summative assessment is separated from the learning process, and is rather about determining what students have achieved and what they have not.

Formative Assessment

Being a comparatively less known new approach in comparison to diagnostic and summative assessments in the literature, formative assessment has come to forefront over the last 10-15 years in Europe and America especially with the book of Black and William (1998) titled Working Inside the Black Box. It is defined as the assessment carried out to learn (Black & William, 2004) and to teach without any purpose of giving marks (Keeley, Eberle & Farrin, 2005). What is meant by assessment carried out to learn and to teach is to find out what students already know about the subject to be taught and to determine how the lesson is going to be given in the light of their prior knowledge (Black & William, 1998; Furtak, 2012; Yin, Shavelson, Ayala, Ruiz-Primo, Brandon, & Furtak, 2008; Yin, Miki, Tomita & Shavelson, 2013). In his book titled Educational Psychology (1968), Ausubel mentioned this in a very impressive way: In the preface to his book *Educational Psychology: A Cognitive View*, he says that “If [he] had to reduce all of educational psychology to just one principle, [he] would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly” (Ausubel, 1968, p. vi)” It is promising that this foresight put forward by Ausubel 40-50 years ago has taken place in the literature of today through reference books (Keeley, 2005; 2007; 2008) and studies (Bulunuz & Bulunuz, 2013; Bulunuz Bulunuz, & Peker, 2014; Keeley, 2011; 2012;Torrance & Pryor, 2001).

After determining the prior knowledge of students at the beginning of the course, the incorrect or inadequate concepts that students have in mind are corrected or improved in the light of this prior knowledge. Since this assessment is made during teaching, an effective feedback is provided to both the student and the teacher regarding the teaching and learning process. According to Black and William (1998), Black, Harrison, Lee, Marshall and William (2004), the lesson that is given in the class can result in conceptual learning when the teaching method is re-adjusted in the light of the feedback received from students. If the information collected in diagnostic assessment regarding what students know /do not know or what they do not know well is not used during the teaching of a lesson, there is no formative assessment. Formative assessment is integrated with learning, continuous, and process-oriented.

Formative assessment method has been known in the international literature since the late 1990s and there are several studies where the effectiveness of this method is investigated (Ali & Iqbal, 2013; Black & William, 1998; Keeley, 2008; 2011; 2012; Kopittke, Behnard Wehr, & Menzies, 2012; Torrance & Pryor, 2001; Trauth-Nare and Buck, 2011; Yin, Tomita, & Shavelson, 2013). The results obtained from these studies generally show that the activities carried out through this method increase the cognitive level of students; students display a positive attitudes towards the lesson; and their critical thinking skills are developed. For example, Black and William (1998) have found out in their meta-analysis study where they reviewed nearly 250 studies that formative assessment method increases students' attendance to the lesson, conceptual understanding, and learning motivations. In the action research where the opinions of student groups were asked regarding the method, the participants stated that the implementer- researcher feature of this method contributed to the development of their pedagogical knowledge and skills and thus they had an idea about a more efficient usage of formative assessment processes in the classroom (Trauth-Nare & Buck, 2011). Nevertheless, the studies conducted on the formative assessment method are very limited in Turkey (Aydeniz & Pabuçcu, 2011; Bulunuz & Bulunuz, 2013: 2014; Metin & Özmen, 2010; Yalaki, 2010).

Formative Assessment Probes

One of the forms of formative assessment that has been used successfully in science education is the formative assessment probe (Keeley, 2011). The equivalent of the word "probe" in Turkish means to investigate, to drill, and to research. According to the Dictionary of TDK (Turkish Language Association) (2014), it means "*the act of checking, looking for, and counting in order to understand whether something or someone is present at some certain place and time*". Similarly, these formative assessment probes are the questions used both to find out the prior knowledge of students about the subject before the lesson and to determine the method to teach the lesson without any purpose of giving marks. According to Keeley (2011), only collecting information about students' ideas does not make a probe formative. If the information is used to improve teaching and learning, then the probe can be formative in nature.

In general, formative assessment probes are composed of two parts. In the first part, there is a problem or a question that is written inside a specific context and there are multiple choice answers under the question, unlike the conventional teaching practices. All the distracters that are wrong in this part are the answers that were obtained from the results of the studies carried out in this field. Students are asked to mark the answer that they think is correct. The second part that comes below is the open-ended section where the student is asked to explain "why the choice that he/she marked is correct" or give a detailed scientific explanation to the question.

Research on Floating and Sinking

The concepts of "floating and sinking" are two very common concepts that have been studied both in different countries and also in Turkey. All around the world, there are numerous studies (Hadjiachilleos, Valanides, & Angeli, 2013; Luo, 2006; Potvin, Masson, Lafortune, & Cyr, 2015; Srisawasdi, & Panjaburee, 2015; Wong, & Lau, 2014; Yin et al., 2013) recently focused specifically on middle school students' conceptual understanding on the concepts of floating and sinking. The findings of these studies listed above indicate that middle school students have limited or incorrect understanding about floating and sinking. The results of the research conducted in other counties are quite similar to the research was conducted in Turkey.

When the studies carried out with middle school students about the concepts of floating, sinking, buoyancy force, and pressure are considered, it is seen that students have alternative concepts and misconceptions in their minds that are not related to science. For example, Şahin and Çepni (2011) developed a 2-stage test in order to determine the differentiations in conceptual structures in the minds of the 8th grade students. They found a very significant difference in favor of the experimental group in which teaching was conducted. In another research on the same subject, Seçer (2008) determined the alternative concepts in the "force and motion" unit among the 6th grade students and observed the students in terms of conceptual development. According to the results of Seçer (2008), the students had wrong concepts in their minds that were similar to many alternative concepts available in the literature, which was noticed from the answers they gave in the pretest. In terms of the conceptual development of the students during the teaching stage, the researcher also found out that the students gave scientific answers about some concepts, but failed to make an absolute progress regarding some others.

In the studies carried out with teacher candidates on the same subject, it is seen that they have different concepts about floating, sinking, buoyancy force, and pressure. Demir, Uzoğlu and Büyükkasap (2012) found out in the research that they conducted with science teacher candidates that they had several misconceptions concerning force and motion concepts. With the aim of determining these misconceptions within the scope of this research, some open-ended questions and questions similar to concept cartoons were used, and it was seen at the end of the research that teacher candidates had many misconceptions that were not related to scientific facts about force and motion subjects.

In another study carried out on university students from different majors, Kalın and Arıkıl (2010) aimed to identify the misconceptions that university students had regarding "solutions" and to determine how the "dissolution" in particle size is defined by students. At the end of the study, it was found out that students did not have much difficulty in mathematically calculating the density of a pure substance and the solution given, but they had misconceptions regarding the concept of density. With the research, the reasons behind the misconceptions that students had in mind were determined to be teachers and failure of students in associating their prior knowledge with the new knowledge they acquire in a reasonable way. In another study conducted by Ültay and Kasap (2014) on the second year students studying in the major of Primary School Teaching, the effect of "*floating and sinking objects and buoyancy force in liquids*" subject that was prepared based on the conceptual change approach on the conceptual understanding of students was investigated. It was found out that students had misconceptions concerning floating and sinking objects and the buoyancy force in liquids, and the conceptual change approach that was applied became efficient in teaching them these concepts correctly.

This study has two purposes. The first purpose is to determine the 8^{th} grade students' levels of conceptual understanding of the concepts of floating and sinking through the formative assessment probes. The second purpose is to determine whether there is a significant difference between the performances of students in the formative assessment probes and their achievement in the TEOG 1 exam. In this study, an attempt was made to answer the below-mentioned research questions:

1. What are the 8^{th} grade students' levels of conceptually understanding the formative assessment probes prepared on the subject of floating and sinking?
2. Is there a difference between the performances that students display in the formative assessment probes and their achievement levels in the TEOG 1 (transition from primary to secondary education) 1 exam?

Method

The Design of the Study

This research has been conducted in the survey model (Karasar, 1998; Kaptan, 1998; & Robson, 1997). According to Karasar (1998, p. 77) the survey model is a research approach aiming to describe a past or present situation. In this study, by using the survey model formative assessment probes were used to collect information about middle school students's current initial understandings about the concepts of floating and sinking. In addition, the students' open ended explananations for thev second part of the formative assessment probes on their choices and their TEOG 1 scores were also used to describe these students' conceptual levels about these physical science concepts.

Participants

This study was designed and carried out jointly by a science teacher, a researcher, and two field experts. It was conducted on 61 8^{th} grade students, 29 of them being girl and 32 of them being boy, in Mehmet Gedik Middle school in Odunpazarı District of Eskişehir in the 2014-2015 academic year. The school is a public school in the city center with a medium socio-economic status that has a science and a computer laboratory and that can provide necessary facilities to its student. The fact that the third writer of this study (researcher-teacher) was working as a science teacher in this school became influential on the choice of this school.

Data Collection Tools

TEOG 1 exam is a set of exams conducted every semester for 6 basic courses at the 8th grade by teachers. It has been in practice since the beginning of the 2013- 2014 academic year. TEOG 1 exam consists of 20 multiple choice questions. Each one of these questions is composed of a question statement, one correct answer, and three other distracters. In the TEOG 1 exam conducted in the 2014- 2015 academic year, questions on mitosis, meiosis, heredity, DNA and genetic code, adaptation, and evolution were asked from the "living beings and the life" unit while there were questions about the buoyancy force of liquids and gases, density, and floating and sinking of an object on/in the water from the "force and motion" unit. In the research, the achievement marks that students obtained from 20 science questions were used. The frequency and percent values of the achievement marks that the students participating in the present study obtained from this exam are indicated in the table below. Four 2-stage questions were used for data collection tool based on the formative assessment method. At the end of the first TEOG 1 exam, 61 8th grade students attending a middle school in Eskişehir were asked to answer four 2-stage formative assessment probes in writing.

Table 1. Frequency and percent values of the students' TEOG 1 achievement scores **(N=61)**

TEOG 1 Scores	**F**	**%**
85-100	28	46
70-84	11	18
55-69	11	18
45-54	7	11
0-44	4	7

In the study, 4 formative assessment probes developed concerning the concepts of force and motion by Keeley and Harrington (2010) were used as a data collection tool based on the formative assessment approach. Before choosing the assessment probes, the gains that were set with regards to the force and motion subject in the curriculum were examined and it was aimed to ensure that the probes were compatible with the gains. The assessment questions selected in line with this aim were adapted to Turkish. In the light of the feedback received from field experts in this process, the necessary changes were made, and the assessment probes were finalized. The formative assessment probes are composed of 2 parts. The first part includes different choices regarding the question. As for the second part, students are asked to explain the rule or logic that they use while choosing one particular answer. In the first assessment probe, the relationship between the amount of matter and density is investigated in objects of different sizes but made of the same matter while in the second probe it is asked what position an object floating on the water will have when a hole is made on it. In the third question, the relationship between the amount of matter and the floating and sinking situation is asked while in the fourth question the relationship between the density of an object and its position in a liquid is investigated. The formative assessment probes used in the research can be found in the Appendix A.

Data Analysis

In the related literature, the analyses of the two stage questions are generally made by classifying the answers of students into categories (Çalık, Kolomuç & Karagölge, 2010; Karataş et al., 2003). The probe questions used in this study were evaluated using a rubric developed for the analysis of two-stage questions by Karataş (2003) (See Appendix B). The assessments were made independently by the first author and the third author (i.e. researcher-teacher) of this paper. Whether there was a consistency between the marks given by the two researchers was determined via SPSS based on the inter-rater reliability coefficient. This coefficient was found to be .95 which showed that the assessments of the two researchers were highly consistent with each other. Accordingly, the data were entered in SPSS by matching the data obtained from the questions with the science scores that students got in the TEOG 1 exam. Later, the average scores that students got from the formative assessment probes were compared, by use of t-test with their average achievement scores in the science test within TEOG 1.

Results

The answers that students gave to the formative assessment probes were analyzed in line with the criteria indicated above. The findings below were obtained:

Part One of the Study

The First Formative Assessment Probe: Comparing Cubes

In the first assessment probe, the "*relationship between the amount of matter and the density in the objects that are of different sizes but made up of the same matter*." was asked. The findings obtained from the analysis of the answers to this question are indicated in Table 2.

Table 2. The findings obtained from the analysis of the first formative assessment probe

	(N= 61)		
Categories	**Sample Answer**	**f**	**%**
C.A – C.E	- Among the objects that are made of the same matter, the bigger one weighs more. - Since their volumes are the same, they have the same shape. As the volume of the objects that are made of the same matter increases, their mass increases as well. - As they are made of the same matter, the amount of floating, sinking, and melting at a certain temperature are all the same. As only one of them is bigger, it weighs more.	10	16
C.A. – P.C.E	- Since the big cube is bigger than the small cube, it weighs more. The small cube weighs less. - The mass and volume of the big cube is more than those of the small cube. - As the size of one cube is different from the other, its volume and mass are different as well.	11	18
C.A. – I.E	- Big cube is heavier than the small cube. *- The mass, atom, melting point, and volume of anything big is more than those of a small one.*	15	25
I.A. I.E	*-Since it is big, its melting rate is slower. A higher temperature is needed to heat it quickly.* *- As they are made of the same matter, their masses are closer to each other.*	25	41

* The italic sentences are the answers that include alternative concepts.

As it is seen in the Table 2, the majority of the students gave answers that fit in the category of (I.A. - I.E) for the question where the concepts of force and motion were asked. 16% of the students gave answers that fit in the category (C.A -C.E) while 18% in (C.A– P.C.E) When we take a look at the category (C.A–I.E), it is seen that 25% of the students gave answers that fit in this category. Also, it was found out that the students had the following alternative conceptions: *The atom, melting temperature and density of any big object will be more than those of a small one*; *the melting temperature of a big object will be lower*; *and the masses of two objects will be similar as they are made of the same matter.*

The Second Formative Assessment Probe: Solids and Holes

In the second assessment probe, whether "the position of an object changes inside the water when a hole is made on it" was asked. The findings obtained through the assessment of the answers to this question in line with the criteria identified are presented in Table 3.

When the Table 3 is analyzed, it is seen that most of the answers are in the category of (I.A. - I.E) While 41% of the students gave answers that fit in this category, 29% of them marked for the category of (C.A. – P.C.E) and 10% of them for (C.A – I.A). Considering the answers that were given to this question, it is clear that the following alternative conceptions exist in the minds of students: "*If there were holes on ships, they would sink. Thus, all matters that have a hole on them sink. They first sink, then float just like the holes on a sponge. Since it floats before the holes, only a small part of it continues floating when a hole is made on it. Its mass remains the same after it has a hole*."

Table 3. The findings obtained from the analysis of the second formative assessment probe

	(N= 61)		
Categories	**Sample Answer**	**f**	**%**
C.A-C.E	- The floating and sinking of an object are about density. Since density is calculated as follows: 'd= mass/volume', both the volume and the mass reduce in the 2nd figure. - As the volumes of both objects are to be the same, they float in the same way. - The volume does not change when a hole is made on the object. If the volume is the same, it floats in the same way.	12	20
C.A-P.C.E	-The volume does not change when a hole is made on the object. -The hole does not make any difference so they continue to float in the same way. -The object continues to float in the same way even if a hole is made on it.	18	29
C.A – I.A	-In the second figure, only holes are made on the object, which means the structure of the matter is not changed, so floating continues in the same way. -It does not make any difference. The object with the hole remains the same. *It has the same mass.*	6	10
I.A – I.E	*-This is because; there are no holes in ships. If there were, they would sink.* *-Thanks to the holes in rocks looking like a sponge, it first sinks and then floats.* *-Only a very small part of it floats. This is because; it was floating when it was a proper square. If we made a hole on it, only a small part of it would float.*	25	41

* The italic sentences are the answers that include alternative concepts.

The Third Formative Assessment Probe: Floating Logs

In the third assessment probe, the "*relationship between the amount of matter and the floating and sinking situation*" was asked. The findings obtained from the analysis of this question are presented in Table 4.

Table 4. The findings obtained from the analysis of the third formative assessment probe

	ESKİŞEHİR (N= 61)		
Categories	**Sample Answer**	**f**	**%**
C.A–C.E.	-I think it does not make any difference if it is big or small. If their densities are the same and they are made of the same matter, they float in the same way. -This is because; the sinking volume of the object is about the density of the object and liquid. No matter how big the object is, its volume will remain the same. -The volume and the mass of the big log have increased but it floats in the same way as its density is the same.	19	31
C.A-P.C.E	-This is because; their densities are the same -This is because; they are made of the same wood. -As the densities of the identical matters are the same, the mass or volume is not important.	19	31
C.A-I.E	- Floating and sinking are not about the size or width. - As they are made up of the same matter, the size is not important. - The choice B is more reasonable compared to A and C.	20	33
I.A- I.E	-As it is 2-fold bigger, it weighs more. *-More than half of the big log floats on the water because its volume is more.* *- If we put a log that is two times bigger than the 1st log, less than half of it floats.*	3	5

* The italic sentences are the answers that include alternative concepts.

In Table 4, it is seen that 31% of the students gave answers that fit in the category of (C.A– P.C.E), 33% of them marked for (C.A–I.E) and 5% of them for (I.A-I.E) In this probe, the following alternative conceptions were detected: *More than half of the big log floats on the water as its volume is higher. If a half of a log floats while the other half sinks, a log that is 2-fold bigger floats with less than half of it sinking in the water.*

The Fourth Formative Assessment Probe: Floating High and Low

The findings obtained from the analysis of the 4th Formative Assessment Probe that questions the "*relationship between density of an object and its position inside a liquid*" are presented in Table 5 below.

Table 5. The findings obtained from the analysis of the fourth formative assessment probe

	(N= 61)		
Categories	**Sample Answer**	**f**	**%**
C.A – C.E.	-For an object to float on the water, its density has to be high. Accordingly, a matter of a higher density may be used or an extra weight may be added to the ball which will increase the density of the ball. -For the ball to sink more under the water, a matter of a higher density but the same size may be used. When the density of the ball increases, it sinks more. Also, an extra weight might be added to the ball as it will sink more easily as its mass increases. -Adding an extra weight to the ball makes a counter-effect and makes the ball sink more. Using a ball of the same size but of a higher density makes the ball sink more because as the density increases the volume that sinks increases as well.	11	18
C.E – P.C.E	-If a matter that is of higher density than the water is used, the ball sinks. If an extra weight is added to the ball, the water will not hold the ball over the surface and it will sink more. -We get this result when a pressure is made on the top of the ball because either the density or the mass must be higher for the ball to sink deep. -Because the matters of a higher density sink deeper. If the material is denser, we will have the lower buoyancy. As the weight increases, the ball goes down in the water because it is inversely proportional with the buoyancy force.	26	43
C.A – I.E	-*As the mass increases, the buoyancy force decreases.* As the density increases, the buoyancy force decreases. When we add some salt inside the water, the ball goes up toward the surface. So it does not sink. -*If the density is high, the volume that sinks decreases.* -If the density of the liquid or the volume of the object changes, the rate of floating and sinking changes as well.	14	23
I.A – I.E	-If it is made of a matter with higher density, it becomes the same because the ball on the right has a higher density. - It is possible if *a bigger ball made of the same matter* or a ball made of a matter with a higher density is used. -*A liquid with much more density should be used here* because the object sinks as the density increases.	10	16

* The italic sentences are the answers that include alternative concepts.

As it is seen on Table 5, 16% of the students gave answers that fit in the category of (I.A-I.E) while 18% of the students marked for (C.A–C.E) and 43% for (C.A-P.C.E) As for the (C.A-I.E) category, it has 23% of the answers. Also, it was found out that students had the following alternative concepts: *As the mass of the matter increases, the buoyancy force of the liquid increases as well. The big ball that is of a bigger size but made up of the same matter sinks much more. For the object to sink deeper, a liquid with a higher density is needed. If the density of the object increases, the volume that is sinking reduces.*

The findings obtained through scoring criteria given in Appendix B are presented in Table 6. When the total scores that students got from the assessment probes are examined in Table 6, it is seen that for the 3rd question, most of the students gave the answers that fit in the category of C.A. - C.E. As for the D.C. – K.D.G category, most of the answers came from the 4th question while the D.C – Y.G category got most of the answers from the 3rd question. When we take a look at the I.A. - I.E. category, it is seen that the least number of answers came from the 3rd and 4th questions while in the rest of them the answers are of the same frequency for this category.

Table 6. The performance scores of the students in formative assessment probes (N=61)

	1. Probe		2. Probe		3. Probe		4. Probe		Total Score
	f	Score	f	Score	f	Score	f	Score	
C.A-C.E	10	**30**	12	**36**	19	**57**	11	**33**	**156**
C.A-P.C.E	11	**22**	18	**36**	19	**38**	26	**52**	**148**
C.A-I.E	15	**15**	6	**6**	20	**20**	14	**14**	**55**
I.A-I.E.	25	**0**	25	**0**	3	**0**	10	**0**	**0**

Part Two of the Study

Is there a difference between the achievement levels that the students reached in TEOG 1 exam and their performances in the formative assessment probes?

Whether there is a difference between the achievement scores that the students got in science and technology in TEOG 1 exam and their performances in the formative assessment probes was analyzed using the matched-pairs t-test. The result of the analysis is presented on Table 7.

Table 7. Average scores from TEOG 1 and the formative assessment probes and their standard deviations

	N	M	SD	t
TEOG 1 Scores	61	75.00	19.57	11,28*
Formative Assessment Probes Scores	61	52.02	23.54	

* p<.001

The results of the matched-pairs t-test revealed that there is a significant difference between the average scores that the students got in science and technology in TEOG 1 exam and their performances in the formative assessment probes: t (61) = 11.28, p =.001.

Conclusion and Discussion

In the first part of the research, the level of conceptual understanding of the 8th grade students about the concepts of floating and sinking was determined through the formative assessment probes. As for the second part, it was found out whether there was a significant difference between the achievement scores of the students in science questions in TEOG 1 and their formative assessment scores. The results obtained in the study are explained below:

Part One of the Study

In order to answer the first research question (i.e. "What are the 8th grade students' levels of conceptually understanding the formative assessment probes prepared on the subject of floating and sinking?"), the answers that the students gave to the 4 formative assessment probes were analyzed. The results are indicated below:

The 1st Formative Assessment Probe: Comparing the Cubes

When the data obtained from the first assessment probe is examined, it is found out that nearly half of the students (41%) neither marked the correct answer for this probe and nor could write the right scientific explanation in the second part. In other words, almost half of the students could not compare correctly the objects of the same size but different volumes in terms of their physical characteristics such as mass, density, floating and sinking, etc. A quarter of the students (25%) marked the correct answer that says 'only the mass of the cubes made of the same matter but being of the different volume will be different' but couldn't write a correct or scientific explanation in the open-ended part of this question.

Based on these data, it can be said that students cannot use their knowledge on the question, nor can they make deductions, and they have difficulty in comparing objects made up of the same matter but being of different sizes in terms of melting point, density, floating and sinking, atom size, mass, and volume and in making an explanation even if they find the correct answer. The reason behind this failure might be the fact that students have been subject to conventional summative evaluation and assessment methods such as "true-false", "matching", "fill in the gaps", and "multiple choice" questions that are applied continuously at the end of units or semesters. These conventional evaluation and assessment methods generally lead to superficial learning and learning by heart as they contain fragmentary and discrete knowledge that is forgotten in a short period of time. In this regard, it is clear that students cannot analyze more than one case at the same time nor can they make deductions and explanations. The results obtained from this assessment probe are in parallel with the results of Şahin and Çepni (2011). Similarly, they also found out that students have a low level of conceptual understanding and have alternative concepts regarding the subjects of density and floating and sinking within the force and motion unit.

The 2nd Formative Assessment Probe: With and Without Hole

In this probe, the question 'whether an object that is floating on the water continues to do so if holes are made on it?' was asked to students. When the answers are examined, it is seen that nearly half of the students (41%) gave answers that fit the category of (I.A. - I.E). Only 20% of the students guessed correctly that making holes on an object will not change its floating on the water, but they did not make the explanations well. Even though they explained the relationship between the density and the floating and sinking situation correctly, they had difficulty in explaining how making a hole in an object can affect its floating and sinking. This shows us that students fail to use their basic conceptual knowledge in different cases.

The examples that students gave by making a wrong analogy in their explanations such as "If there were holes in ships, they would sink. So any object with a hole on it must sink in the water." and "There are holes on sponge as well, so the object first sinks and then floats on the water." also confirm that. These findings reveal that students cannot put what they learn in the lesson into practice in their daily lives, and they learn the information written on course books by heart and thus have difficulty in building a cause-effect relationship in different questions. The results reached through this question are in parallel with the results of Ültay and Kasap (2014) who determined the conceptual understanding levels of students regarding floating and sinking objects.

The 3rd Formative Assessment Probe: Floating Logs

To the question that asked the position of a log that is floating on the water first but then is made two-fold bigger one, most of the students (95%) gave the correct answer. When compared to the other probes, the highest level of achievement was achieved in this one. This may be because; this question did not involve more than one situation that had to be compared. When the students think about only one situation, they can find the answers more easily. However, when they have to consider more than one situation in the questions, it can be said that they have difficulty in interpreting. Similar to Kalın and Arıkıl (2010), it was seen in the present study that students do not have difficulty while making a density calculation but find it difficult to make an interpretation concerning the density concept in different situations and have many misconceptions about the subject.

The 4th Formative Assessment Probe: Floating and Sinking

Most of the students gave the following answers to the question of 'how the volume of the sinking part of a ball the half of which is floating on the water can be increased?': "By using an object of the same size but with more density" and "By adding a weight to the ball". In this probe, most of the students gave the correct answer, but they could not make the right justification properly. Similarly, in another study Seçer (2008) conducted with the 6th grade students, it was found out that students gave scientific answers regarding some concepts about force and motion but failed to make an absolute progress regarding some others. This shows us that they marked the correct answer thanks to the knowledge that they gained by heart but could not write why they chose that answer or indicate the correct scientific explanation of the concept.

Part Two of the Study

In the second part of the research, it was investigated whether there is a significant difference between the performances of the 8th grade students in formative assessment questions and their achievement scores in science questions in TEOG 1 exam regarding the concepts of floating and sinking. The significant difference between these scores in favor of TEOG 1 exam shows that students are more successful in the standardized middle school science test (TEOG 1) compared to the formative assessment probes. The most important reason why the students generally obtained low scores in formative assessment probes is that they were asked to explain in detail the justification behind the answers that they marked as correct in the second part of the exam.

Since the 8th grade students were used to having multiple choice exams, they did not have any difficulty in finding the right answer in the multiple choice part of the assessment questions. For example, more than 50% of the students gave the correct answer to all assessment questions. However, the analysis results indicate that the students who found the correct answer had difficulty in explaining why they chose that answer in the second part of the assessment questions (23%). This result demonstrates that the explanation and interpretation skills of students are underdeveloped. This is because; even though approximately 15% of the students found the correct answer in the first part, they gave a wrong justification in the second part; and while 14% of the students marked the correct answer in the first part, the explanation they wrote in the second part was partially correct. This finding shows that generally one third, which is a very high rate, of the students have difficulty in making an explanation in the assessment probes. This result might have several reasons. The first reason is that the word 'assessment' has almost all the time come to mean multiple choice tests in the Turkish education system. Since the TEOG 1 exam is composed of multiple choice test questions, both the written exams that teachers hold at schools and the questions in course books are composed of multiple choice tests and there is no question based on reasoning. Letting students be subject to test questions from primary school to middle school does not improve their reasoning and explanation skills, which is not a surprising result. The fact that students cannot make an explanation about the correct answer of a question indicates that they have not understood the subject (Murchan, Shiel,Vula, Bajgora, & Balidemajson, 2013). Among the reasons why students fail when they encounter the question types different from multiple choice tests may be as follows: teachers do not go beyond the conventional methods while evaluating the performance of students; they do not diversify the examples while teaching the subject and do not associate the lessons with the daily life; and they just convey the information in books to the students.

On the other hand, students do not feel a need to make an explanation about why a particular choice is correct even if they find the correct answer because the current assessment system measures mostly the information. Instead of thinking 'How can I use this information in my daily life? or 'How can I make use of the information I have in different situations?', students always worry about solving more and more test questions. This is because they are assessed through the TEOG 1 exam, are subject to an achievement order, and are placed in a high school according their scores. For this reason, students are concerned about the question "How can I keep more information in mind?" rather than "How can I fulfill conceptual learning?" or "What should I do for permanent learning?" All of these can be considered among the reasons why students fail to make an explanation or indicate their ideas in writing about their answers in an exam. One of the most important differences between the formative assessment method and the summative method is that the former helps to re-arrange the lesson plan based on the feedbacks that teachers receive from students through the formative assessment. Conceptual learning can be realized only when that occurs. Since our students have been raised in an assessment system that is based on getting marks at the end of each semester, they cannot receive an effective and objective feedback about their performance in the lesson from their teachers, which causes them to fail to learn the subjects properly and on a scientific basis (Black & William, 1998; Black, et al., 2004).

Recommendations

1. Though formative assessment has efficiently been used abroad for many years, there are very few studies conducted in this area in Turkey. This subject should be brought to the agenda during the in-service training seminars and be introduced to teachers and principals comprehensively. During these seminars, the following points should be explained to the participants with examples from the national and international literature: what is formative assessment?; what makes it different from the conventional assessment methods?; what is its contribution to permanent learning and conceptual change?; what methods and techniques may be used to apply the formative assessment method?; and so on.

2. In order to implement the formative assessment methods on their students and to increase their performances, teachers should be encouraged to do an action research by applying new formative assessment methods and to present the results of their studies at congresses or to share them with stakeholders by publishing the results.

3. The teachers who have been accustomed to making a summative assessment should go beyond the ordinary and concentrate on the questions that improve the reasoning and interpretation skills and the abilities of students to explain their ideas verbally or in writing and on the activities that will improve these skills in the classroom.

4. Teachers should ask about the prior knowledge of students regarding the subject that they are going to teach, schedule their lesson plan in the light of this information, and rearrange the course of the lesson within the scope of the feedbacks they receive while teaching the subject and thus give efficient and objective feedbacks to their students in return.

5. The subject of floating and sinking is one of the subjects that is less known or about which there are a lot of misconceptions in the minds of students, as is the case in many subjects within the science curriculum for middle schools. In order to teach this subject in a more effective way, the problems that are included in the probe questions should be selected from the daily life.

References

Ali, I., & Iqbal, H.M. (2013). Effect of formative assessment on students’ achievement in science, *World Applied Sciences Journal. 26* (5), 677-687.

Angelo, T., & Cross, K. P. **(**1993). *Classroom Assessment Techniques: A Handbook for “College Teachers.* San Francisco: Jossey-Bass Publishers.

Atkin, J. M., Coffey, J. E., Moorthy, S., Sato, M., & Thibeault, M. (2005). *Designing everyday assessment in the science classroom.* New York: Teachers College Press.

Ausubel, D. P. (1968). *Educational Psychology: A Cognitive View.* New York and Toronto: Holt, Rinehart and Winston.

Aydeniz, M., & Pabuçcu, A. (2011). Understanding the impact of formative assessment strategies on first year university students’ conceptual understanding of chemical concepts. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education*, 5 (2), 18-41.

Black, P. J. (1993). Formative and summative assessment by teachers. *Studies in Science Education, 21,* 49-97.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education, 5* (1), 7–74.

Black, P., Harrison, C., Lee, C., Marshall, B., & Wiliam, D. (2004) Working inside the black box: Assessment for learning in the classroom. *Phi Delta Kappan, 86* (1), 8-21

Bulunuz, M., & Bulunuz, N. (2013). Fen öğretiminlumede Biçimlendirici Değerlendirme ve Etkili Uygulama Örneklerinin Tanıtılması. *Türk Fen Eğitimi Dergisi (TUSED), 10*(4), 119-135.

Bulunuz, N., Bulunuz M., & Peker, H. (2014) Effects of Formative Assessment Probes Integrated in Extra-Curricular Hands-On Science: Middle School Students' Understanding. *Journal of Baltic Science Education, 13(2),* 1-19.

Butler, R. (1987). Task-involving and ego-involving properties of evaluation: effects of different feedback conditions on motivational perceptions, interest and performance. *Journal of Educational Psychology, 79* (4), 474–482.

Butler, R., & Neuman, O. (1995). Effects of task and ego-achievement goals on help seeking behaviours and attitudes. *Journal of Educational Psychology, 87* (2), 261-271.

Crooks, T. J. (1988) The impact of classroom evaluation practices on students, *Review of Educational Research, 58,* 438-481.

Çepni, S., & Şahin, Ç. (2012). Effect of different teaching methods and techniques embedded in the 5E instructional model on students' learning about buoyancy force. *Eurasian Journal of Physics and Chemistry Education*, *4*(2).

Demir, Y., Uzoğlu, M., & Büyükkasap, E. (2012). Fen Bilgisi Öğretmen Adaylarının Kuvvet ve Hareket ile İlgili Sahip Olduğu Kavram Yanılgılarının Belirlenmesinde Kullanılan Karikatürlerin ve Çoktan Seçmeli Soruların Etkililiğinin Karşılaştırılması. *Eğitim ve Öğretim Araştırmaları Dergisi*, *1 (1),* 2146-9199.

Furtak, E. M. (2012). Linking a learning progression for natural selection to teachers’ enactment of formative assessment. *Journal of Research in Science Teaching, 49* (9), 1181–1210.

Hadjiachilleos, S., Valanides, N., & Angeli, C. (2013). The impact of cognitive and affective aspects of cognitive conflict on learners’ conceptual change about floating and sinking. *Research in Science & Technological Education*, *31*(2), 133-152.

Kalın, B., & Arıkıl, G. (2010). Çözeltiler Konusunda Üniversite Öğrencilerinin Sahip Olduğu Kavram Yanılgıları. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi*, *4 (2)*, 177-206.

Kaptan, S. (1998). *Bilimsel araflt›rma ve istatistik teknikleri*. Ankara: Tek›fl›k Web Ofset Tesisleri.

Karasar, N. (1998). *Bilimsel araştırma yöntemi*. Ankara: Nobel Yayın Dağıtım.

Karataş, F. Ö. (2003). *Lise 2 kimyasal denge konusunun öğretiminde bilgisayar paket programları ile klasik yöntemlerin etkililiğinin karşılaştırılması*, KTÜ Fen Bilimleri Enstitüsü, Yayınlanmamış Yüksek Lisans Tezi, Trabzon.

Karataş, F. Ö., Köse, S. & Coştu, B. (2003). Öğrenci yanılgılarını ve anlama düzeylerini belirlemede kullanılan iki aşamalı testler, *Pamukkale Üniversitesi Eğitim Fakültesi Dergisi*, 1, 13, 54-69.

Kavanagh, C., & Sneider, C. (2007). Learning about gravity I. free fall: A guide for teachers and curriculum developers. *The Astronomy Education Review, 5* (2), 21-52.

Keeley, P., Eberle, F., & Farrin, L. (2005). *Uncovering student ıdeas in science, vol. 1: 25 formative assessment probes.* California: Corwin & NSTA Press.

Keeley, P., Eberle, F., & Tugel, J. (2007). *Uncovering student ıdeas in science, vol. 2: 25 formative assessment probes.* California: Corwin & NSTA Press.

Keeley, P. (2008). *Science formative assessment: 75 practical strategies for linking assessment, ınstruction, and learning.* California: Corwin & NSTA Press.

Keeley, P. (2009). *Uncovering student ıdeas in science**, volume 4: **25** new formative assessment probes*. California: Corwin & NSTA Press.

Keeley, P., & Harrington, R. (2010). *Uncovering student ıdeas in physical science, vol.1 – 45 new force and motion assessment probes.* California**:** Corwin & NSTA Press.

Kopittke, P. M., Bernhard Wehr, J., & Menzies, N. (2012). Does Formative Assessment Improve Student Learning and Performance in Soil Science? Journal of Natural Reasources & Life Sciences Education, 41 (1), 59-64.

Luo, H.J. (2006). Case study on students' understanding on floating and sinking: Preliminary findings. Retrieved 15 February 2009 from http://se.risechina.org/rjsy/200608/1737.html (in Chinese).

Metin, M., & Özmen H. (2010). Biçimlendirici Değerlendirmeye Yönelik Öğretmen Adaylarının Düşünceleri. *Milli Eğitim Dergisi*, 187, 293-310.

Murchan, D., Shiel, G., Vula, E., Bajgora, A. G., & Balidemaj, V. (2013). Formatif [Biçimlendirici Değerlendirme] (2013) file:///C:/Users/User/Downloads/Formatif%20De%C4%9Ferlendirme.pdf adresinden indirilmiştir.

Potvin, P., Masson, S., Lafortune, S., & Cyr, G. (2015). Persistence of the intuitive conception that heavier objects sink more: A reaction time study with different levels of interference. *International Journal of Science and Mathematics Education*, *13*(1), 21-43.

Robson, C. (1997). *Real world research: A resource for social scientists and practitioner-researchers.*Oxford: Blackwell.

Seçer, S. (2008). *6. sınıf öğrencilerinin kuvvet ve hareket konusundaki alternatif kavramlarının belirlenmesi ve kavramsal gelişimin incelenmesi.* Yüksek Lisans Tezi, Balıkesir Üniversitesi, Fen Bilimleri Enstitüsü.

Srisawasdi, N., & Panjaburee, P. (2015). Exploring effectiveness of simulation-based inquiry learning in science with integration of formative assessment. *Journal of Computers in Education*, 1-30.

Şahin, Ç. & Çepni, S. (2011). "Yüzme- Batma, Kaldırma Kuvveti ve Basınç" Kavramları ile İlgili iki Aşamalı Kavramsal Yapılardaki Farklılaşmayı Belirleme Testi Geliştirilmesi. *Türk Fen Eğitimi Dergisi*, *8 (1)*, 79-110.

Tan, Ş. (2010). *Öğretimde ölçme ve değerlendirme.* Ankara: Pegem Akademi.

TDK Sözlük (2013). [Online] http://www.tdk.gov.tr/index.php?option=com_gts&view=gts.

Torrance, H., & Pryor, J. (2001). Developing formative assessment in the classroom: Using action research to explore and modify theory. *British Educational Research Journal*, *27*(5), 615-631.

Trauth-Nare, A., & Buck, G. (2011). Using reflective practice to incorporate formative assessment in a middle school science classroom: A participatory action research study. *Educational Action Research, 19(3),* 379–398.

Ültay, N., & Kasap, G. (2014). Kavramsal Değişim Yaklaşımına Göre Hazırlanan Etkinliklerin Öğrencilerin Yüzen-Batan Cisimleri Anlamalarına Etkisinin Belirlenmesi. *Kastamonu Eğitim Dergisi, 22 (2),* 455-472.

Wong, D., & Lau, C. Y. (2014). The Development and Implementation of a Guided-Inquiry Curriculum for Secondary School Physics. In *Inquiry into the Singapore Science Classroom* (pp. 89-110). Springer Singapore.

Yalaki, Y. (2010). Simple formative assessment, high learning gains in college generalchemistry. *Eğitim Arastırmaları - Eurasian Journal of Educational Research*, 40, 223-240.

Yin, Y., Shavelson, R. J., Ayala, C. C., Ruiz-Primo, M. A., Brandon, P. R., Furtak, E. M., Tomita,M. K., & Young, D. B. (2008). On the impact of formative assessment on students' motivation, achievement, and conceptual change. *Applied Measurement in Education, 21* (4), 335–359.

Yin, Y., Tomita, M. K., & Shavelson, R. J. (2008). Diagnosing and dealing with student misconceptions: Floating and sinking. *Science Scope*, 31(8), 34–39.

Yin, Y., Tomita, M.K., & Shavelson, R. J. (2013) Using formal embedded formative assessments aligned with a short-term learning progression to promote conceptual change and achievement in science, International *Journal of Science Education,* DOI: 10.1080/09500693.2013.787556.

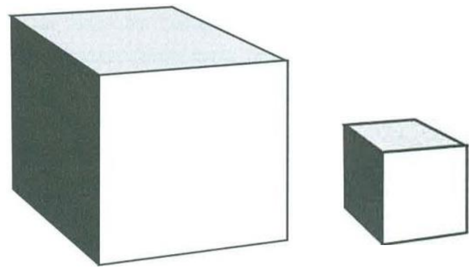
Appendices

Appendix A

First Formative Assessment Probe

COMPARING CUBES

Sofia has two solid cubes made of the same mate- rial. One cube is very large, and the other cube is very small. Put an X next to all the statements you think are true about the two cubes.



A. The larger cube has more mass than the smaller cube.

B. The larger cube has less mass than the smaller cube.

C. The larger cube melts at a higher temperature than the smaller cube.

D. The larger cube melts at a lower temperature than the smaller cube.

E. The density of the larger cube is greater than the smaller cube.

F. The density of the larger cube is less than the smaller cube.

G. The larger cube is more likely to float in water than the smaller cube.

H. The larger cube is more likely to sink in water than the smaller cube.

I. The larger cube is made up of larger atoms than the smaller cube.

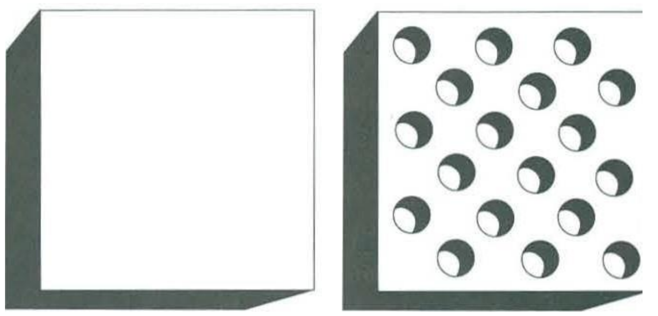
J. The larger cube is made up of smaller atoms than the smaller cube.

Explain your thinking. Describe the "rule" or reasoning you used to compare the cubes.

Second Formative Assessment Probe

SOLIDS AND HOLES

Lance had a thin, solid piece of material. He placed the material in water and it Boated. He took the material our and punched holes all the way through it. What do



you think Lance will observe when he puts te materi- al with holes back in the water? Circle your prediction.

A It will sink.

B It will barely float.

C It will float the same as it did before the holes were punched in it.

D It will neither sink nor float. It will bob up and down in the water.

Explain your thinking. Describe the "rule" or reasoning you used to make your prediction.

____

____

____

____

____

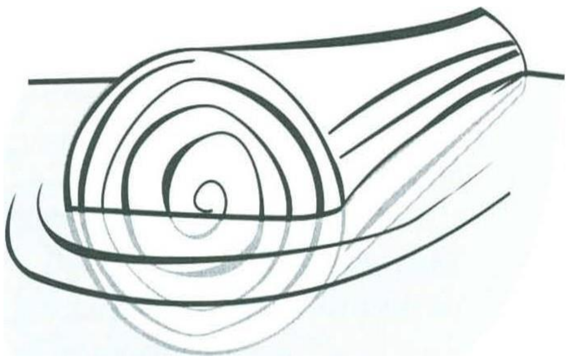
____

____

Third Formative Assessment Probe

FLOATING LOGS

A log was cut from a tree and put in water. The log floated on its side so that half the log was above the water surface. Another log was cut from the same tree. This log was twice as long and twice as wide. How does the larg- er log float com pared with the smaller log? Circle the best answer:



A More than half of the larger log floats above the water surface.

B Half of the larger log floats above the water surface.

C Less than half of the larger log floats above the water surface.

Explain your chinking. Describe the "rule" or the reasoning you used for your answer.

____

____

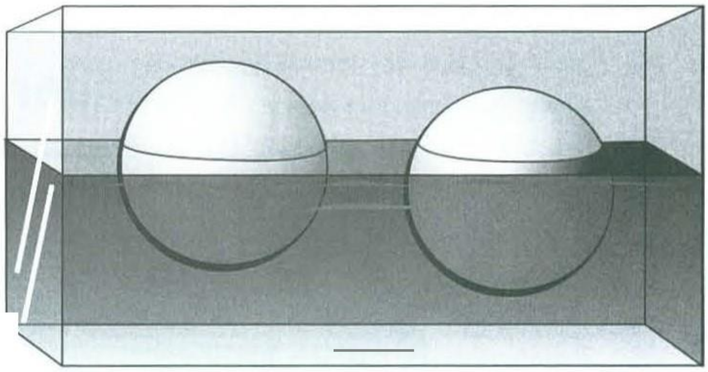
____

____

Fourth Formative Assessment Probe

FLOATINGHIGH AND LOW

Sam put a solid ball in a tank of water. As shown by the ball on the left, it floated halfway above and halfway below the water level. What can Sam do to make a ball float like the ball on the right? Put an X next to all the things Sam can do to have solid ball float *so* that most of it is below the water level.



A. Use a larger ball made out of the same material.
B. Use a smaller ball made out of the same material.
C. Use a ball of the same size made out of a denser material.
D. Use a ball of the same size made out of less dense material.
E. Add more water to the tank so it is deeper.
F. Add salt to the water.
G. Attach a weight to the ball.

Explain your thinking. Describe the "rule" or reasoning you used to determine how to change how an object floats in water.

____
____
____
____
____
____
____
____
____
____
____

Appendix B

GRADING MANUAL

The Rubric Used for Evaluating the Answers Given to the Two-Tiered Formative Assessment Probes 1.

Comprehension Levels	Explanation	Evaluation Criteria	Scores
Correct Elaboration	Integrated with scientific perspective and clear with elaboration	Correct Answer- Correct Elaboration **(C.A-C.E.)**	**3**
Partially Correct Elaboration	Partially correct or limited elaboration	Correct Answer- Partially Correct Elaboration **(C.A-P.C.E.)**	**2**
Incorrect Elaboration	Incorrect answer or clearly evident misconception	Incorrect Answer- Correct Elaboration **(I.A-C.E)**	**2**
No Answer	No response or clearly evident misconception	Correct Answer-Incorrect Elaboration **(C.A-I.E.)**	**1**
		Incorrect Answer- Incorrect Elaboration **(I.A-I.E.)**	**0**

Journal of Education in Science, Environment and Health
Volume 2, Issue 1, 2016 ISSN: 2149-214X

Using the Scientific Method to Engage Mathematical Modeling: An Investigation of pi

Lester A. C. Archer[1*], Karen E. Ng[2]
[1]Louisiana State University
[2]Indian River State College

Abstract

The purpose of this paper is to explain how to use the scientific method as the framework to introduce mathematical model. Two interdisciplinary activities, targeted for students in grade 6 or grade 7, are explained to show the application of the scientific method while building a mathematical model to investigate the relationship between the circumferences and the diameter of circular objects. In the first activity, a research question is pursued as it relates to the stated hypothesis. In the second activity, the same research question is retained; however, the use of exploration helps to build the hypothesis. The activities serve as examples to show how middle school math teachers may use scientific inquiry to motive students' understanding of mathematical models as well as engage in science beyond the science classroom. Students will be able to identify, describe, analyze, interpret, validate, and report relationships between variables.

Key words: Math modeling, math integration, STEM education, Scientific method, Science education

Introduction

Mathematics and science integration, as it relates to efficacious outcomes, benefits students (Berlin & White, 1994). In fact, a recent study infusing mathematics into an eighth-grade science curriculum supported the hypothesis that mathematics-infused science significantly impacts mathematics content knowledge, found student-reasoning skills increased for students in the infusion group, and these students "had more practice and were better prepared on a variety of mathematical concepts and scored significantly higher on the NYS eighth-grade mathematics assessment" (Burghardt, Lauckhardt, Kennedy, Hecht, & McHugh, 2015, p. 214). In addition, these researchers found that students in the lowest quartiles on the pretest showed the greatest improvement. Another study found that STEM activities are likely to foster or maintain science dispositions (Christensen, Knezek, & Tyler-Wood, 2015). The need for math and science integration is well established (Berlin & White, 1994). As a result, the need for teachers to have an array of activities to use science disposition in the mathematics classrooms should be encouraged. As they engage in mathematics and science integration, middle school math teachers can use mathematical modeling to motivate students to develop science dispositions.

Conceptual understanding requires a demonstration of how well learners have connected concepts and are able to display dispositions (Bransford, Brown, & Cocking 2000). Therefore, it may be argued that students need a curriculum with less emphasis only on skills building. Theorists posit that skills building (habituation), learning as conceptual (construction), and learning as social (enculturation)—each promoting understanding—should be balanced in the math curriculum and engaged with carefully and separately (Kirshner 2004). The opportunity to engage students in math modeling allows for increased conceptual understanding. The use of the scientific method while implementing mathematical models among middle school students provides an opportunity to engage in science dispositions.

The Council of Chief State School Officers (CCCSO) and the National Governors Association Center for Best Practices (NGA Center) suggest that, in the United States, school age children should use mathematical modeling. As a result, the Common Core State Standards for Mathematics (CCSSM), published by the CCCSO articulates mathematical modeling. These standards provide guidelines for what students should understand and be able to do (CCCSO & NGA Center, 2010), and they situate students at the intersection of conceptual understanding and content mastery (Conley & Gaston, 2013). The intent of the Standard of Mathematical

* Corresponding Author: *Lester A. C. Archer, larche2@lsu.edu*

Practice 4 (MP4): Model with Mathematics is to encourage teachers to engage students with modeling, which in turn, should increase their understanding of mathematical concepts while engaged with enriching experiences.

Mathematical modeling

The Standard of Mathematical Practice 4 (MP4): Model with Mathematics suggests that teachers encourage their students to build models that link classroom mathematics and statistics to everyday life, work, and decision-making. According to the standard, modeling includes (a) identifying variables in the situation and selecting those that represent essential features, (b) formulating models that describe relationships between the variables, (c) analyzing and performing operations on these relationships, (d) interpreting the results, (e) validating the conclusions, and (f) reporting on the conclusions and the reasoning (CCCSO & NGA Center, 2010).

Questions, however, are raised about the successful implementation of the standard. For instance, how do teachers lead students in their ability to describe how one quantity depends on another and to apply what they know to simplify a complicated situation? How do teachers get students to identify important quantities and map their relationships using tools, and mathematically analyze these relationships to draw conclusions? How do students interpret their mathematical results in the context of a situation and reflect on whether the results make sense? How best do teachers assess knowledge? How do teachers afford students the opportunity to meet and exceed MP4?

Teachers need to know that the CCSSM does not provide a prescriptive approach to the question: How best should math teachers engage students in modeling? However, teachers need the confidence to know that implementing these standards provide learning opportunities and classroom benefits. Therefore, we propose that the scientific method affords not only an option as an overarching approach to assist teachers with the implementation of mathematical model but also provides learning opportunities.

Scientific Method

According to The National Research Council (NRC), students should develop an understanding of science in order to engage the world in which they live. Furthermore, they reiterate that "students need to understand what is meant….by observation, a hypothesis, an inference, a model, a theory, or a claim and be able to distinguish among them" (NRC, 2012, p. 79). As a result, students experience the foundation of scientific inquiry. With this in mind, science standards for states around the country have all included scientific inquiry as a mandatory part of science courses in schools. Although the newest version of the recommended science standards do not include the scientific method as a standard, the focus on its incorporation as the underpinning in science investigations of every concept suggests the importance of the use of scientific method as early as elementary school (Achieve, 2013). Scientific inquiry is a process in which students, guided by their teacher, attempt to discover the answer to a question or problem (Gormally, Brickman, Hallar, & Armstrong, 2009). Scientific inquiry is important because it teaches students how to explore their environment in a logical manner. Science inquiry involves all students actively learning by answering questions through data collection and analysis (Bell, Smetana, & Mills, 2005).

Science teachers have the responsibility for teaching the process of science as well as the science content but invariably spend most of their time in the classroom teaching content (Stiles, 1942; D'Costa & Schlueter, 2013). Science teachers know that science inquiry is important but do not have the confidence or knowledge to go beyond the cookie cutter labs and therefore identify these labs as inquiry when they are not (Bell, Smetana, & Mills, 2005). An excellent way to motivate students is to present them with a problem or question to solve (Prince & Felder, 2007). D'Costa and Schlueter (2013) and Gormally, et al. (2009) report that while students find scientific inquiry more challenging than the traditional method of learning science by taking notes, students admit that they learn more and had a more rewarding experience. D'Costa and Schlueter (2013) and Gormally, et al. (2009) argue that science teachers need to teach students these science-processing skills, which allow students to ask questions, formulate hypotheses, test these hypotheses and arrive at answers to their questions. Students can then apply these skills to other aspects of their lives outside of the science classrooms.

The scientific method provides an accessible approach to inquiry that presents an effective and convenient way that allows students to experience the process of science (Blystone & Blodgett, 2006). The scientific method involves a series of steps, namely, observation, question, hypothesis, materials, procedure, data collection, data analysis and conclusion (Blystone & Blodgett, 2006; Palmer & Mahan, 2013). However, the danger in teaching the scientific method is that students may believe it just involves these simple steps (Lederman, et al., 2014; McPherson, 2001). While no specific set of steps could possibly consider all of the strategies a researcher may use to answer a question and to understand the world, the steps of the scientific method is a good approximation to use (Blystone & Blodgett, 2006; Guy, 2001). Many students reach the college level knowing how to recite the different steps of the scientific method but fail to understand the process, e.g., the use of variables (D'Costa & Schlueter, 2013). Therefore, it is important that science teachers scaffold the various steps of the scientific method to allow students to learn the stages without becoming frustrated and giving up due to perceived failure and just being content to learn the steps by rote without understanding (D'Costa & Schlueter, 2013).

Connecting Math and Science

Measurement is a concept common to math and science as seen in both sets of standards (Achieve, 2013; CCCS, 2010; NRC, 2012). Therefore, measurement is a good topic to use to integrate math and science in the classroom (Hurley & Normandia, 2005). Exposing students to the role of math and science as an integrated unit is important (Arnett & Van Horn, 2009). Such integration is necessary for an increase in knowledge acquisition and application (Cawley & Foley, 2002; Weinburgh & Silva, 2011). Furthermore, Arnett and Van Horn (2009) report that students appreciate learning math in the context of science. Activities that integrate math and science help students to practice skills such as hypothesize, measure, collect and analyze data, form discussions and conclusions (Schlenker & Schlenker, 2002).

Activity – Investigating pi using the Scientific Method

These activities outlined here offer two possible uses of scientific inquiry as it relates to one research question. The research question remains the same; however, the variation occurs with a hypothesis that is stated or not stated. First, we introduce the activity with the stated hypothesis and then we show the activity without a stated hypothesis. In the first activity, students experience the step by step approach of the scientific method, whereas in the second activity students are exposed to scientific inquiry without the guidance of a hypothesis. This removal of the hypothesis introduces students to the idea that scientific inquiry does not need to follow a prescribed set of steps (Lederman, et al., 2014).

In these activities, students receive guidance through the steps of the scientific method in order to investigate the relationship of the circumference to the diameter of circular objects. The steps used in these activities are questioning, researching, hypothesizing (in first activity), data collecting and analyzing, discussing and concluding. These activities offer two possible uses of scientific inquiry as it relates to one research question. The research question remains the same; however, the variation occurs with a hypothesis that is stated or not stated.

Hypothesis Stated

Question: What is the relationship between the circumference and the diameter of a circular object?
Research: Students research the meaning of the words circumference, diameter and how these terms are related. Students discover that the relationship of the circumference of a circular object to its diameter is the constant pi.

Hypothesis: If the circumference of circular objects is measured then the diameter of those objects will have a relationship to their circumferences that is constant. Here, the teacher may take the opportunity to scaffold or guide students to arrive at a particular hypothesis. The teacher uses deductive language in guiding students to formulate the hypothesis. Materials are then selected for activities to test the hypothesis.

Materials: For illustrative purposes we used the following materials:

- a penny, hula hoop, plate, cd, cookie
- tape measure or string and ruler
- pencil
- paper
- Table for data collection and calculation (see Table 1)
  (A spreadsheet coded incorporates an opportunity for integrating technology)

Procedure: First, measure the circumference and diameters of the circular objects. Next, enter the measurements on the data table. Then complete calculations which includes finding the ratio of the average circumference to its respective average diameter.

Data: We conducted three trials in the measurement of the circumference and diameter for each object, then found the average so as to arrive at a measurement that is as accurate as possible (see Table 1). This may stimulate some discussion about measurement, accuracy and the purpose for central tendency.

Table 1. Data collected and compiled

Object	Circumference				Diameter				Ratio
	Trial 1	Trial 2	Trial 3	Mean	Trial 1	Trial 2	Trial 3	Mean	
Penny	5.8	6.1	6.3	6.07	1.8	2.1	1.9	1.93	3.1379
Hoop	222.2	221.8	222.6	222.20	71.5	71.8	71.4	71.57	3.1048
Plate	79.0	78.8	78.7	78.83	25	24.6	24.9	24.83	3.1745
Cd	38.0	37.6	38.3	37.97	11.9	11.6	12.2	11.90	3.1905
Cookie	14.5	14.3	14.3	14.37	4.6	4.6	4.7	4.63	3.1007
								Mean	3.1417

Analysis of data: For each of the circular objects, three measurements were taken and computation of the ratio of the circumference to its diameter revealed a range of approximate measures from 3.1007 to 3.1905 with an average of 3.1417, an approximation of the value of the constant pi. In science experiments, error is calculated to ascertain the precision of calculations so as to the lessen limitations of the experiment. We calculated an error of 0.0001. [Error = experimental value – theoretical value]. The percentage error is 0.0032%. [Percentage error = (error / theoretical value) x 100].

Conclusion of experiment: The hypothesis states if the circumference of circular objects is measured then the diameter of those objects will have a relationship to their circumferences that is constant. Since the relationship of circumference to diameter of all of the circular objects had an average constant of 3.1417, the hypothesis is not rejected. Therefore, the relationship of the circumference to the diameter of a circular object is constant. We discussed the limitations of the experiment. The limitations of this investigation include inaccuracy of measurements of the circumferences and diameters of the circular objects as indicated by the percentage error.

Hypothesis Non-stated

The variation of our experiment using the non-stated hypothesis affords students a shift from thinking that a hypothesis should always be constructed (McPherson, 2001; Lederman, et al., 2014). Non-stated hypotheses disabuse students of this notion and encourages exploration. Students are able to use the scientific inquiry, but come to the realization that engaging in exploration and pattern seeking motivates the formulation of hypotheses. The scientific inquiry may or may not utilize a hypothesis (McPherson, 2001). Here, students state their research questions, but explore explanations that lead to the construction of a hypothesis. We use the activity above as a framework to demonstrate the use of the non-stated hypothesis in scientific inquiry.

Question: What is the relationship between the circumference and the diameter of a circular object?

Research: Students research the meaning of the words circumference then discuss possible ways that mathematics may be used to find the relationship between the circumference and the diameter. The teacher could use discussion to encourage the use of addition, subtraction, multiplication, and division.

Materials: We used the same objects for illustrative purposes.

Procedure: We followed the procedure from Activity 1.

Data: Since they afford the most accurate measurements, we used the average measurements from the first activity.

Analysis of data: We made the following observation. For each object, an exploration to detect patterns in the results for each computation of addition, subtraction, multiplication, and division reveal differences (see Table 2). From the results, the additive and subtractive magnitudes reveal no immediate discernible patterns. However, the ratios suggest a consistency. The use of central tendency (the mean) for these ratios shows an approximation to three decimal places of 3.144 and 0.317 respectively. We used the first approximation and calculated an error of 0.003. [Error = experimental value – theoretical value]. The percentage error is 0.076%. [Percentage error = (error / theoretical value) x 100].

Table 2. Data used to compute the mathematical operations

Object	Circumference + Diameter	Circumference - Diameter	Diameter - Circumference	Circumference / Diameter	Diameter / Circumference
Penny	8.00	4.14	-4.14	3.145	0.318
Hoola hoop	293.77	150.63	-150.63	3.105	0.322
Plate	103.66	54.00	-54.00	3.174	0.315
Cd	49.87	26.07	-26.07	3.191	0.313
Cookie	19.00	9.74	-9.74	3.104	0.320
			Mean	3.144	0.318

Conclusion of experiment: The research question pursued was to investigate the relationship between the circumference and diameter of circular objects. While there was no stated hypothesis, four basic mathematical operations of addition, subtraction, multiplication, and division were invoked as points of departure for exploration. We found that the ratio of the circumference to the diameter and its inverse afforded a detection of the simplest pattern. Armed with these results, it was concluded that circular objects share a common relationship grounded in their ratio, and this ratio is found between each object's circumference and diameter. The discussion about the implications were similar to the first activity.

Discussion and Conclusion

Our activities serve as examples for teachers to interweave notions of scientific inquiry while engaging students in math modeling. Such integration reinforces concepts, clears up misconceptions, and increases the ability to apply concepts in real life situations. In these two activities, teachers scaffold the scientific method to motivate middle school math students to grasp notions of mathematical modeling. Ernest (2002) posited that learners need confidence—mathematical empowerment in their knowledge and skills; confidence in their ability to engage in routine and non-routine tasks; confidence in their ability to understand new and taken as shared mathematical ideas and concepts; a sense of mathematical self-efficacy; and to have a sense of personal ownership and creative approaches to mathematics. Mathematical empowerment fits into the expectations of mathematical modeling.

As an extension, students can look for patterns. Students can be challenged to transfer this knowledge into real life situations. For example, they can be asked to design a wheel for a given diameter and confidently predict that the circumference will be a little over three times that of the diameter. Students can be asked to examine various bicycle tires.

The goals of mathematics and science inquiry driven by the scientific method, as outlined above, coincide with problem solving and pattern recognition. Since students experience math rife with computation, students conclude that mathematics does not involve exploration and investigation. For many students, integrating math and science is a novel way to think in the mathematics classroom. In the experiments above, students see how mathematical and scientific knowledge integrate to investigate and answer questions. The students get to see mathematics in action, rather than in the usual abstract manner. Computations come with exploration and thinking.

Mathematicians use a method of inquiry when problem solving; therefore, mathematics activities align with the scientific method. Mathematicians and scientists solve problems, with and without hypothesis in their search for answers. With some guidance from the teacher, students experience constructing hypothesis, gathering and analyzing data, then formulating conclusions and engaging in discussions to explore a mathematical phenomenon, namely pi. Scientific investigation coupled with mathematical modeling provide opportunities for students to build intellectual dispositions. Scientists use mathematics and mathematicians engage science. Mathematical modeling affords space for science and mathematics to integrate conceptual knowledge building.

References

Achieve Inc. (2013). *The next generation science standards*. Retrieved from http://www.nextgenscience.org.

Arnett, A., & Van Horn, D. (2009). Connecting mathematics and science: A learning community that helps math-phobic students. *Journal of College Science Teaching*, *38*(6), 30-34.

Bell, R. L., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction. *The Science Teacher*, *72*(7), 30-33.

Berlin, D. F., & White, A. L. (1994). The Berlin-White integrated science and mathematics model. *School Science and Mathematics*, *94*(1), 2-4.

Blystone, R. V., & Blodgett, K. (2006). WWW:The scientific method. *CBE-Life Sciences Education*, *5*(1), 7-11. doi: 10.1187/cbe.05-12-0134.

Bransford, J. D., Brown, A., & Cocking, R. R. (Eds) (1999). *How people learn: Mind, brain, experience, and school*. Washington, DC: National Research Council.

Burghardt, M. D., Lauckhardt, J., Kennedy, M., Hecht, D., & McHugh, L. (2015). The effects of a mathematics Infusion curriculum on middle school student mathematics achievement. *School Science and Mathematics*, *115*(5), 204-215.

Cawley, J. F., & Foley, T. E. (2002). Connecting math and science for all students. *Teaching Exceptional Children*, *34*(4), 14.

Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Alignment of hands-on stem engagement activities with positive stem dispositions in secondary school students. *Journal of Science Education and Technology*, 1-12.

Common Core State Standards Initiative. (2015). *Common Core State Standards for mathematics*. Retrieved from http://www.corestandards.org/wp-content/uploads/Math_Standards.pdf

Conley, D. T., & Gaston, P. L. (2013, October). *A path to alignment: Connecting K-12 and higher education via the Common Core and the Degree Qualifications Profile*. Indianapolis, IN: Lumina Foundation. Retrieved from http://www.luminafoundation.org/publications/DQP/A_path_to_alignment.pdf

Culliton, B. J. (1976). Scientists' rights: Academy adopts "affirmation of freedom". *Science 192*(4241), 767-769.

D'Costa, A. R., & Schlueter, M. A. (2013). Scaffolded instruction improves student understanding of the scientific method & experimental design. *The American Biology Teacher*, *75*(1), 18-28.

Ernest, P. (2002). Empowerment in mathematics education. *Philosophy of Mathematics Journal*, *15*, 1-16. Retrieved from http://people.exeter.ac.uk/PErnest/pome15/empowerment.htm

Gormally, C., Brickman, P., Hallar, B., & Armstrong, N. (2011). Lessons learned about implementing an inquiry-based curriculum in a college biology laboratory classroom. *Journal of College Science Teaching*, *40*(3), 45-51. Retrieved from http://www.peggybrickman.uga.edu/pdfs/GormallyEtAl2011 copy.pdf

Kirshner, D. (2004,). Enculturation: The neglected learning metaphor in mathematics education. In D. McDougall & J. A. Ross (Eds.), *Proceedings of the twenty-sixth annual meeting of the International Group for the Psychology of Mathematics Education, North American Chapter* (vol 2, 765-772), Toronto: OISE/UT.

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry—The views about scientific inquiry (VASI) questionnaire. *Journal of Research in Science Teaching*, *51*(1), 65-83.

McPherson, G. R. (2001). Teaching & learning the scientific method. *The American Biology Teacher*, *63*(4), 242-245.

Palmer, L. K., & Mahan, C. G. (2013). Teaching the Scientific Method using Current News Articles. *The American Biology Teacher*, *75*(5), 355-356.

Prince, M., & Felder, R. (2007). The many faces of inductive teaching and learning. *Journal of College Science Teaching*, *36*(5), 14-20.

Schlenker, R. M., & Schlenker, K. R. (2000). Integrating science, mathematics, and sociology in an inquiry-based study of changing population density. *Science Activities: Classroom Projects and Curriculum Ideas*, *36*(4), 16-19.

Shipulina, O. V., Smith, D. H., & Liljedahl, P. (2013). Bringing reality into calculus classrooms: Mathematizing a real-life problem simulated in a virtual environment. *iJEP*, *3*(1), 29-35. Retrieved from http://www.peterliljedahl.com/wp-content/uploads/JA-iJEP-2013.pdf

Stiles, K. A. (1942). Outline for Teaching the Scientific Method. *Bios, 13*(2), 78-87.

Weinburgh, M., & Silva, C. (2011). Math, science, and models. *Science and Children*, *49*(1), 58-62.

JESEH
Journal of Education in Science, Environment and Health
Volume 2, Issue 1, 2016 ISSN: 2149-214X

Integrating E-books into Science Teaching by Preservice Elementary School Teachers

Ching-San Lai*
National Taipei University of Education

Abstract

This study aims to discuss the issues of integrating e-books into science teaching by preservice elementary school teachers. The study adopts both qualitative and quantitative research methods. In total, 24 preservice elementary school teachers participated in this study. The main sources of research data included e-books produced by preservice elementary school teachers, a feedback questionnaire on e-book production, and elementary school students' feedback on the use of e-books. The main results of the study are: (1) the preservice elementary school teachers were satisfied with the processes of e-book production; (2) the preservice elementary school teachers demonstrated excellent performance in e-book production; (3) elementary school students were happy to use e-books.

Key words: E-learning, Electronic book, IT education, Science education, Teacher education.

Introduction

In recent years, the booming and rapid development of e-books has had a huge influence on both the information and education industries. An e-book is a new-generation technological product combining several technologies. As early as 1992, van Dam (1992) proposed the phrase "Electronic Book" (also called E-book or eBook for short), which is widely referred to as a medium using electronic channels to store and transport a variety of information and multimedia information-transporting technologies that integrate text, sound, images, videos, and animations.

Since the Amazon online bookstore launched Kindle, Apple Inc. launched the iPad, and Google launched Google books using its own cloud technology, the use of e-books has increased. In recent years, many researchers have conducted studies on the use of e-books for teaching, and they have discovered that e-books could enhance the readers' learning outcomes (Chen, Kao, & Sheu, 2005; Chen, Kao, Sheu, & Chang, 2003; Encheff, 2013; Huang, Huang, and Chen, 2012; Ihmeideh, 2014; Korat, Levin, Atishkin, & Turgeman, 2014; Li, Yang, & Yang, 2013; Liang & Huang, 2014; Liu, Wang, Liang, Chan, Ko, & Yang, 2003; Maynard, 2010; Moody, 2010; Morgan, 2014; Schneider, Kozdras, Wolkenhauer, & Arias, 2014; Schugar, Smith, & Schugar, 2013; Verhallen, Bus, & deJong, 2006; Wang, Lu, and Lee, 2011; Zucker, Moody, & McKenna, 2009).

Studies on e-book production indicate that if we can strengthen training in the production and use of e-books by preservice elementary school teachers' as early as during their preservice teacher training, we may be able to enhance their e-book production and teaching abilities, thus providing multiple experiences and fruitful learning outcomes to their elementary school students. As a consequence, this study aims to discuss the issues of integrating e-books into science teaching by preservice elementary school teachers.

Literature Review

E-books

The changes and development of information technologies have brought infinite possibilities to interactive teaching. E-books have been around for approximately 20 years. Hsieh, Lee, and Cheng (2007) pointed out that e-books are digitally-formed content presented in a multitude of ways, such as texts, images, videos, and

* Corresponding Author: *Ching-San Lai, clai@tea.ntue.edu.tw*

animations. By using reading devices and corresponding reading software, e-books can replace traditional paper-based reading, and spread information to the public.

Cheng (2009) has further divided the development of e-books in Taiwan into three stages, including: (1) first generation e-books from 1990 to 1998 when PCs and keyboards were used, and the main content was text; (2) second generation e-books from 1999 to 2006 when a mouse was used for PC and PDA operations, and the main content included text, sound and images; and (3) third generation e-books from 2007 to the present when PCs, smart phones, and specialized reading devices are used, finger-touch applications are applied, and the main content includes text, sound, images, videos, and animation.

With respect to the types of e-books, Liao, Tai, and Lin (2010) concluded that common e-books could be divided into three types, including disk e-books, handheld e-books, and computer-system e-books. Kang, Wang, and Lin (2009) pointed out that e-books are portable, have comparatively large screens, and can support learners' studies in different places. Lin and Huang (2010) further explained that the new generation e-books already integrate sound, video, images, and text, and create new features that differ from traditional books.

The advantages of e-books include automatic character searching, and the free readjustment of fonts and font sizes. Page-mode e-books are comfortable to hold, and convenient for making notes and reading. In addition, they eliminate damage problems, such as abrasion and tearing. The cost of an e-book is small and they do not consume environmental resources like trees. They feature rapid and convenient consulting, related information connection, dynamic reading, interactive design, and have other functions, such as electronic bookmarks and annotation tools (Hsieh, Lee, and Cheng, 2007; Lin and Huang, 2010).

However, e-books have several limitations and disadvantages. E-books can only be read with a reading device, and some e-books in special formats can only be displayed after installing special software. For readers, this software may not always be free, and for those who are used to computers, compatibility is not guaranteed (Lin and Huang, 2010).

Hwang, Pan, Liu, and Liu (2012) emphasized that e-books can reduce the need for paper and they consume low levels of energy. Considering the current energy crisis and protection of the environment, it is beneficial for students to use e-books in their studies. In the future, if e-books can replace paper textbooks, it will be of immense benefit to the protection of the Earth.

Many in the fields of industry and academia have conducted discussions and studies on the future development of e-books. In the foreseeable future, e-books may move in two different directions. First, product functions may diversify, i.e. a multi-functional e-book reading device may combine different functions. Based on the display function of electronic paper, future reading devices may also combine touch panel functions, such as handwriting and drawing. Also, considering a phonetic system with human voices, and wireless communication networks, e-books will become similar to current multi-functional portable computers, while their function as an e-book will remain the same or even be improved. They will become smaller, and more convenient to carry. They may have enhanced display technologies, such as flexible screens, low power consumption and be more lightweight. Many value-added functions may also receive more attention. After the success of the touch panel, e-books are one of the applications having the highest potential in the future (Chen, 2009).

To summarize, compared to paper books, e-books have many unique advantages. E-books transform the content of textbooks from a single plane into three dimensions, and integrate multimedia functions, such as video and animation. They provide a richer reading experience, enhance students' motivation and interest in reading, and make learning more lively and interesting.

Teaching and learning with e-books

Pan (2011) pointed out that the success of e-books had spread worldwide. In the future, students will no longer need to carry heavy schoolbags. Instead, they can carry an e-book reader for their studies, which are convenient both to carry and for making notes. A revolution in studies may occur. Dalton (2014b) also pointed out that the digital technologies incorporated into e-books are excellent multimedia tools that could promote the studies of learners.

With respect to the use of and teaching with e-books, Hwang, Pan, Liu, and Liu (2012) have pointed out that a more important advantage of e-books was that they could stimulate new ideas in the learning environment and in activity design, and enable learning to be conducted outside classrooms and under real learning situations. Knowledge could be used in a lively way and be carried along with the student. Hwang, Pan, Liu, and Liu (2012) further pointed out e-books could assist with learning in classrooms, and also in different places. In recent years, due to the development of reading devices, e-books have become mainstream applications in both classroom learning and outdoor learning and are useful tools for teaching and learning. If good use is made of their advantages, e-books can help with the development of more diversified teaching and richer learning.

With respect to the application of e-books in teaching, Wen, Juang, Lu, and Chen (2010) proposed that when teachers applied innovative technologies in classroom teaching, the core values were: (1) selection and presentation of e-teaching materials rather than the exhibition of sound, light and image effects; (2) enhancement of the interaction between a teacher and students; and (3) encouraging students' initiatives in exploring and thinking. These are the true meanings of blending the information technologies of e-books into teaching practice. Wen, Juang, Lu, and Chen (2010) further explained that the innovations of e-books in recent years were faster and more efficient than what was expected by teachers. Practical utility and teaching efficiency not only attract the attention of students, but also change traditional teaching procedures. As a consequence, teachers can use e-books whenever applicable to their teaching.

From interactive e-books to electronic blackboards, and electronic schoolbags to future classrooms, current information technology tools all emphasize the need to use high-tech situational learning to strengthen students' key abilities. Yang and Liu (2012) have emphasized that the application of information technology tools in teaching should focus on increasing students' willingness to learn and to interact with others, enabling first generation e-learning students to have more opportunities to experience different learning experiences and share in the joy of learning.

However, Ho (2010) also proposed introspection, and emphasized current e-books and cloud education topics had doubtlessly caused revolutionary changes to teaching methods, the forms of teaching materials, and learning methods, which was a challenge that educators, students, and parents could not avoid. Facing technological products that are indispensable to daily life and education, we should not only capitalize on their advantages to benefit teaching methodology, teaching resources, learning behavior, and learning content, but also address the need to avoid the negative influences of these information technology products on the mind and body.

In recent years, many scholars have conducted research on the use of e-books in teaching. The study results show that e-books can promote readers' motivation and engagement (Ciampa, 2012a, 2012c, 2012d; Felvégi & Matthew, 2012; Geist, 2011; Hoseth & McLure, 2012; Jones & Brown, 2011; Maynard, 2010; Nelson, Arthur, Jensen, & Van Horn, 2011; Roskos, Burstein, & Byeong-Keun, 2012; Sloan, 2012; Smith, Moyer, & Schugar, 2011), can improve readers' reading and writing abilities (Ciampa, 2012b; De Jong & Bus, 2004; Ertem, 2010; Gonzalez & Johnson, 2012; Higgins & Hess, 1999; Huang, Liang, & Chiu, 2013; Ihmeideh, 2014; Korat & Shamir, 2012; Korat, Levin, Atishkin, & Turgeman, 2014; Morgan, 2014; Schneider, Kozdras, Wolkenhauer, & Arias, 2014; Schugar, Smith, & Schugar, 2013; Segal-Drori, Korat, Shamir, & Klein, 2010; Shamir & Baruch, 2012), can enhance readers' scientific comprehension (Encheff, 2013; Li, Yang, & Yang, 2013; Wang, Lu, and Lee, 2011; Wen, Juang, Lu, and Chen, 2010), and can increase readers' learning efficiency (Chen, Kao, & Sheu, 2005; Chen, Kao, Sheu, & Chang, 2003; Huang, Huang, & Chen, 2012; Liang & Huang, 2014; Liu, Wang, Liang, Chan, Ko, & Yang, 2003; Moody, 2010; Sun, Flores, & Tanguma, 2012; Verhallen, Bus, & deJong, 2006; Wen, Juang, Lu, & Chen, 2010; Zucker, Moody, & McKenna, 2009).

A study by Wang, Lu, and Lee (2011) has shown that students participating in the study produced mental images that were pleasant, interesting, and enlightening towards the teaching content, teaching material design, and computer interfaces. The study results showed that e-books can be blended into teaching, achieve efficient learning, improve students' attitudes towards science, promote students' reading motivation, and increase students' learning comprehension of science.

A study by Huang, Huang, and Chen (2012) has shown that students' acceptance of e-book learning is affected by gender differences. Girls demonstrate a higher acceptance of e-book learning than boys. However, there are no significant differences in background variables, such as grades, amount of computer use each week, and the monthly frequency of using mobile devices for e-reading. Other studies have also shown similar results. Huang, Liang, and Chiu (2013) have pointed that out although, in stereotyping, boys were considered to be more interested in computers and information technology applications, their study showed girls performed better in e-book reading than boys.

A study by Encheff (2013) has shown that after using e-books for study, students gained a better comprehension of science concepts, and developed more proficient scientific technology application abilities. Meanwhile, students' problem-solving abilities in subject-based learning are cultivated, and their self-efficiency and confidence in learning are enhanced.

Li, Yang, and Yang (2013) used different teaching strategies to discuss the learning outcomes of e-book teaching. The study results showed that the method of teachers explaining the knowledge first, and then using e-books to conduct teaching has the best learning outcome. However, there are no significant differences in variables, such as cognitive load and learning motivation.

To summarize, e-books can inspire reading motivation and interest, and improve readers' learning outcomes. It is worthwhile when promoting e-books to allow students to have more opportunities to encounter different learning experiences, and share the joy of learning. However, when using e-books, proper assistance and guidance should be provided to students to avoid Ho's (2012) concern that information technology products can negatively influence the mind and body.

E-book Production and Preservice Teacher Education

To strengthen and promote e-book learning, the Digital Textbook Collaborative (2012) has also proposed a framework and blueprint for e-book design and application. The Digital Textbook Collaborative (2012) has also further emphasized when designing e-books, with respect to the application of e-books, that designers should pay more attention to the provision of richer, interactive learning experiences and customized learning to students, encourage cooperative learning, and provide learning feedback, plus supportive and formative assessments that help students to study.

Second, with respect to the cultivation of e-book production and design abilities, Liao and Pan (2010) pointed out that people in the digital publishing industry should possess seven abilities, including text editing, graphic design, digital design, video production, digital distribution, digital copyright management, and program design (quoted from Liao, Pan, & Tsai, 2013, p. 65). Liao, Pan, and Tsai (2013) further pointed out that the professional abilities for e-book production and design included (1) software operation and setting, (2) text style setting, (3) picture and text layout, (4) dynamic document setting, and (5) format transformation.

The above-mentioned professional abilities required for e-book production are actually abilities that should be cultivated and taught during the preservice training of elementary school teachers (Dalton, 2014a). When teachers are proficient in the digital technology tools of e-books, self-education can benefit their professional improvement, and will help them to guide their students and promote better learning outcomes.

Dalton (2014a) further pointed out that teachers are designers of learning, and in the 21st century, teachers should acquire the knowledge-ability of producing their own e-books. Dalton (2014a) has recommended using Book Builder (a free software package developed by the non-profit organization CAST, website: www.cast.org) as the tool for compiling e-books, as Book Builder could integrate texts, sounds, images, and videos, and is easy to operate.

At the same time, Li and Huang (2012) pointed out that as technology and e-book reading devices advanced day by day, the content of the e-books should also be enhanced to meet the requirements of learners. Huang (2013) further explained that due to the Internet and the digital convergence technology of the media, traditional media forms, such as the presentation method of a book, video, and sound, enable us to create diversified designs and innovations. Taking interactive e-books as an example, in terms of creation, creators can apply the features of multimedia into the text content. Instead of a single presentation method for the original media, creators can now blend in additional multimedia features. In terms of production, producers should make better use of the features of multimedia, use systematic planning, and combine the multimedia elements of animations, images, and videos to assist creators to realize their creative ideas. In terms of browsing, producers should also design a good reading environment and interfaces so any interest in reading and appreciation will not be harmed due to operational problems.

To summarize, in today's knowledge-based economy, e-books topics show e-books offer great educational functions and value. If the use and promotion of e-books can be strengthened, it is believed that greater educational outcomes will be brought to elementary school classrooms. As a consequence, how to strengthen training in the professional abilities of e-book production for preservice elementary school teachers is an initiative worth promoting and implementing. E-books designed by preservice teachers can be used as study materials by elementary school students. E-books can also help elementary school students to enhance their reading literacy, develop lifelong reading habits, improve their learning outcomes, and promote the goals of information literacy.

Research Methods

This study adopted both qualitative and quantitative research methods. The participants were 24 preservice elementary school teachers. The participants first received a three-week training course on e-book production. Referring to strategies proposed by the Digital Textbook Collaborative (2012), the training emphasizes how the design content of an e-book should aim to provide a rich interactive learning experience and customized learning for students, encourage cooperative learning, and provide learning feedback as well as supportive and formative assessments. The software used for e-book production in this study was the free package software ShineCue 2.0.0.27 (this software was developed by Chiayi Educational Network Center, and the center authorizes teachers and students from contract standard schools to use the website which can be found on ebook.cy.edu.tw). Following on from the training course, the preservice elementary school teachers then conducted a six-week e-book production session. Each teacher finally completed one e-book. Consequently, a total of 24 e-books were produced.

Second, considering the requirements of subsequent e-book promotion and teaching, with respect to the subject content of e-books, the preservice elementary school teachers were asked to use minerals and rocks as their theme. The future users of the e-books were deemed to be Grade 5 and 6 students.

After the preservice teachers produced their e-books, the e-books were used in an elementary school. In this way, the study assessed the feasibility and practical utility of the e-books produced, and used them as indices to assess the e-book production outcomes of these preservice teachers. The users of these e-books were Grade 6 students from an elementary school in New Taipei City. A total of 48 students from two classes used the e-books. The reading devices used were tablet PCs assigned to the school by the municipal government of New Taipei City. The use and teaching processes were as follows. Each student freely selected an e-book from the 24 e-books on offer. From the second week, study groups of two or three students were formed to conduct learning and discussions. In the final week, each group selected one e-book to complete an e-book reading and comprehension sheet. The content of the e-book reading and comprehension sheet included (1) drawing the content of the e-book in the form of a reading mind map (each group drew one mind map), (2) scoring the likeability levels of the e-books (the full score was 10, and each member of the group had to give a mark), and (3) obtaining feedback and suggestions on learning.

The data of this study were mainly collected from e-books produced by the preservice elementary school teachers, feedback questionnaire on e-book production using a Likert five-point scale. The Cronbach's α reliability was 0.77. The feedback and suggestions on e-book use by the elementary school students were obtained using an e-book reading and comprehension sheet, including the drawing of reading mind maps, scoring the likeability levels of e-books, and an open-ended question. The validity of the research tools was examined by three content experts, and the research tools were confirmed to have good validity.

Results and Discussion

Feedback on e-book Production by Preservice Elementary School Teachers

After the preservice teachers had completed an e-book production, this study conducted a survey using a Feedback Questionnaire on E-book Production consisting of a 5-point Likert-type scale. A total of 24 preservice elementary school teachers returned a valid feedback questionnaire. The backgrounds of these teachers are shown in Table 1. The Distribution Summary of the Measurement Results of the Feedback Questionnaire on E-book Production are shown in Table 2.

Table 1. Background of the Preservice Elementary School Teachers

Gender	Number	Percentage (%)
Male	12	50.0
Female	12	50.0

According to Table 2, the results from the Feedback Questionnaire on E-book Production are as follows: (1) 37.5% of the preservice teachers indicated they were suited to producing e-books while 33.3% of the teachers indicated that they disagreed or strongly disagreed. The remaining 29.2% of the teachers indicated undecided. (2) 33.3% of the preservice teachers indicated the e-book compilation software was easy to operate while 37.5% of the teachers indicated that they disagreed or strongly disagreed. The remaining 29.2% of teachers indicated undecided. (3) 20.8% of the preservice teachers indicated the functions of the e-book compilation software were sufficient for use while 54.2% of the teachers indicated that they disagreed or strongly disagreed, with the remaining 25.0% of teachers indicating undecided. (4) 58.3% of the preservice teachers indicated that e-books are charming while 25.0% of the teachers indicated that they disagreed or strongly disagreed, with the remaining 16.7% of teachers indicating undecided. (5) 75.0% of the preservice teachers indicated that e-books can help increase students' comprehension of science content while only 8.3% of the teachers indicated that they disagreed or strongly disagreed. The remaining 16.7% of teachers indicated undecided. (6) 62.5% of the preservice teachers indicated that e-books can help students conduct science experiment exploration while 20.8% of teachers indicated that they disagreed or strongly disagreed, with 16.7% of the teachers indicating undecided. (7) 54.1% of the preservice teachers indicated that e-books can help with their science teaching while 16.7% of the teachers indicated that they disagreed or strongly disagreed, with the remaining 29.2% of teachers indicating undecided. (8) 45.8% of the preservice teachers indicated that after using e-books, they were willing to use them in their science teaching while 20.8% of the teachers indicated that they disagreed or strongly disagreed, with the remaining 33.3% of teachers indicating undecided. (9) Overall, 41.7% of the preservice elementary school teachers indicated that they liked producing and using e-books, while 20.8% of the teachers indicated that they disagreed or strongly disagreed. The remaining 37.5% of teachers indicated undecided.

Table 2. Summary of the Measurement Results of the Feedback Questionnaire on E-book Production (N=24)

Item	Strongly Agree		Agree		Undecided		Disagree		Strongly Disagree	
	N	%	N	%	N	%	N	%	N	%
1	2	8.3	7	29.2	7	29.2	6	25.0	2	8.3
2	0	0	8	33.3	7	29.2	7	29.2	2	8.3
3	0	0	5	20.8	6	25.0	10	41.7	3	12.5
4	3	12.5	11	45.8	4	16.7	5	20.8	1	4.2
5	2	8.3	16	66.7	4	16.7	2	8.3	0	0
6	1	4.2	14	58.3	4	16.7	5	20.8	0	0
7	2	8.3	11	45.8	7	29.2	3	12.5	1	4.2
8	2	8.3	9	37.5	8	33.3	5	20.8	0	0
9	0	0	10	41.7	9	37.5	4	16.7	1	4.2

The study results showed that the usage satisfaction of the preservice elementary school teachers with the e-book compilation software ShineCue was of low to medium-level. It is considered that the reason could be that ShineCue being free software rather than business software, the functions and interfaces of the operational system may not have been smooth, exquisite, and user-friendly enough. As a result, the user satisfaction with ShineCue remained at the low to medium-levels. The study did not adopt the software Book Builder recommended by Dalton (2014a) because it is written in English, which was not appropriate for the use of preservice elementary school teachers and elementary school students in Taiwan for whom the medium of instruction is Mandarin.

On the other hand, the preservice elementary school teachers highly praised the qualities and educational functions of e-books (75.0% of the teachers believed that e-books can increase students' comprehension of science content, and 62.5% of the teachers believed that e-books can help students carry out science experiment exploration), indicating the teachers agreed that e-books can help students with their learning and teachers with their teaching. Finally, overall, 41.7% of the preservice elementary school teachers indicated that they liked producing and using e-books, while 20.8% of the teachers indicated that they disagreed or strongly disagreed, with the remaining 37.5% of teachers indicating undecided. This means that a large proportion of the teachers approved of the production and use of e-books. However, if the functions and interfaces of the e-book compilation software could be greatly improved, it is believed that more preservice teachers would approve of and also use it.

Assessment of e-books

Preservice elementary school teachers who participated in this study produced one piece of work after each conducting a course on e-book compilation and production. The 24 preservice teachers produced 24 e-books in total. The assessors then conducted an assessment of the e-books from the perspective of content quality, scientific correctness, and design originality.

The assessment results showed that in terms of the content of the e-books produced by the preservice teachers, all the 24 e-books fully displayed the special effects of an e-book. Together, the text presentation, pictures and images, colors and picture composition, sounds, videos, and animations fully presented the exquisite multimedia effects of the e-books. Some of the works even made good use of sound and video to compile splendid dynamic images, and present exquisite reading qualities, and the overall appearance of these works was rather exquisite and delicate. Second, in terms of performance with regard to science content, the content of all the e-books clearly explained the correct scientific characteristics of minerals and rocks, the features of their appearance, and the aesthetic presentation of minerals and rock samples to attract the readers' attention and enable them to recognize minerals and rocks correctly. In terms of the performance of design originality, many works combined the multimedia elements of pictures, sounds, videos, and animations very well to produce scientific images and rich artistic connotations, and to give full considerations to the features and advantages of e-books. This result confirms the opinions on e-books presented by Ho (2012), Hsieh, Lee, and Cheng (2007), Hwang, Pan, Liu, and Liu (2012), and Lin and Huang (2010). In addition, one of the works entered an e-book design competition held by Tang Digital Integration, and was successful in achieving a Finalist Award.

Feedback on the Use of e-books by Elementary School Students

After the preservice teachers completed their e-book production, the e-books were used by elementary school students in an elementary school. The students were subsequently required to conduct an assessment of these e-books. A total of 48 students from Grade 6 used the e-books. The 48 students (divided into 18 groups) completed the reading and comprehension sheets of 18 e-books. The contents of the e-books and the comprehension sheets included (1) drawing a reading mind map, (2) scoring the likeability levels of the e-books (full score of 10), and (3) providing feedback and suggestions on learning.

After the elementary school students completed their e-book reading and comprehension sheets, the 18 comprehension sheets were analyzed. According to the contents of the reading mind maps drawn by each group, all participating students were found to be inspired by e-book reading, and all groups could effectively transform the content of the e-books into mind maps, presenting the themed science concepts of the e-books very well. The study results showed that elementary school students can ascertain the corresponding science concepts through e-book reading, and the content of e-books can actually enhance elementary school students' comprehension of science.

Second, the results of the e-book likeability scoring showed that the average score for the 48 elementary school students was 8.46 (the full score was 10), with a standard deviation of 1.69. The study results indicated that the elementary school students enjoyed the e-book reading activity, indicating that the contents of the e-books were relevant to their science studies.

As a consequence, on the whole, the e-books produced by the preservice elementary school teachers were well received by the elementary school students, and the contents of the e-books were able to improve the learning outcomes of the elementary school students, indicating that the production and performance of the e-books achieved the intended educational goals.

Conclusion

In recent years, due to the rapid development of e-book reading devices, e-books have started a revolution in learning. In view of the importance of e-books, this study conducted e-book production and training into science teaching by preservice elementary school teachers. The study results showed that although the satisfaction of the e-book compilation software ShineCue by the preservice teachers was only of a low and medium-level, the teachers had a high opinion of the qualities and teaching functions of e-books, generally believing that e-books can help both students and teachers with their learning and teaching, respectively. Second, e-books produced by the preservice teachers were exquisite and delicate, and clearly explained the scientific characteristics of minerals and rocks, demonstrating the features of multimedia, and fully manifesting scientific images and rich artistic connotations. In addition, the feedback on e-book use by elementary school students showed that these e-books were actually well received by elementary school students as the contents of the e-books improved their science learning outcomes. As a consequence, the production and performance of the e-books by preservice elementary school teachers attained considerable educational achievements.

Acknowledgements

This study was funded by the Ministry of Science and Technology, Taiwan, under contract no. MOST103-2511-S-152-009.

References

Chen, Y. (2009). An introduction to e-books. *Display-All, 16*, 6-10.

Chen, Y., Kao, T., & Sheu, J. (2005). Realizing outdoor independent learning with a butterfly watching mobile learning system. *Journal of Educational Computing Research, 33*(4), 395-417.

Chen, Y., Kao, T., Sheu, J., & Chang, C. (2003). A mobile learning system for scaffolding bird watching learning. *Journal of Computer Assisted Learning, 19*(3), 347-359.

Cheng, Y. (2009). Digital reading in Taiwan – The development of Taiwan's academic e-books. *New Books: Recent Publications in Taiwan, ROC, 124*, 33-38.

Ciampa, K. (2012a). Electronic storybooks: A constructivist approach to improving reading motivation in grade 1 students. *Canadian Journal of Education, 35*(4), 92-136.

Ciampa, K. (2012b). ICANREAD: The effects of an online reading program on grade 1 students' engagement and comprehension strategy use. *Journal of Research on Technology in Education, 45*(1), 27-59.

Ciampa, K. (2012c). Improving grade one students' reading motivation with online electronic storybooks. *Journal of Educational Multimedia & Hypermedia, 21*(1), 5-28.

Ciampa, K. (2012d). Reading in the digital age: Using electronic books as a teaching tool for beginning readers. *Canadian Journal of Learning & Technology, 38*(2), 1-26.

Dalton, B. (2014a). DIY E-books. *The Reading Teacher, 67*(7), 543-546.

Dalton, B. (2014b). E-text and e-books are changing the literacy landscape. *Phi Delta Kappan, 96*(3), 38-43.

De Jong, M., & Bus, A. (2004). The efficacy of electronic books in fostering kindergarten children's emergent story understanding. *Reading Research Quarterly, 39*, 378-393.

Digital Textbook Collaborative. (2012). *Digital textbook playbook*. Washington, DC: Federal Trade Commission. www.fcc.gov/encyclopedia/digital-textbook-playbook

Encheff, D. (2013). Creating a science E-book with fifth grade students. *TechTrends: Linking Research & Practice to Improve Learning, 57*(6), 61-72.

Ertem, I. S. (2010). The effect of electronic storybooks on struggling fourthgraders' reading comprehension. *Turkish Online Journal of Educational Technology, 9*(4), 149-155.

Felvégi, E., & Matthew, K. I. (2012). Ebooks and literacy in K-12 schools. *Computers in the Schools, 29*(1/2), 40-52.

Geist, E. (2011). The game changer: Using iPads in college teacher education classes. *College Student Journal, 45*(4), 758-768.

Gonzalez, M. R., & Johnson, E. (2012). Universally designed ebooks: Comprehension implications for struggling readers. *Journal of Technology Integration in the Classroom, 4*(2), 5-16.

Higgins, N., & Hess, L. (1999). Using electronic books to promote vocabulary development. *Journal of Research on Computing in Education, 31*, 425-430.

Ho, R. (2012). Educational technology: A brief retrospect and prospect in Taiwan. *Taiwan Education Review, 674*, 41-47.

Hoseth, A., & McLure, M. (2012). Perspectives on e-books from instructors and students in the social sciences. *Reference & User Services Quarterly, 51*(3), 278-288.

Hsieh, Y., Lee, J., & Cheng, H. (2007). The production and publish of e-books - A case study of "graphic communication arts e-book". *Taiwan University of Arts, 80*, 137-163.

Huang, H., Huang, T., & Chen, S. (2012). Cognition and acceptance of vocational high school students using e-books in e-learning - A case of Taipei City's public and private vocational high school. *Ming Hsin Journal, 38*(1), 103-116.

Huang, T. (2013). Problem-solving approach to the analysis of development principles for information technology integrated with teaching. *Journal of Education Research, 236*, 57-71.

Huang, Y., Liang, T., & Chiu, C. (2013). Gender differences in the reading of E-books: Investigating children's attitudes, reading behaviors and outcomes. *Educational Technology & Society, 16*(4), 97-110.
Hwang, W., Pan, S., Liu, Y., & Liu, H. (2012). Preliminary study of investigating potential applications and research with e-readers. *Instructional Technology & Media, 100*, 49-58.
Ihmeideh, F. M. (2014). The effect of electronic books on enhancing emergent literacy skills of pre-school children. *Computers & Education, 79*(10), 40-48.
Jones, T., & Brown, C. (2011). Reading engagement: A comparison between ebooks and traditional print books in an elementary classroom. *International Journal of Instruction, 4*(2), 5-22.
Kang, Y., Wang, M., & Lin, R. (2009). Usability evaluation of E-books. *Displays, 30*, 49-52.
Korat, O., & Shamir, A. (2012). Direct and indirect teaching: Using e-books for supporting vocabulary, word reading, and story comprehension for young children. *Journal of Educational Computing Research, 46*(1), 135-152.
Korat, O., Levin, I., Atishkin, S., & Turgeman, M. (2014). E-book as facilitator of vocabulary acquisition: support of adults, dynamic dictionary and static dictionary. *Reading & Writing, 27*(4), 613-629.
Li, C., Yang, C., & Yang, M. (2013). A study of using mobile and interactive ebooks on plant-watching courses. *Journal of Liberal Arts and Social Sciences, 9*(3), 173-188.
Li, Z., & Huang, S. (2012). Multiple intelligence and e-book. *Elementary Education, 52*(4), 11-18.
Liang, T., & Huang, Y. (2014). An investigation of reading rate patterns and retrieval outcomes of elementary school students with E-books. *Journal of Educational Technology & Society, 17*(1), 218-230.
Liao, S., Pan, Y., & Tsai, Y. (2013). The web-based assessment applied to development of professional competences on producing full-text ebooks. *Research of Educational Communications and Technology, 103*, 61-76.
Liao, S., Tai, M., & Lin, S. (2010). The study of the e-book reader development. *Journal of CAGST*, 450-465.
Lin, C., & Huang, W. (2010). A study on electronic book exploration and campus mobile learning. *Journal of Engineering Technology and Education, 7*(5), 862-868.
Liu, T., Wang, H., Liang, J., Chan, T., Ko, H., & Yang, J. (2003). Wireless and mobile technologies to enhance teaching and learning. *Journal of Computer Assisted Learning, 19*(3), 371-382.
Maynard, S. (2010). The impact of e-books on young children's reading habits. *Publishing Research Quarterly, 26*(4), 236-248.
Moody, A. K. (2010). Using electronic books in the classroom to enhance emergent literacy skills in young children. *Journal of Literacy & Technology, 11*(4), 22-52.
Morgan, H. (2014). Using digital story projects to help students improve in reading and writing. *Reading Improvement, 51*(1), 20-26.
Nelson, L. L., Arthur, E. J., Jensen, W. R., & Van Horn, G. (2011). Trading textbook for technology. *Phi Delta Kappan, 92*(7), 46-50.
Pan, Y. (2011). *Illustrated science and technology*. Taipei: Shu Quan Press.
Roskos, K., Burstein, K., & Byeong-Keun, Y. (2012). A typology for observing children's engagement with ebooks at preschool. *Journal of Interactive Online Learning, 11*(2), 47-66.
Schneider, J. J., Kozdras, D., Wolkenhauer, N., & Arias, L. (2014). Environmental E-books and green goals. *Journal of Adolescent & Adult Literacy, 57*(7), 549-564.
Schugar, H. R., Smith, C. A., & Schugar, J. T. (2013). Teaching with interactive picture E-books in grades K-6. *The Reading Teacher, 66*(8), 615-624.
Segal-Drori, O., Korat, O., Shamir, A., & Klein, P. (2010). Reading electronic and printed books with and without adult instruction: Effects on emergent reading. *Reading & Writing, 23*(8), 913-930.
Shamir, A., & Baruch, D. (2012). Educational e-books: A support for vocabulary and early math for children at risk for learning disabilities. *Educational Media International, 49*(1), 33-47.
Sloan, R. H. (2012). Using an e-textbook and iPad: Results of a pilot program. *Journal of Educational Technology Systems, 41*(1), 87-104.
Smith, C. A., Moyer, C. A., & Schugar, H. R. (2011). Helping teachers develop positive dispositions about technology-based learning: What a brief global learning project revealed. *Journal of Educational Technology Development & Exchange, 4*(1), 1-14.
Sun, J., Flores, J., & Tanguma, J. (2012). E-textbooks and students' learning experiences. *Decision Sciences Journal of Innovative Education, 10*(1), 63-77.
van Dam, A. (1992). Electronic books and interactive illustrations - Transcript of a talk. In S. Cunningham & R. J. Hubbold (eds.), *Interactive learning through visualization*, (pp. 9-24). Berlin: Springer-Verlag.
Verhallen, M. J. A. J., Bus, A. G., & deJong, M. T. (2006). The promise of multimedia stories for kindergarten children at risk. *Journal of Educational Psychology, 98*(2), 410–419.
Wang, L., Lu, J., & Lee, K. (2011). A study on elementary students' preferences for fish image revealed on interfaces of ocean e-books. *Journal of CAGST, 2011*, 485-499.

Wen, J., Juang, M., Lu, H., & Chen, C. (2010). Exploration of application for e-books in elementary school disaster prevention and technology education. *Journal of Industrial Technology Education, 3*, 87-94.

Yang, H., & Liu, Y. (2012). Innovative learning: The application and implementation of information technology. *Instructional Technology & Media, 100*, 36-41.

Zucker, T., Moody, A., & McKenna, M. (2009). The effects of electronic books on pre- kindergarten-to-grade 5 students' literacy and language outcomes: a research synthesis. *Journal of Educational Computing Research*, *40*, 47-87.

Journal of Education in Science, Environment and Health
Volume 2, Issue 1, 2016 ISSN: 2149-214X

Effects of the Scientific Argumentation Based Learning Process on Teaching the Unit of Cell Division and Inheritance to Eighth Grade Students

Ceyda Balci[1*], Nilgun Yenice[1]
[1]Adnan Menderes University

Abstract

The aim of this study is to analyse the effects of scientific argumentation based learning process on the eighth grade students' achievement in the unit of "cell division and inheritance". It also deals with the effects of this process on their comprehension about the nature of scientific knowledge, their willingness to take part in discussions and their attitude towards the course of science and technology. The study employed the design of pretest-post test matched control group design which is part of semi-experimental design techniques. The participants of the study were 77 students, 38 of whom were in the experiment group and 39 of whom in the control group. The data of the study were collected using four tools: achievement test for the unit of cell division and inheritance, the nature of scientific knowledge scale, argumentation survey and the science and technology course attitude scale. All data collection tools were administered to experiment and control groups as pre- and post test. The data collected were analysed through t- test and ANCOVA (covariance analysis). The findings indicated that academic achievement, comprehension, willingness to discuss and the attitudes towards the course of science and technology of experiment students were significantly better than those of control students at the end of the implementation.

Key words: Scientific argumentation, Science education, Cell divison and inheritance, Nature of scientific knowledge, Attitudes towards the course of science and technology

Introduction

Social and economic expectations from individuals have changed due to the changing science and technology in recent period. In this process science education has a significant role to play. The major goal of science education is to make students have a scientific perspective and to make it possible for them to use it to learn how scientific knowledge is constructed (MONE, 2013). Scientific knowledge is not absolute and unchangeable, but may change based on conditions. Scientific knowledge is constructed when several arguments are expressed and discussed (Kuhn, 1992). Therefore, an efficient science education can be realized in a classroom setting where students can easily and freely express their views, justify these views based on evidence, develop counter arguments related to the arguments by their peers and scientific argumentation based learning process is dominant (Kaya and Kılıç, 2010). In the scientific argumentation based learning process students have social communication with one another, improve their knowledge base and support their arguments. This learning process makes it possible for students to understand the relationship among evidence, claims and justifications and improves their critical thinking skills (Erduran, Simon and Osborne, 2004). Research suggests that the scientific argumentation based learning process have positive effects on students' learning of higher level of cognitive skills such as interpretation of events from different perspective using quality arguments, improving claims through analyses and syntheses and developing sophisticated views (Jiménez-Aleixandre, Rodriguez and Duschl, 2000; Duschl and Osborne, 2002; Erduran et. al., 2004; Osborne, Erduran and Simon, 2004; Kaya, 2005; Uluçınar Sağır, 2008; Von Aufschnaiter, Erduran and Osborne, 2008; Deveci, 2009; Tekeli 2009; Erdoğan, 2010; Gültepe, 2011; Gümrah, 2013; Boran, 2014; Çınar and Bayraktar, 2014). Tekeli (2009) concluded that eighth grade students who took the course of science and technology through scientific argumentation based learning process had significantly better comprehension of conceptual change about acid - base and the nature of science, better scientific reasoning skills and better attitudes towards the course. It was also found that their willingness to participate in discussions was improved. The program of the course of science and technology indicates that using the scientific argumentation based learning process in the course requires several activities. This study provides different ways of using such activities in classrooms.

* Corresponding Author: *Ceyda Balcı, cydbalci@gmail.com*

Scientific Argumentation

There are different definitions of scientific argumentation. Hakyolu (2010) argues that scientific argumentation is a process of mental and social activities in which individuals exchange ideas to reach a conclusion about a topic and try to persuade other people about their views using scientific evidence. Jimenez-Aleixandre and Erduran (2008) state that scientific argumentation refers to the evaluation and justification of views in order to account for the relationship between claims and data. Therefore, scientific argumentation can be defined as a social activity which attempts to explain different views and ideas using positive critical thinking to overcome “undecided” position, to reveal truth and unknown in detail. This activity employs not only verbal communication but also visual materials to persuade people about a certai subject. Scientific argumentation takes place in an environment in which arguments are developed. Realist arguments are needed to persuade people and to have significant discussions in the process of scientific argumentations (Yeşiloğlu, 2007). Therefore, scientific argumentation includes the presentation and justification of several ideas about a topic (Küçük, 2012).

The Toulmin Model of Argumentation

Toulmin (1958) developed a model of argumentation in his book *The Uses of Argument* in order to account for how scientific argumentation takes place in its natural process. The model explains the basic constituents of argumentation and functional relations of them. This model is used in many fields of study, including science courses for the analysis of discussions (Newton, 1999; Driver, Newton and Osborne, 2000; Erduran et. al., 2004). Three major constituents of the model are grounds, warrant and claim. It also includes three supporting elements, namely backing, rebuttal and qualifiers. The model is given in figure 1.

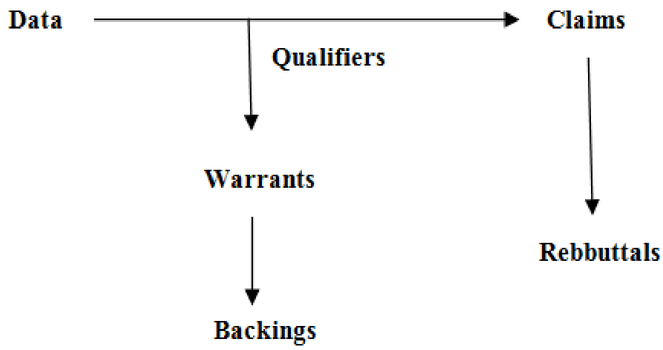


Figure 1. The Toulmin Model of Argumentation (Toulmin, 1958)

In this model the basic constituents of scientific argumentation are explained and given as follows (Driver et. al., 2000).

Claim: The position or claim being argued for; the conclusion of the argument.
Data: Reasons or supporting evidence that bolster the claim.
Warrant: he principle, provision or chain of reasoning that connects the grounds/reason to the claim.
Backing: support, justification, reasons to back up the warrant.
Rebuttal: exceptions to the claim; description and rebuttal of counter-examples and counter-arguments.
Qualifiers: specification of limits to claim, warrant and backing. The degree of conditionality asserted.

Science, Scientific Argumentation and Science Education

One of the distinctive features of science is that it includes reasoning processes supporting explanations and models and employs rational ways such as argumentation. Therefore, science can be regarded as a process in which arguments are backed by grounds and are confirmed by proper explanations (Tümay and Köseoğlu, 2011). Similarly, scientific argumentation is consisted of intragroup or individual interactions based on attempts of persuasion presenting valid and acceptable alternatives (Clark and Sampson, 2007). In science courses discussion can take place using proper strategies and therefore, students are provided with an opportunity to defend their ideas through the elements of scientific argumentation. Some of the activities and strategies that can be used for this end are given as follows:

- *Expression Tables:* In this activity students are given a table of statements about a scientific topic. This table includes both correct and incorrect statements. Students are asked to state with which statements they agree and with which statements they do not agree and also, to tell their reasons (Osborne et. al., 2004).
- *Concept maps***:** Students are given a concept map, which includes several scientific concepts prepared based on the review of related literature. Then they discuss each concept in a group setting and develop arguments concerning whether or not these concepts are correct (Osborne et. al., 2004; Yeşiloğlu, 2007; Ceylan, 2012).
- *Competing theories- Stories:* Students are given two or more competing theories in the form of stories and are asked to answer the questions such as which theory they are supporting and why.
- *Competing theories- cartoons:* Students are given two or more competing theories in the form of cartoons. They are asked to choose a cartoon which they think that it includes the correct theory and to explain the reasons for their preference with related arguments (Osborne et. al., 2004).
- *Ideas and evidence:* Students are given two or more competing theories about the topic at hand. They are also given evidence statements about each theory. The class is divided into small groups and each group of students discusses each evidence statement (Solomon et. al. 1992, cited in Osborne et. al., 2004).
- *Developing arguments:* Students are given at most four ground statements about how a physical event takes place. Then they are asked to choose the best statement which explains the event and to develop arguments about the reasons for it (Osborne et. al., 2004).
- *Predict- Observe – Explain:* Students are shown a picture of an event without giving any detail. They are divided into small groups and develop arguments about the potential results of the event. At the end of the activity the result of the event. Then students are asked to make comparisons between the actual result of the event and their predictions about it (Özkara, 2011).
- *Designing an experiments:* The class is divided into small groups. They are given several hypothese such as “sound is much faster transmitted in solids.” They are asked to design about the hypothesis they are given. They are also asked to develop arguments in support for their design following discussions with other groups (Osborne et. al., 2004).
- *Experiment reports:* Students are given a report and findings of an experiment carried out by other students. They are asked to develop arguments about the experiment based on this report (Golds Worthy, Watson and Wood- Robinson, 2000; cited in Osborne et. al., 2004).
- *Evidence cards:* Students are given two or more claims about a scientific topic and evidence cards to prove these claims. They are expected to present grounds and justification for the claims they selected. In activity students work in groups and reach a conclusion based on group discussions (Osborne et. al., 2004).
- *Discussion with models:* In the activity students are asked to develop or draw a model about a scientific topic or concept given. Then they are asked to develop arguments how they developed the model and which grounds they used for it. They are expected to present evidence supporting the model and rebut the other models giving counter arguments (Osborne et. al., 2004).

All the activities some of which given above aim at improving students’ scientific thinking skills and their attempts to defend their position in a scientific manner. These activities make it possible for students to ask questions, defend their position using acceptable grounds, evaluate counter arguments and to follow a scientific way to achieve these activities. Activities of scientific argumentation are the basis for both science and science education (Kuhn, 1986; cited in Altun, 2010).

In Turkey the effects of scientific argumentation on student achievement in science education, student attitudes, debate skills of students and other related skills on different group of participants, including student teachers (Acar, 2008; Demirci, 2008; Tümay, 2008; Özdem, 2009; Aslan, 2010; Ceylan, 2010; Hakyolu, 2010; İşbilir, 2010; Top and Can, 2010; Kutluca, 2012; Şekerci, 2013; Boran, 2014), high school students (Yeşiloğlu, 2007; Özer, 2009; Çelik, 2010; Gültepe, 2011), primary and secondary students (Kaya, 2005; Kaya and Kılıç, 2008; Uluçınar Sağır, 2008; Kaya, 2009; Deveci, 2009; Tekeli, 2009; Altun, 2010; Erdoğan, 2010; Hacıoğlu, 2011; Keçeci, Kırılmazkaya and Kırbağ, 2011; Özkara, 2011; Ceylan, 2012; Küçük, 2012; Okumuş, 2012; Uluay, 2012; Cin, 2013; Çınar, 2013; Öğreten, 2014; Polat, 2014). These studies generally concluded that scientific argumentation has positive effects on the variables analysed. On the other hand, there are less studies concerning the effects of scientific argumentation on the eighth grade science and technology course (Kaya, 2009; Tekeli, 2009; Özkara, 2011; Okumuş, 2012). Some of the studies are about the use of scientific argumentation in specific topics (i.e., global warming, environment, etc) covered in the course of science and technology (Deveci, 2009; Domaç, 2011; Karışan, 2011; Keçeci et. al., 2011; Yaman, 2011; Kutluca, 2012; Soysal, 2012).

There is no specific study about the effects of scientific argumentation on the students' achievement in the unit of "cell division and inheritance" covered in the eighth grade science and technology course, on their comprehension about the nature of scientific knowledge, their willingness to take part in discussions and their attitude towards the course of science and technology. Therefore, the findings of this study will provide new insights about the use of scientific argumentation in science education.

Aim

The study aims at identifying the effects of scientific argumentation on the students' achievement in the unit of "cell division and inheritance" covered in the eighth grade science and technology course, on their comprehension about the nature of scientific knowledge, their willingness to take part in discussions and their attitude towards the course of science and technology. In parallel to these aims the study tries to answer he following research questions:

1) Do the scores of the experiment students and of the control students from achievement test for the unit of cell division and inheritance significantly vary?
2) Do the scores of the experiment students and of the control students from the nature of scientific knowledge scale significantly vary?
3) Do the scores of the experiment students and of the control students from the argumentation survey significantly vary?
4) Do the scores of the experiment students and of the control students from the scale for attitudes towards science and technology course significantly vary?

Method

Model of the Study

The study is deasigned as a pretest-post test matched control group research which is part of semi-experimental design techniques (Balcı, 2005).

Participants

The participants of the study were 77 eighth grade students attending two sections of a public secondary school in Sultangazi district of Istanbul during the school year of 2014-2015. Students in one section were assigned to the experiment group in which scientific argumentation was employed as learning process. The remaining students in the other section were assigned to the control group in which the course was delivered through traditional teaching methods. The experiment group consisted of 38 students of which 21 were females (55.3%) and 17 males (44.7%). There were 39 students in the control group of which 18 were females (46.2%) and 21 males (53.8%).

Data Collection Instruments

Achievement test for the unit of cell division and inheritance was developed by the author to determine the current knowledge of students about the topic. The test included 60 items developed based on the stated goals for the unit. It was used in a pilot study and then item analysis was carried out. Following the analysis the number of test became thirty. The analysis showed that its KR-20 reliability coefficient was .86.

Nature of Scientific Knowledge Scale

The nature of scientific knowledge scale was developed by Rubba and Anderson (1978) to reveal student understanding about the nature of scientific knowledge. The scale specifically addresses the understanding of students at the ages of 12-15. The scale was translated into Turkish by Taşar (2006). It was developed based on the model of scientific knowledge. It is a 5-point Likert scale, which covers 48 items of which 24 are positive statements and 24 are negative statements. The maximum score is 240, while the minimum score is 48. Higher scores in each dimensions mean that students have correct understanding about the nature of scientific knowledge. In the study it was found that the scale has six dimensions and the Cronbach's Alpha coefficients for the dimensions are as follows: for the dimension of ethics .87, for the dimension of creativty .87, for the dimension of development .86, for the dimension of simplicity .86, for the dimension of testability .86, and for the dimension of combination .86. The overall Cronbach's Alpha coefficient for the scale was found to be .84.

Argumentation Test

Argumentation test was administered to the experiment students to determine if any change took place in their willingness to participate in discussions. The test was developed by Infante and Rancer (1982). It was translated into Turkish by Kaya (2005). It is a 5-point Likert type scale of which Cronbach's Alpha coefficient was found to be .79.

Attitudes towards Science and Technology Course Scale

Developed by Tekeli (2009) the attitudes towards science and technology course scale was employed to reveal the particpants' attitudes towards the course. It is a 5-point Likert type scale which is consisted of fifteen items. Of these items, ten are positive statements and five negative statements. The original Cronbach's Alpha coefficient of the scale was found to be .96. In this study the reliability analysis of the scale was carried out on 118 eighth grade students. The results of confirmatory factor analysis showed that the scale did not have necessary statistical conditions for a single dimension (x^2/sd= 4.14; RMSEA= .164). Then the scale was analysed using exploratory factor analysis. It was found that the Kaiser Mayer Olkin (KMO) coefficient for four dimensions was .85. It was also found that the result of the Barlett's test was 804.866 ($p< .01$) and that it accounted for 68,09% of the total variance. Confirmatory analysis showed that four dimensions had x^2/sd=1.26. It is suggested that the rate between chi-square consistency and degree of freedom should be at most 5 or lower. In the analysis the x^2/sd rate was found to be lower than two, indicating that factor consistency is perfect (Kline, 2005). In addition, consistency indexes of four dimensions indicated that mean error square root RMSEA was .047. If the value of RMSEA is between 0 and .05, it refers to good consistency. The value of RMSEA between .05 and .08 reefrs to an acceptable consistency (Brown, 2006; Şimşek, 2007; Yılmaz and Çelik, 2009). In the current study the value of RMSEA was found to be .047, indicating that the consistency was good. Non-normalized fit index (NNFI) was found to be .94, and comparative fit index (CFI) was found to be .95. In short, the factor analysis showed that the scale had four dimensions: positive attitude towards science and technology course, negative attitude towards science and technology course, importance attached to the science and technology course and interest in science and technology course. The Cronbach's Alpha coefficients of these dimensions are found as follows: for the dimension of positive attitude towards science and technology course it was .88, for the dimension of negative attitude towards science and technology course it was .80, for the dimension of importance attached to the science and technology course it was .71 and for the dimension of interest in science and technology course .77. The overall Cronbach's Alpha coefficient of the scale was found to be .88.

Activities of Scientific Argumentation

In order to develop study sheets for the classroom activities based on scientific argumentation several studies were reviewed (i.e., Osborne et. al., 2004; Uluçınar-Sağır, 2008; Altun, 2010; Şahin and Hacıoğlu, 2010; Hacıoğlu, 2011; Özkara, 2011; Yaman, 2011; Kutluca, 2012; Puig, Torija and Jimenez-Aleixandre, 2012; Soysal, 2012). In the study the following scientific argumentation-based activities and strategies were employed: developing arguments, competing theories-cartoons, predict-observe-explain, competing theories-ideas and evidence, expressions table, concept maps and competing theories-stories. Study sheets were developed by the author. These sheets were reviewed by science education specialists and science and technology teachers in terms of scope validity.

Procedure

The unit was delivered in the control group through activities covered in the textbook. It was delivered in the experiment group through the activities mentioned above. All these activities were based on the Toulmin model of argumentation. The activities were implemented by the scholar. Table 1 shows the strategies of scientific argumentation and small group techniques used in the activities.

Table 1. Strategies of scientific argumentation and small group techniques used in the activities

Activities	**The Strategies**	**Group Techniques**
In The Activities of Introduction to and Preparation for Scientific Argumentation	Developing Arguments	Pair Talk
I am Examining Mitosis	Developing Arguments	Listening Triads
In the Activities of Living Beings and Their Chromosome Numbers	Competing Theories- Cartoons	Pairs and Quadruples
Astonishment of The King	Case Text- Developing Arguments	Pairs and Quadruples
I'm Geeting to Know Mendel	Predict- Observe – Explain Competing Theories- Cartoons	Pair Talk
Hereditary diseases	Case Text- Developing Arguments	Pair Talk
Let's Draw Irem's Family Tree	Competing Theories-Ideas and Evidence	Ambassadors
I am Learning Meiosis	Developing Arguments	Pair Talk
Differences Between Mitosis and Meiosis	Expression Tables	Listening Triads
My Concept Map	Concept Map	Pairs ad Quadruples
Nucleotides, DNA, Genes, Chromosome	Expression Tables	Listening Triads
Modification- Mutation	Case Text- Developing Arguments	Pair Talk
Genetic Engineering	Competing Theories- Stories	Discussions
Living Clone	Competing Theories- Cartoons	Ambassadors
Why are we taller than our grandparents?	Case Text- Developing Arguments	Discussions

As Table 1 shows in the activities the following small group techniques based on scientific argumentation were used: pair talk (in the activities of introduction to and preparation for scientific argumentation, I am geting to know Mendel, hereditary diseases, I am learning meiosis, modification- mutation), listening triads (I am examining mitosis, differences between mitosis and meiosis, nucleotides, DNA, genes, chromosome), pairs and quadruples (in the activities of living beings and their chromosome numbers, astonishment of the king, my concept map), ambassadors (in the activities of let's draw Irem's family tree, living clone) and discussions (in the activity of genetic engineering and why are we taller than our grandparents?).

In the experimental group students were informed about how scientific argumentation based learning process would be carried out. Two additional activities titled "young or old?" and "fraudulent tracks" were made. The study lasted for 24 class hours. Students were randomly divided into small groups during the activities where necessary.

Data Analysis

The pre-test scores of both groups were analysed using t-test, which indicated that the groups had similar scores ($p>.05$). The comparison of the post-test scores of the groups was made by ANCOVA. The distribution of ANCOVA analysis and introgroup regressions were analysed (Leech, Barrett and Morgan, 2005). The analysis showed that all conditions were proper for the ANCOVA analysis.

Results

Results of the Achievement Tests

Table 2 shows mean pre- and post-test scores of the experiment and control groups in the achievement test, standard deviation and corrected post-test mean scores and standard deviation in the Bonferroni test.

Table 2. Mean pre- and post-test scores of the experiment and control groups in the achievement test, standard deviation and corrected post-test mean scores and standard error

Groups	N		Total Points		Corrected Post-Test Mean Scores	
			$\bar{X}$	S.S	$\bar{X}$	S.e
Experiment	38	Pre test	11.50	4.688		
		Post test	19.05	4.724	18.99	.606
Control	39	Pre test	11.33	4.468		
		Post test	16.20	5.161	16.26	.599

Table 2 indicates that mean post-test score of the experiment group is 19.05, while that of the control group is 16.20. Following the correction of the pre-test scores mean post-test score of the experiment group is 18.99, while that of the control group is 16.26. Therefore, it can be stated that the academic achievement of the experiment students is much higher than that of the control students. In order to see whether or not the corrected post-test scores of the groups significantly vary ANCOVA analysis was used. The results of the ANCOVA analysis are given in Table 3.

Table 3. Results of the ANCOVA analysis about the corrected post-test scores of the groups

Source	Sum of Squares	df	Mean Square	F	Sig.
Pre test(regression)	804.066	1	804.066	57.534	.000
Groups (experiment/control)	143.218	1	143.218	10.248	.002*
rror	1034.188	74	13.976		
Total	25874.000	77			
Corrected Total	1994.312	76			

Table 3 indicates that when the pre-test scores of the groups are controlled there appears a statistically significant difference between the post-test score of the experiment group and that of the control group ($F_{(1,74)}$= 10.248, $p< .05$). More specifically, the corrected mean post-test score of the experiment group (X= 18.99) is higher than that of the control group (X= 16.26). Therefore, using a scientific argumentation based learning process has significant and positive effects on the student achievement in regard to the unit of cell division and inheritance.

Results of the Nature of Scientific Knowledge Scale

Mean post-test scores of the experiment students was found to be 27.21 for the dimension of ethics. It was found found to be 29.86 for the dimension of creativity, 28.63 for the dimension of development, 26.13 for the dimension of simplicity, 33.57 for the dimension of testability and 29.86 for the dimension of combination. For the control group the following mean post-test scores were found: for the dimension of ethics it was 25.46, for the dimension of creativity it was 28.12, for the dimension of development it was 25.89, for the dimension of simplicity it was 23.53, for the dimension of testability it was 30.87 and for the dimension of combination it was 28.12.

When the pre-test scores of the experiment students are controlled their mean post-test scores for the dimension of the scale were found to be higher ethics ($\boldsymbol{X}_D$=27.33; $\boldsymbol{X}_K$= 25.33), creativity ($\boldsymbol{X}_D$=30.28; $\boldsymbol{X}_K$=27.72), development ($\boldsymbol{X}_D$=28.68; $\boldsymbol{X}_K$= 25.84), simplicty ($\boldsymbol{X}_D$=26.07; $\boldsymbol{X}_K$=23.59), testability ($\boldsymbol{X}_D$=33.41; $\boldsymbol{X}_K$= 31.03) and combination ($\boldsymbol{X}_D$=32.44; $\boldsymbol{X}_K$= 32.33)) than those of the control students. Therefore, it safe to argue that the experiment students had much more developed views about the nature of scientific knowledge than the control students. In order to see whether or not the corrected post-test scores of the groups significantly vary ANCOVA analysis was used. The results of the ANCOVA analysis are given in Table 4.

Table 4 indicates that when the pre-test scores of the groups are controlled there appears a statistically significant difference between the corrected mean post-test scores of both groups for five dimensions of the scale: ethics ($F_{(1,74)}$= 6.407, $p< .05$), creativity ($F_{(1,74)}$= 6.188, $p< .05$), development ($F_{(1,74)}$= 7.933, $p< .05$), simplicity ($F_{(1,74)}$= 10.190, $p< .05$) and testability ($F_{(1,74)}$= 9.128, $p< .05$). The experiment students had higher mean post-test scores for the dimensions mentioned above than the control students. For the sixth dimension, namely combination, the mean corrected post-test score for the experiment group ($\boldsymbol{X}$=32.44) was higher than that of the control group ($\boldsymbol{X}$=32.33). However, when the pre-test scores of both groups are controlled, it appears that this difference is not statistically significant ($F_{(1,74)}$= .017, p> .05). These findings suggest that the experiment students had much more developed and correct understandings about the ethical, creativity, developmental, simplicity and testability dimensions of scientific argumentation than the control students. Therefore, it can be argued that scientific argumentation based learning process has positive and significant effects on the student understanding about the nature of scientific knowledge.

Table 4. Results of the ANCOVA analysis about the corrected post-test scores of the groups

Subdimension	Source	Sum of Squares	df	Mean Square	F	Sig.
Ethics	Pre test(regression)	465.114	1	465.114	38.808	.000
	Groups(experiment/control)	76.793	1	76.793	6.407	.013*
	Error	886.894	74	11.985		
	Corrected Total	1410.883	76			
Creativity	Pre test(regression)	889.980	1	889.980	44.298	.000
	Groups(experiment/control)	124.327	1	124.327	6.188	.015*
	Error	1486.722	74	20.091		
	Corrected Total	2434.987	76			
Development	Pre test(regression)	821.054	1	821.054	42.211	.000
	Groups(experiment/control)	154.299	1	154.299	7.933	.006*
	Error	1439.378	74	19.451		
	Corrected Total	2404.312	76			
Simplicty	Pre test(regression)	332.703	1	332.703	28.517	.000
	Groups(experiment/control)	118.883	1	118.883	10.190	.002*
	Error	863.331	74	11.667		
	Corrected Total	1325.455	76			
Testability	Pre test(regression)	511.795	1	511.795	43.242	.000
	Groups(experiment/control)	108.036	1	108.036	9.128	.003*
	Error	875.827	74	11.835		
	Corrected Total	1528.675	76			
Combination	Pre test(regression)	480.964	1	480.964	41.679	.000
	Groups(experiment/control)	.198	1	.198	.017	.896
	Error	853.947	74	11.540		
	Corrected Total	1340.312	76			

Results of Argumentation Test

Table 5 shows the pre- and post-test mean scores of the groups in the argumentation test and standard deviation. It also indicates the corrected post-test mean scores and standard deviation which were found as a result of the ANCOVA analysis.

Table 5. Pre/post-test mean and corrected post-test mean scores

Groups	N		Total Points		Corrected Post-Test Mean Scores	
			$\bar{X}$	S.S	$\bar{X}$	S.e
Experiment	38	Pre test	64.13	12.760		
		Post test	71.13	13.293	71.14	.968
Control	39	Pre test	64.15	10.080		
		Post test	66.79	11.772	66.78	.956

Table 5 indicates that the mean post-test score of the experiment group was found to be 71.13. It was found to be 66.79 for the control group. When the pre-test scores are controlled the mean post-test score for the experiment group was found to be 71.14, and it was found to be 66.78 for the control group. Therefore, it can be stated that willingness of the experiment students to participate in discussions is higher than that of the control students. ANCOVA was employed to see whether or not there was a significant difference between the corrected post-test scores of the groups. The results of the analysis are given in Table 6.

Table 6. ANCOVA results about the pre- and post-test scores of both groups

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Pre test(regression)	9169.192	1	9169.192	257.453	.000
Groups (experiment/control)	365.563	1	365.563	10.264	.002*
Error	2635.509	74	35.615		
Total	378074.000	77			
Corrected Total	12166.675	76			

Table 6 indicates that when the pre-test scores of the groups are controlled there appears a statistically significant difference between the corrected mean post-test scores of the groups ($F_{(1,74)}$= 10.264, $p< .05$). More specifically, the corrected mean post-test score of the experiment group ($\boldsymbol{X}$= 71.14) is higher than that of the control group ($\boldsymbol{X}$= 66.78). Therefore, it can be argued that scientific argumentation based learning process has positive and significant effects on the student willingness to participate in discussions.

Results of the Attitudes towards Science and Technology Course Scale

The mean post-test scores for the experiment group were found to be 25.02 for the positive attitudes, 12.18 for the negative attitudes, 12.65 for the importance given to the course and 13.15 for the interest in the course. For the control group the mean post-test scores were found to be 22.64 for the positive attitudes, 12.17 for the negative attitudes, 12.41 for the importance given to the course, and 11.76 for the interest in the course. When the pre-test scores are controlled, the mean post-test scores for the dimensions for the experiment group (positive attitude ($\boldsymbol{X}_D$=25.11; $\boldsymbol{X}_K$= 22.55), negative attitude ($\boldsymbol{X}_D$=12.68; $\boldsymbol{X}_K$=12.38), importance ($\boldsymbol{X}_D$=12.63; $\boldsymbol{X}_K$= 12.43) and interest ($\boldsymbol{X}_D$=12.93; $\boldsymbol{X}_K$=11.98) were higher than those for the control group. Therefore, the attitudes of the experiment students towards the science and technology course much higher than those of the control students. ANCOVA was employed to see whether or not there was a significant difference between the corrected post-test scores of the groups. The results are given in Table 7.

Table 7. ANCOVA results about the pre- and post-test scores of both groups

Subdimension	**Source**	**Sum of quares**	**df**	**Mean Square**	**F**	**Sig.**
The Positive Attitudes	Pre test(regression)	446.563	1	446.563	66.977	.000
	Groups(experiment/control)	126.097	1	126.097	18.913	.000*
	Error	493.386	74	6.667		
	Corrected Total	1049.455	76			
The Negative Attitudes	Pre test(regression)	115.741	1	115.741	41.661	.000
	Groups(experiment/control)	1.784	1	1.784	.642	.426
	Error	205.582	74	2.778		
	Corrected Total	331.169	76			
Importance	Pre test(regression)	73.484	1	73.484	33.463	.000
	Groups(experiment/control)	.736	1	.736	.335	.564
	Error	162.504	74	2.196		
	Corrected Total	237.169	76			
Interest	Pre test(regression)	87.715	1	87.715	62.257	.000
	Groups(experiment/control)	16.405	1	16.405	11.643	.001*
	Error	104.260	74	1.409		
	Corrected Total	229.091	76			

Table 7 shows that when the pre-test scores are controlled, there appear significant differences between the post-test scores of the groups for two dimensions: positive attitude ($F_{(1,74)}$= 18.913, $p< .05$) and interest ($F_{(1,74)}$= 11.643, $p< .05$). More specifically, the experiment group had higher mean post-test scores for these dimensions than the control group. In addition, the experiment group had a higher mean post-test scores for the dimension of interest than the control group ($\boldsymbol{X}$=12.68 and $\boldsymbol{X}$=12.38, respectively). However, when the pre-test scores are controlled, it is found that this difference is not statistically significant ($F_{(1,74)}$= .642, p> .05). Similarly, the experiment group had a higher mean post-test scores for the dimension of importance than the control group ($\boldsymbol{X}$=12.63 and $\boldsymbol{X}$=12.43, respectively). However, when the pre-test scores are controlled, it is found that this difference is not statistically significant ($F_{(1,74)}$= .335, p> .05). These findings suggest that scientific argumentation based learning process has positive and significant effects on the student attitudes towards the course of science and technology.

Discussion and Conclusion

In the study it was found that scientific argumentation based learning process is much more efficient in improving student achievement than traditional and textbook based teaching methods. The finding of the study that scientific argumentation based learning process improves student achievement is consistent with previous findings (Yerrick, 2000; Zohar and Nemet, 2002; Kaya, 2005; Demirci, 2008; Sağır-Uluçınar, 2008; von Aufschnaiter et. al., 2008; Deveci, 2009; Köroğlu, 2009; Tekeli, 2009; Altun, 2010; Özkara, 2011; Ceylan, 2012; Okumuş, 2012; Uluay, 2012; Öğreten, 2014; Polat, 2014). For instance, Özkara (2011) analysed the effects of the scientific argumentation based learning process on the achievement of eighth graders in relation to the unit of pressure and concluded that this process has a significant effects on student achievement. Similarly, Polat (2014) compared the scientific argumentation based learning process and traditional teaching method on seventh graders and found that the former had positive effects on student achievement. On the other hand, this finding of the study is also consistent with the findings of the previous studies carried out on secondary students and student teachers (Yeşiloğlu, 2007; Özer, 2009; Demircioğlu and Uçar, 2015). However, Gümrah (2013) found no significant difference between the scientific argumentation based learning process and traditional methods on the ninth grade students' achievement. This inconsistency might have arised due to the use of different groups of participants.

Students who are taught through the scientific argumentation based learning process may experience several steps involved in the scientific process (Driver et. al., 2000). In the study it was found that the experiment group had higher mean post-test scores for five out of six dimensions of the nature of the scientific knowledge scale, namely ethics, creativity, development, simplicity and testability. On the other hand, although the difference is not statistically significant, the experiment group also had higher mean post-test score for the dimension of combination than the control group ($\boldsymbol{X}$=32.44 and $\boldsymbol{X}$=32.33, respectively). Therefore, it is safe to argue that the experiment students had much more developed understandings about the nature of scientific knowledge. This finding of the study is consistent with previous studies (Kaya, 2005; Uluçınar Sağır, 2008; von Aufschnaiter et. al., 2008; Tekeli, 2009; Altun, 2010). On the other hand, this finding of the study is also consistent with the findings of the previous studies carried out on secondary students and student teachers (Özer, 2009; Tümay and Köseoğlu, 2010; Gümrah, 2013; Boran, 2014). For instance, Gümrah (2013) found that the scientific argumentation based learning process has positive effects on student understandings about the nature of scientific knowledge. However, there are also studies which concluded that the scientific argumentation based learning process has no significant effects on student understandings about the nature of scientific knowledge (Yeşiloğlu, 2007, Ceylan, 2012, Şekerci, 2013). This inconsistency might have arised from the use of different groups of participants or the subject analysed.

The use of small groups in teaching scientific concepts makes it possible for students to perceive scientific concepts in a social pattern. In the study it was found that the experiment students had higher levels of willingness to take part in discussions than the control students. This finding is similar to those of the previous studies (Kaya, 2005; Uluçınar Sağır, 2008; Tekeli, 2009, Erdoğan, 2010; Yeh and She, 2010; Çınar, 2013). For instance, Çınar (2013) found that the experiment students who were taking the fifth grade science and technology course in a scientific argumentation based learning setting had higher levels of willingness to take part in discussions than the control students. On the other hand, this finding of the study is also consistent with the findings of the previous studies carried out on secondary students and student teachers (İşbilir, 2010; Şekerci, 2013; Demircioğlu et. al., 2015).

In the study it was also found that the scientific argumentation based learning process had positive effects in improving the student attitudes towrds the course of science and technology. More specifically, the experiment students had higher mean post-test scores for the dimensions of positive attitudes towards the course of science and technology and of interest in the course. It is thought that the reasons for these improved student attitudes are about the experience of a different teaching and learning process and intragroup interactions. The finding about the positive effects of the scientific argumentation based learning process on student attitudes is consistent with previous findings (Kaya, 2005; Tekeli, 2009; Erdoğan, 2010; Küçük, 2012). For instance, Küçük (2012) found the positive effects of the scientific argumentation based learning process on the attitudes of the seventh grade students towards the course of science and technology. Research suggests that student attitudes resist to change (Uluçınar Sağır, 2008; Altun, 2010; Özkara, 2011; Ceylan, 2012). On the other hand, Yeşiloğlu (2007) found that the scientific argumentation based learning process had no significant effect on the attitudes of the tenth grade students towards the chemistry course. This inconsistency can be stemmed from the use of different groups of participants and the analysis of different study subjects. In short, it is found that the scientific argumentation based learning process had significant and positive effects on student achievement, student understandings about the nature of scientific knowledge and their attitudes towards the course of science and technology.

Acknowledgements

This study is a version of the MA thesis under the supervision of Assoc. Prof. Dr. Nilgün YENİCE at Adnan Menderes University and was supported by the scientific research project directorate of Adnan Menderes University.

References

Acar, Ö. (2008). *Argumentation skills and conceptual knowledge of undergraduate students in a physics by ınquiry class.* Unpublished Doctoral Dissertation, The Ohio State University, Ohio.

Altun, E. (2010). *Işık ünitesinin ilköğretim öğrencilerine bilimsel tartışma (argümantasyon) odaklı yöntem ile öğretimi.* Yayımlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Aslan, S. (2010). *Ortaöğretim 10. sınıf öğrencilerinin üst bilimsel süreç ve eleştirel düşünme becerilerinin geliştirilmesine bilimsel tartışma odaklı öğretim yaklaşımının etkisi.* Yayımlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi, Eğitim Bilimleri, Ankara.

Balcı, A. (2005). *Sosyal Bilimlerde Araştırma: Yöntem Teknik ve İlkeler*. Ankara, Pegema Yayıncılık.

Boran, G. H.(2014). *Argümantasyon temelli fen öğretiminin bilimin doğasına ilişkin görüşler ve epistemolojik inançlar üzerine etkisi,* Yayımlanmamış Doktora Tezi, Pamukkale Üniversitesi, Eğitim Bilimleri Enstitüsü, Denizli.

Brown, T. A. 2006. Confirmatory Factor Analysis for Applied Resarch. First Edition., Guilford Publications, New York.

Ceylan, Ç. (2010). *Fen laboratuvar etkinliklerinde argümantasyon tabanlı bilimögrenme-atbö yaklasımının kullanımı.* Yayımlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi, Egitim Bilimleri Enstitüsü, Ankara.

Ceylan, K. E. (2012*). İlköğretim 5. Sınıf öğrencilerine dünya ve evren öğrenme alanının bilimsel tartışma (argümantasyon) odaklı yöntem ile öğretimi*, Yayımlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Cin, M. (2013). *Argümantasyon yöntemine dayalı kavram karikatürü etkinliklerinin öğrencilerin kavramsal anlama düzeylerine ve bilimsel süreç becerilerine etkileri.* Yayımlanmamış Yüksek Lisans Tezi, Dokuz Eylül Üniversitesi, Eğitim Bilimleri Enstitüsü, İzmir.

Clark, B., & Sampson, D. (2007). Personally-seeded discussions to scaffold online argumentation. *International Journal of Science Education*, 29: 253–277.

Çelik, A., Y. (2010). *Bilimsel tartışma (argümantasyon) esaslı öğretim yaklaşımının lise öğrencilerinin kavramsal anlamaları, kimya dersine karşı tutumları, tartışma isteklilikleri ve kalitesi üzerine etkisinin incelenmesi*, Yayımlanmamış Doktora Tezi, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara.

Çınar, D. (2013). Argümantasyon temelli fen öğretiminin 5. Sınıf öğrencilerinin öğrenme ürünlerine etkisi, Yayımlanmamış Doktora Tezi, Necmettin Erbakan Üniversitesi, Eğitim Bilimleri Enstitüsü, Konya.

Cinar, D. & Bayraktar, S. (2014). Evaluation of the effects of argumentation based science teaching on 5th grade students' conceptual understanding of the subjects related to "matter and change". *International Journal of Education in Mathematics, Science and Technology, 2*(1), 49-77.

Demirci, N., (2008). *Toulmin'in Bilimsel Tartışma Modeli Odaklı Eğitimin Kimya Öğretmen Adaylarının Temel Kimya Konularını Anlama ve Tartışma Seviyeleri Üzerine Etkisi*, Yayımlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Demircioğu, T., & Uçar, S. 2015. Investigating the effect of argument-driven inquiry in laboratory ınstruction. *Educational Sciences: Theory ve Practice***,** 15(1), 267-283.

Deveci, A. (2009). *İlköğretim Yedinci Sınıf Öğrencilerinin Maddenin Yapısı Konusunda Sosyo bilimsel Argümantasyon, Bilgi Seviyeleri Ve Bilişsel Düşünme Becerilerini Geliştirmek,* Yayımlanmamış Yüksek Lisans Tezi, Marmara Üniversitesi, Eğitim Bilimleri Enstitüsü, İstanbul.

Domaç, G. G. (2011). B*iyoloji eğitiminde toplumbilimsel konuların öğrenilmesinde argümantasyon tabanlı öğrenme sürecinin etkisi,* Yayımlanmamış Yüksek LisansTezi, Gazi Üniversitesi, Eğitim Bilimler Enstitüsü, Ankara.

Driver, R., Newton, P.,& Osborne, J.(2000). Establishing the norms of argumentation in classrooms. *Science Education*, 84: 287–312.

Duschl, R., Obsorne, J. (2002). Supporting and romoting argumentation discourse. *Studies in Science Education***,** 38: 39-72.

Erdoğan,S. (2010). *Dünya, güneş ve ay konusunun ilköğretim 5. Sınıf öğrencilerine bilimsel tartışma odaklı yöntem ile öğretilmesinin öğrencilerin başarılarına, tutumlarına ve tartışmaya katılma istekleri üzerine etkisinin incelenmesi,* Yayımlanmamış Yüksek Lisans Tezi,Uşak Üniversitesi, Sosyal Bilimler Enstitüsü, Uşak.

Erduran, S., Simon, S., & Osborne, J., (2004). TAPping into Argumentation: developments in the application of toulmin's argument pattern for studying science discourse. *Wiley Periodicals, Inc.* 88(2): 915-933.

Gültepe, N. (2011). *Bilimsel Tartışma Odaklı Öğretimin lise Öğrencilerinin Bilimsel Süreç Ve Eleştirel Düşünme Becerilerinin Gelişimine Etkisi,* Yayımlanmamış, Yüksek Lisans Tezi, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Gümrah, A. (2013). *Bilimsel tartışma yönteminin ortaöğretim öğrencilerinin kimyasal değişimler konusunu anlamaları, bilimin doğası hakkındaki görüşleri, bilimsel süreç, iletişim ve argüman becerileri üzerine etkisi,* Yayımlanmamış Doktora Tezi, Marmara Üniversitesi, Eğitim Bilimleri Enstitüsü, İstanbul.

Hakyolu, H.(2010). *Farklı öğrenme seviyelerindeki öğrencilerin fen derslerinde oluşturulan argüman ortamlarındaki performansları*, Yayımlanmamış Yüksek Lisans Tezi, Marmara Üniversitesi, Eğitim Bilimleri Enstitüsü, İstanbul.

Infante, D. A., & Rancer, A. S. (1982). A conceptualization and measure of argumentativeness**.** *Journal of Personality Assessment***,** 46(1): 72-80.

İşbilir, E. (2010). *Investigating Pre-Service Science Teachers's Quality of Written Argumentations about Socio-Scientific Issues in Relation to Epistemic Beliefs and Argumentativeness*, Unpublished Yüksek Lisans Tezi, Ankara: ODTÜ, Fen Bilimleri Enstitüsü.

Jimenez-Aleixandre, M.P., Rodriguez, B., & A Duschl, R., A. (2000). Doing the lesson or Doing Science. Argument in High School Genetics. *Science Education,* 84: 757-792.

Jimenez – Aleixandre, M.P., & Erduran, S. (2008). Argumentation in science education : an overview. Argumentation İn Science Education : Perspectives From Classroom – Based Research (Erduran, S., Jimenez – Aleixandre, M.P., Eds.), Springer, pp. 292, Dordrecht

Kaya, O. N.(2005). *Tartışma Teorisine Dayalı Öğretim Yaklaşımının Öğrencilerin Maddenin Tanecikli Yapısı Konusundaki Başarılarına ve Bilimin Doğası Hakkındaki Kavramalarına Etkisi,* Yayımlanmamış Doktora Tezi, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Kaya, B. *(*2009*). Araştırma Temelli Öğretim ve Bilimsel Tartışma Yönteminin İlköğretim Öğrencilerinin Asitler ve Bazlar Konusunu Öğrenmesi Üzerine Etkilerinin Karşılaştırılması,* Yayımlanmamış Yüksek Lisans Tezi, Marmara Üniversitesi, Eğitim Bilimleri Enstitüsü, İstanbul.

Kaya, O. N., & Kılıç, Z. (2010). Fen sınıflarında meydana gelen diyaloglar ve öğrenme üzerine etkileri. *Kastamonu Eğitim Dergisi*, 18(1), 115-130.

Keçeci, G., Kırılmazkaya, G., & Kırbağ F. Z. (2011). İlköğretim öğrencilerinin genetiği değiştirilmiş organizmaları on-line argümantasyon yöntemi ile öğrenmesi**,** *6. International Advance Technologies Symposium*, (16-18 Mayıs 2011), Elazığ.

Kline, R. B. (2005*). Principles and Practice of Structural Equations Modelling.* Guilford Press, New York.

Köroğlu, L. S. (2009). *Sekizinci sınıf fen ve teknoloji dersi kalıtım konusunun tartışma öğeleri temelli rehber sorularla desteklenen benzetim ortamında öğretiminin akademik başarı ve tartışma öğelerini kullanma düzeyine etkisi*, Yayımlanmamış Yüksek Lisans Tezi, Çukurova Üniversitesi, Sosyal Bilimler Enstitüsü, Adana.

Kuhn, D. (1992). Thinking as argument. *Harvard Educational Review*, 62, 155–178.

Kutluca, A. Y. (2012). *Fen ve Teknoloji Öğretmen Adaylarının Klonlamaya İlişkin Bilimsel ve Sosyobilimsel Argümantasyon Kalitelerinin Alan Bilgisi Yönünden İncelenmesi*, Yayımlanmamış Yüksek Lisans Tezi, Abant İzzet Baysal Üniversitesi, Eğitim Bilimleri Enstitüsü, Bolu.

Küçük, H. (2012). *İlköğretimde bilimsel tartışma destekli sınıf içi etkinliklerin kullanılmasının öğrencilerin kavramsal anlamalarına, sorgulayıcı öğrenme becerileri algılarına ve fen ve teknoloji'ye yönelik tutumlarına etkisi*, Yayımlanmamış Yüksek Lisans Tezi, Sıtkı Koçman Üniversitesi, Eğitim Bilimleri Enstitüsü. Muğla.

Leech, N. L., Barrett, K. C. & Morgan, G.A. (2005*). SPSS for intermediate statistics: Use and interpretation*. (2. Baskı). NJ: Lawrence Erlbaum Associates, Inc

MEB, (2013). *İlköğretim Fen Bilimleri Dersi (3, 4, 5, 6, 7 ve 8. Sınıflar) Öğretim Programı*, MEB, Ankara.

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science**.** *International Journal of Science Education*, 21, 553– 576.

Okumuş, S. (2012). "*maddenin halleri ve ısı" ünitesinin bilimsel tartışma (argümantasyon) modeli ile öğretiminin öğrenci başarısına ve anlama düzeylerine etkisi,* Yayımlanmamış Yüksek Lisans Tezi, Karadeniz Teknik Üniversitesi, Eğitim Bilimleri Enstitüsü, Trabzon.

Osborne J. F., Erduran S., & Simon S. (2004). Enhancing the quality of argumentation in school science. *Journel of Research in Science Teaching*, 41: 994-1020.

Puig, B., Torija, B. B., & Jimenez-Aleixandre, M. P., (2012). Argumentation In The Classroom: Two Teachıng Sequences. Danú, *Santiago de Compostela*, Spain.

Öğreten, B. (2014). *Argümantasyona (bilimsel tartışmaya) dayalı öğretim sürecinin akademik başarı ve tartışma seviyelerine etkisi,* Yayımlanmamış Yüksek Lisans, Amasya Üniversitesi Fen Bilimleri Enstitüsü, Amasya.

Özdem, Y. (2009). *The nature of pre-service science teachers' argumentation in inquiry-oriented laboratory context. Yayımlanmamış Yüksek Lisans Tezi Ortadoğu Teknik Üniversitesi Sosyal Bilimler Enstitüsü, Ankara.*

Özer, G. (2009). *Bilimsel tartışmaya dayalı öğretim yaklaşımının öğrencilerin mol kavramı konusundaki kavramsal değişimlerine ve başarılarına etkisinin incelenmesi*, Yayımlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Özkara, D. (2011). *Basınç konusunun sekizinci sınıf öğrencilerine bilimsel argümantasyona dayalı etkinlikler ile öğretilmesi,* Yayımlanmamış Yüksek Lisans Tezi, Adıyaman Üniversitesi, Fen Bilimleri Enstitüsü, Adıyaman.

Polat, H. (2014). *Atomun yapısı konusunda argümantasyon yönteminin ilköğretim 7. Sınıf öğrencilerinin başarısı üzerine etkisi*, Yayımlanmamış Yüksek Lisans Tezi, İnönü Üniversitesi, Eğitim Bilimleri Enstitüsü, Malatya.

Rubba, P. & Anderson, H. (1978). Development of an instrument to assess secondary students' understanding of the nature of scientific knowledge. *Science Education*, 62(4), 449-458.

Soysal, Y. (2012). *Sosyo-bilimsel argümantasyon kalitesine alan bilgisi düzeyinin etkisi: genetiği değiştirilmiş organizmalar*, Yayımlanmamış Yüksek Lisans Tezi, Abant İzzet Baysal Üniversitesi, Eğitim Bilimleri Enstitüsü, Bolu.

Şahin, F., & Hacıoğlu, Y. (2010). Bilimsel tartışma destekli örnek olayların 8. Sınıf öğrencilerinin "kalıtım" konusunda kavram öğrenmelerine ve okuduğunu anlama becerilerine etkisi. *International Conference on New Trends in Education and Their Implications,* 11-13 November, pp., 269-276, Antalya.

Şekerci, A. R. (2013). *Kimya laboratuvarında argümantasyon odaklı öğretim yaklaşımının öğrencilerin argümantasyon becerilerine ve kavramsal anlayışlarına etkisi*, Yayımlanmamış Doktora Tezi, Atatürk Üniversitesi, Eğitim Bilimleri Enstitüsü, Erzurum.

Şimşek, Ö. F. (2007). *Yapısal Eşitlik Modellemesine Giriş: Temel İlkeler ve Lisrel Uygulamaları*, Ekinoks, Ankara.

Tasar, M. F. (2006). Probing preservice teachers' understandings of scientific knowledge by using a vignette in conjunction with a paper and pencil test. *Eurasia Journal of Mathematics, Science and Technology Education*, 2(1), 53-70.

Tekeli, A. (2009). *Argümantasyon odaklı sınıf ortamının öğrencilerin asit-baz konusundaki kavramsal değişimlerine ve bilimin doğasını kavramalarına etkisi*, Yayımlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Top, M.,& Can, B., (2010). Tartışma odaklı öğretimin fen öğretmen adaylarının öz yeterlilik inançlarına etkisi, *IX. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi,* Dokuz Eylül Üniversitesi, İzmir.

Toulmin, S. (1958). *The Uses of Argument*. Cambridge: Cambridge University Pres.

Tümay, H. (2008). *Argümantasyon odaklı kimya öğretimi.* Yayımlanmamış Doktora Tezi, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara.

Tümay, H., & Köseoğlu, F. (2010). Bilimde argümantasyona odaklanan etkinliklerle kimya öğretmen adaylarının bilimin doğası hakkındaki anlayışlarını geliştirme. *Gazi Eğitim Fakültesi Dergisi*, 30, 3, 859-876.

Tümay, H., & Köseoğlu, F. (2011). Kimya öğretmen adaylarının argümantasyon odaklı öğretim konusunda anlayışlarının geliştirilmesi. *Türk Fen Eğitimi Dergisi*, 8, 3, 105-119.

Uluay, G. (2012). *İlköğretim 7. sınıf fen ve teknoloji dersi kuvvet ve hareket konusunun öğretiminde bilimsel tartışma (argümantasyon) odaklı öğretim yönteminin öğrenci başarısına etkisinin incelenmesi.* Yayımlanmamış Yüksek Lisans Tezi Kastamonu Üniversitesi Fen Bilimleri Enstitüsü, Kastamonu.

Uluçınar-Sağır, Ş. (2008). *Fen bilgisi dersinde bilimsel tartışma odaklı öğretimin etkililiğinin incelenmesi,* Yayımlanmamış Doktora Tezi, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Von Aufschnaiter, C., Erduran, S., Osborne, J., Simon, S.(2008). Arguing to learn and learning to argue: case studies of how students’ argumentation relates to their scientific knowledge. *Journal of Research in Science Teaching,* 45, 101–131.

Yaman, H. H. (2011). *Argümantasyon tabanlı biyoetik eğitiminde örnek bir uygulama: genetiği değiştirilmiş organizma ve genetik tarama testi.* Yayımlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara.

Yeh, K.H., & She, H.C. (2010). On-Line synchronous scientific argumentation learning: nurturing students' argumentation ability and conceptual change in science context. *Computers & Education,* 55,586-602.

Yerrick, K., R. (2000). Lower track science students' argumentation and open inquiry instruction. *Journal of Research in Scıence Teaching*, 37, 807-838.

Yeşiloğlu, N. (2007). *Gazlar konusunun lise öğrencilerine bilimsel tartışma (argümantasyon) odaklı yöntem ile öğretimi*. Yayımlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Yılmaz, V., & Çelik, H. E. (2009). *Yapısal Eşitlik Modellemesi1: Temel Kavramlar, Uygulamalar, Programlama.* PegemA Yayıncılık, Ankara.

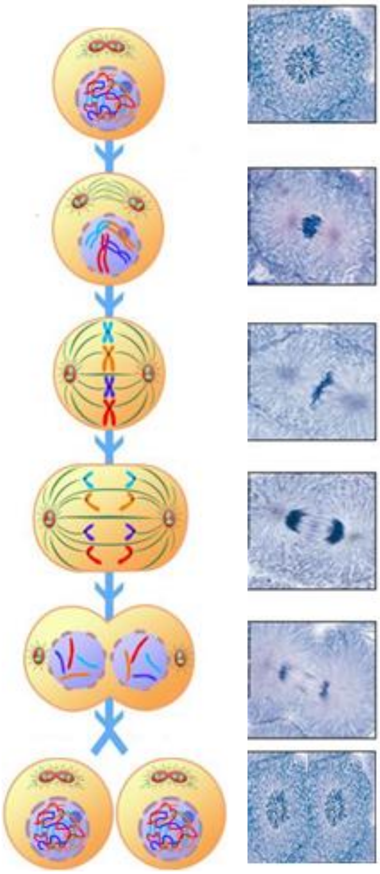
Zohar, A., & Nemet, F. (2002). Fostering students’ knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching***,** 39(1), 35-62.

APPENDIX

Activity 2: Learning Mitosis

Please review the figures about the steps in mitosis. Tell what you have seen.

How many cells occur following the division?



What happens to parent cell following the division?

What is the relationship between parent cell and newly formed cells?

Compare the sizes of parent cell and daughter cells.

Why are newly formed daughter cells the same as parent cell?

My claim :

My justification:

Zooblast is responsible for cell division.

True ☐ False ☐

My claim :

My justification:

Rebuttal: If there was a group member who did not agree with your idea, how did you persuade him?

……
……
………

Chromosome can be seen with a microscope only during the cell division.

True ☐ False ☐

My claim	:
My justification	:

Chromosome exists in cystoblast.

True ☐ False ☐

My claim	:
My justification	:

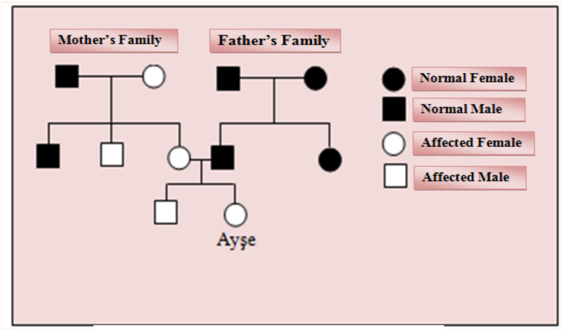
Chromosome can always be seen with a microscope.

True ☐ False ☐

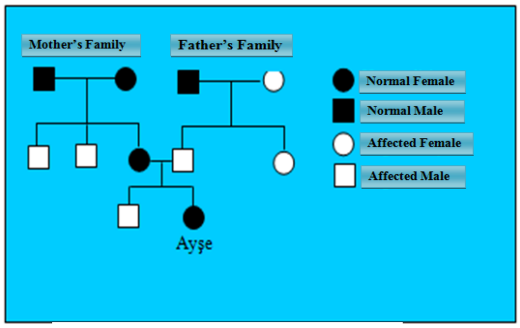
My claim	:
My justification :	

Activity 7: Let's draw İrem's family tree

Family tree is a schematic figure which makes it possible for us to see better the family relations. In family tree different signs are used for male members and female members of the family. Irem, an eighth grade student, was asked by her teacher to prepare a family tree focusing on a disease experienced in the family. She first makes a research about her family past. She learns that both grandfathers and one grandmother of her were color-blind and that her mother has gene for color-blindness. Based on this information Irem draws two family frees on cards with different colors. However, she is not sure about which one is correct.



The Pink Card



The Blue Card

Based on the information given above discuss which family tree is correct.

Theory 1: Family tree on pink card is correct.

Theory 2: Family tree on blue card is correct.

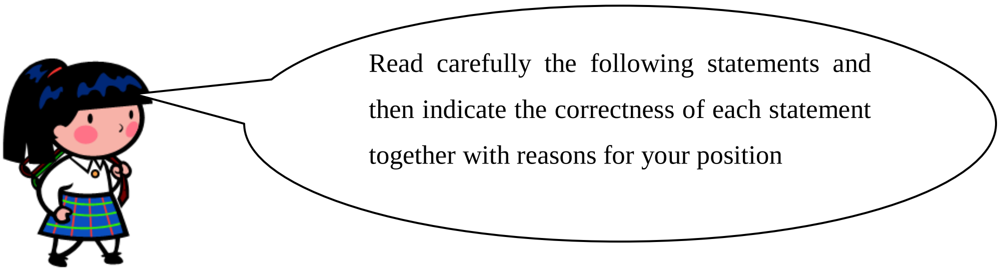
There should be at least one reason for your group to support for your argument.

<u>**Claims/ reasons**</u>

- Given that the mother of her father was color-blind, her father should also be color-blind.
- Gene for color-blindness can be transmitted to female members through their mothers or fathers.
- Given that her father is color-blind, she should also be color-blind.
- Her grandmother on her mother side is color-blindness carrier.
- Given that her mother has gene for color-blindness, she may also be color-blind.
- Color-blindness is a hereditary disease depending on X chromosome.
- Her sister does not get gene for color-blindness from her father.
- Given that the mother and father of her father were color-blind, her aunt is certainly color-blind.

If you have other reasons or evidence, please tell these.

Activity 9: Differences between mitosis and meiosis



Differences between mitosis and meiosis	True	False	Supporting reasons
Mitosis does not provide hereditary diversity.			
During mitosis homologous chromosomes seperate from each other.			
Meiosis provides diversity among living beings.			
Meiosis results in four cells.			
Mitosis consists of two consecutive steps.			
During mitosis parts are exchanged in homologous chromosomes.			
Mitosis results in reproduction in single-celled beings.			
Meiosis occurs in reproduction host cells.			
Sperm, egg and pollen cells are the results of mitosis.			
Mitosis results in two daughter cells which are the exact copies of parent cell.			

JESEH
Journal of Education in Science, Environment and Health
Volume 2, Issue 1, 2016 ISSN: 2149-214X

Enhancing Teacher Beliefs through an Inquiry-Based Professional Development Program

Tammy R. McKeown*, Lisa M. Abrams, Patricia W. Slattum, Suzanne V. Kirk
Virginia Commonwealth University

Abstract

Inquiry-based instructional approaches are an effective means to actively engage students with science content and skills. This article examines the effects of an ongoing professional development program on middle and high school teachers' efficacy beliefs, confidence to teach research concepts and skills, and science content knowledge. Professional development activities included participation in a week long summer academy, designing and implementing inquiry-based lessons within the classroom, examining and reflecting upon practices, and documenting ways in which instruction was modified. Teacher beliefs were assessed at three time points, pre- post- and six months following the summer academy. Results indicate significant gains in reported teaching efficacy, confidence, and content knowledge from pre- to post-test. These gains were maintained at the six month follow-up. Findings across the three different time points suggest that participation in the professional development program strongly influenced participants' fundamental beliefs about their capacity to provide effective instruction in ways that are closely connected to the features of inquiry-based instruction.

Key words: Inquiry-based learning, teacher professional development, diverse student populations, teacher self-efficacy beliefs, science teaching

Introduction

Students in the United States consistently underperform relative to standards which have been set in science education (National Center for Education Statistics, 2012). To promote improved academic performance and achievement in science the Next Generation Science Standards (NGSS), have been developed to provide all students an internationally benchmarked science education. The NGSS essentially raise the performance expectations for what all students in K-12 science classes should know and be able to do. These new standards reflect a higher benchmark for all students by promoting the use of inquiry-based methods when teaching science. The NGSS generally define inquiry in science as a process that requires a wide range of cognitive, social, and physical activities (NGSS, 2013). The implementation of the NGSS demonstrates a fundamental shift from previous National Science Education Standards (NRC, 1996, 2001) in two significant ways: (a) a substantial increase in the level of higher-order thinking skills that all students are expected to master and (b) greater integration of authentic scientific practice with traditional science content (Marshall & Alston, 2014).

The NGSS do not contain a precise definition of inquiry teaching but includes examples that frame inquiry as scientific practices similar to the actual work of scientists (NRC, 2012). Generally, the essential features of inquiry include the learner asking scientific questions, generating hypotheses, collecting data to provide evidence for conclusions and explanations, and communicating findings (NRC, 2001). As a result, Inquiry-based learning is essentially a question-driven approach to teaching and learning that can benefit students in a number of ways including increased engagement in the learning process, enhanced understanding, development of higher-order thinking abilities, and the acquisition of research skills (Spronken-Smith, Bullard, Ray, Roberts, & Keiffer, 2008). Research has found that effective science teachers use features of inquiry-based instruction such as encouraging students to actively participate with ideas and evidence, utilizing challenging curricular tools in order to promote deeper understanding, and fostering an environment in which students investigate and construct their own knowledge (Tyler, 2003). Using inquiry-based teaching and learning techniques in science education allows students to develop important skills such as observing and describing objects and events, formulating research questions, testing hypotheses, collecting data, developing valid explanations, and the ability to communicate findings. This type of student-centered learning allows students to construct their

* Corresponding Author: *Tammy R. McKeown, mckeowntr@vcu.edu*

knowledge and understanding of science concepts with reasoning and higher thinking skills (National Research Council, 1996).

While there is strong evidence that supports the value of inquiry-based science instruction for students from all demographic backgrounds, extant research suggests that creating student-centered knowledge that is applicable to every-day life may be especially advantageous for students with known academic risk factors such as those with low-socio-economic status or English language learners (Lee, Buxton, Lewis, & LeRoy, 2005; Marshall & Alston, 2014). Teaching science in school settings that have larger percentages of English language learners and students from lower socio-economic backgrounds can be difficult since teachers are presented with formidable challenges such as overcrowding, scarce funding and resources, and lack of high-quality science instructional materials (Lee, Buxton, Lewis, & LeRoy, 2005). However, research has shown that students from diverse backgrounds can master complex science concepts when provided with learning opportunities equal to their counterparts with more resources (Lee & Buxton, 2008). In fact, inquiry-based strategies have been shown to reduce the achievement gap of minority students when accompanied with teacher professional development and support from school administrators (Geier et al., 2008). Marshall and Alston (2014) analyzed a professional development project for teachers designed to facilitate more frequent and higher quality use of inquiry-based instruction; improve student achievement in science, and narrow the achievement gap among various student groups. The five-year program, which included more than 10,000 students, found significant gains in achievement on three science tests for all student groups when compared to a comparison group of students of non-participating teachers. Specifically, students of teachers who focused heavily on inquiry-based instruction significantly outperformed similar students in classrooms where teachers used more traditional forms of instruction. In addition to an increase in overall performance for all groups, a narrowing of the achievement gap of minority students compared to Caucasian students was observed, and findings held for female, Hispanic, and black students at all ability levels.

Despite the fact that inquiry-oriented approaches have been shown to be beneficial to student learning, implementing these methods in a classroom setting can be challenging. Encouraging students to pose questions, design experiments, collect data, and draw conclusions has been broadly appealing to teachers, however inquiry-oriented approaches to teaching and learning are demanding because they often require teachers to change their classroom management strategies, as well as how they organize content and assessment procedures. Inquiry methods place additional demands on teachers' subject-matter knowledge, which must be deeper and broader than in traditional passive teaching methods in order to accommodate students' questions and use of research procedures (Fishman, Marx, Best, & Tal, 2003). Effective implementation of the inquiry method can also be difficult because it calls for teachers to understand students' learning styles, plan and use a variety of teaching strategies, and encourage student investigations within a supportive classroom context (Bhattacharyya, Volk, & Lumpe, 2009). Inquiry-based methods also require teachers to assume complex and varied roles. In a case study of a high school biology teacher who successfully implemented inquiry-based instruction in his classroom, Crawford (2000) found that the teacher assumed several nontraditional roles, including that of scientist, innovator, diagnostician, motivator, learner, guide, monitor, mentor and collaborator to support student learning. Crawford asserts that typical teacher education programs do not adequately prepare teachers for these roles and most teachers do not see these types of roles modeled by their peers within school settings.

Given these obstacles, Wallace and Kang (2004) advocate for supportive professional development programs as a means to equip teachers to use inquiry-based strategies and work with students in ways that go beyond the basic notion of teacher as facilitator. In fact, calls for educational reform in general have included promoting high quality professional development as a central component of improving science education (National Commission on Mathematics and Science Teaching, 2000). Research indicates that professional development which focuses on specific instructional practices, such as the use of higher order instructional methods, translates to greater use of these practices in the classroom (Desimone, Porter, Garet, Yoon, & Birman, 2002).

Fishman, Marx, Best, and Tal (2003) maintain that professional development should fundamentally strive to foster changes in knowledge, beliefs, and attitudes of teachers that lead to the acquisition of new skills, new concepts, and new processes related to teaching. They argue that a primary objective of professional development should be to facilitate changes in teachers' knowledge, beliefs, and attitudes, because these components of teacher cognition have shown a strong correlation to teachers' classroom practices. Research on teacher beliefs has been linked to the use of inquiry practice in the classroom. Wallace and Kang's (2004) study of six experienced teachers, revealed that the beliefs teachers held about factors such as school culture, student efficacy, and how students best learn science, influenced the degree of implementation of inquiry and laboratory experiments in their science classrooms.

Fishman, Marx, Best, & Tal (2003) also argue that since teacher beliefs have been shown to have a strong positive correlation to instructional practice, an important goal of professional development should be to influence teacher beliefs. Similarly, Luft and Roehrig (2007) found that teacher beliefs are, in fact, malleable and can change or be modified by external factors, such as professional development. Ballone and Czerniak (2001) posit that research on the role of teacher beliefs is essential for successful science education reform. Consequently, evaluating teacher change as an outcome of professional development, would therefore involve measuring changes in teacher beliefs as well as changes in teacher knowledge and classroom practice (Ballone & Czerniak).

Essential to the development of students' inquiry skills, in addition to pedagogy and teachers' content knowledge, are teachers' personal characteristics and beliefs about science teaching. These beliefs are referred to as science self-efficacy (Haney, Lumpe & Czerniak, 2002). Teacher beliefs, particularly efficacy beliefs, are especially relevant to science teaching when using inquiry methods (Bhattacharyya, Volk & Lumpe, 2009). Self-efficacy refers to one's belief in one's own ability to successfully perform a specific task. Bandura (1994) defined perceived self-efficacy as "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over the events that affect their lives" (p.1). Teacher efficacy is the extent to which teachers believe that they can have a positive impact on student performance (Henson, 2001). Teachers are generally concerned about the adequacy of their professional training as well as their ability to apply new teaching methods. Therefore, training which focuses solely on content knowledge and pedagogy, without aiming to increasing teachers' self-efficacy, is not likely to increase inquiry-based teaching (Bhattacharyya, Volk, & Lumpe, 2009).

Research supports the connection between teachers' self-efficacy and effective classroom practice. The relationship between teacher efficacy and increased student achievement has also been documented (Allinder, 1995; Bruce, Esmonde, Ross, Dookie, & Beatty, 2010). Czerniak and Schriver (1994) found that science teachers with high self-efficacy used a wider variety of instructional strategies as compared with teachers who reported lower levels of efficacy and who relied heavily on didactic teaching methods. Both groups implemented science experiments approximately the same number of times in their classrooms, however the high efficacy group encouraged more discussion with the whole class and with small group of students, as well as before and after the lab experiments. Allinder (1995) found that teachers with higher personal efficacy and higher teaching efficacy set rigorous end-of-year goals for students more often than teachers with lower personal and teaching efficacy. Higher levels of efficacy among teachers were aslo associated with greater growth in student performance than those of low efficacy teachers. Lakshmanan, Heath, Perlmutter, and Elder (2011) contend that understanding and implementing professional development programs which improve teacher self-efficacy can eventually result in improving student achievement.

There have been a number of studies which link teacher efficacy beliefs to classroom practice and student achievement. This paper explores an initial examination of the impact of participation in a teacher professional development program on teachers' beliefs. Specifically, the following research question guided the study design and data collection: What impact does participating in an inquiry-based professional development program have on teacher beliefs?

Project Context

This study was conducted as part of Project CREEST – *Enhancing Clinical Research Education for Science Students and Teachers*. Project CRESST is a multi-year program funded by the National Institutes of Health (NIH) Science Education Partnership Award (SEPA). Broadly, Project CRESST was designed to increase awareness and understanding of how clinical research can contribute to improved public health, specifically improved childhood health. The project includes a week-long professional development program that is supplemented with inquiry-based curricular materials aligned with state and national standards. During the academy middle and high school science and physical education teachers are exposed to the clinical research process through interactions with VCU faculty and investigators conducting ongoing research in childhood obesity, health, and wellness. Participants explore how they can modify their instruction to infuse concepts of clinical research into their curriculum using inquiry-based instructional methods. The professional development program aims to improve teachers' content knowledge and pedagogical skills for teaching research concepts using inquiry-based instructional approaches within a childhood health and wellness content framework. Teachers are invited to participate in the program and complete an application process prior to final selection. Following participating in the week-long professional development program, teachers implement the curriculum and content in their classrooms during the following school year. The project was developed through partnerships among University faculty from multiple units including the Schools of Education, Pharmacy, Medicine and the College of Humanities and Sciences. The project activities and curriculum have been informed by middle and high school teachers, students, and parents.

Teacher Professional Development

Ball and Cohen (1999) created a "practice-based" theory of professional development that emphasizes long-term active engagement, connections between teachers' work and their students' learning, and opportunities to practice and apply what students learn in a real world context. Teacher participants in Project CRESST attend a week-long professional summer academy in which they are engaged in activities that focus on the clinical research process, have authentic experiences with childhood health sciences, and model the CRESST curriculum. The academy, when combined with pre-academy assignments, exposes teachers to over 50 hours of professional development activities. During the academy, teachers develop an instructional plan which encourages reflection and requires teachers to identify how they can re-structure or modify their existing lesson plans to include inquiry activities as well as replace lessons with the curricular tools provided by the project. Consistent with Ball and Cohen's (1999) theory of professional development, the program's curricular activities aim to ultimately increase students' active participation in meaningful, real world research that affects their every-day lives.

Inquiry-Based Curricular Tools

Fishman, Marx, Best, & Tal (2003) maintain that curriculum holds a central place in any model of teacher learning because it embodies what teachers are required to teach in classrooms. They assert that curriculum should play a large role in influencing the kinds of professional development activities that are to be offered. Some researchers have argued that curriculum materials play a significant role in teacher learning because curricular tools themselves are a potential source of professional development (Ball & Cohen, 1996). The concept of professional development that is content-driven and includes opportunities for active engagement and activities aligned with state and national standards has been shown to enhance teachers' knowledge and skills (Garet, Porter, Desimone, Birman, & Yoon, 2001). Similarly, Loucks-Horsley, Hewson, Love and Stiles (1998) identified high quality professional development strategies, one of which is curriculum implementation which involves having teachers use and refine instructional materials in the classroom. Development of the CRESST Curriculum was informed by extant research on inquiry-based tools. The CRESST Curriculum was created prior to the implementation of the summer professional development component of the project and was guided by highly qualified and experienced science and physical education teachers. The curriculum is inquiry-based and aligns with state and national standards. The lessons and suggested activities encourage students to interact with research concepts and the clinical research process in authentic ways. During the summer academy these activities are modeled and participating teachers experience the curricular materials as their students would.

Follow-up Classroom Implementation

Loucks-Horsley, Hewson, Love, and Stiles (1998) maintain that high quality professional development includes activities in which teachers examine practice such as discussion of classroom scenarios or examining actual classroom instruction. Following the CRESST professional development, teachers continue to increase their knowledge of inquiry based methods during the academic year through a series of follow up activities. Throughout this process, teachers are provided with continued support for implementing inquiry-based practices in their classrooms. Follow up activities include designing and implementing inquiry based lessons that reflect techniques and content introduced during the academy. Teachers also examine their classroom practices, document ways in which they modify their instruction, reflect on how students respond to the inquiry based lessons, and identify opportunities for cross-disciplinary as well as interdepartmental collaborations.

Methods

Participants

This study involved 72 middle and high school teachers who participated in Project CRESST. The teachers represent diverse school settings and student populations as well as science and health content areas. As shown in Table 1, participants taught in urban (18%), suburban (44%) and rural (38%) school districts in a south eastern state in the US. They had an average of 14 years of teaching experience, with a range of 1-38 years, and taught in traditional and alternative school settings (see Table 1).

Table 1. Demographic information for teacher participants

Characteristics	*N*	%
Teaching Experience (years)		
Mean	14	--
Range	1 - 38	--
Grade Currently Teaching		
Middle School	44	61
High School	28	39
School Setting		
Urban	13	18
Suburban	32	44
Rural	27	38
Content Area		
Physical Education	20	28
Life Science	14	19
Physical Science	13	18
Earth Science	5	7
Biology	15	21
Chemistry	4	6
Physics	1	1
Ethnicity		
African American	9	13
Asian	2	3
Caucasian	61	88
Gender		
Male	14	19
Female	58	81

Note: Total $N = 72$

Research Design

In order to examine the research question posed for this study, a pre-post follow-up design was employed. Participants completed a pre-survey prior to attending the summer academy and a post-survey at completion of the program. Participants were then administered a follow-up survey approximately six months after the academy to determine if any of the pre- to post-test differences were maintained over the school year.

Data Sources

Teacher Self-Report Measures

Participating teachers complete pre-, post- and follow-up surveys which were developed from existing measures. The surveys contained items from the Teachers' Efficacy Beliefs System-Self (TEBS-Self; Dellinger, Bobbett, Oliver, & Ellett, 2008) as well as the Self-Efficacy Teaching and Knowledge Instrument for Science Teachers-Revised (SETAKIST-R; Pruski et al., 2013). The TEBS-Self measures teachers' beliefs about their abilities to successfully perform specific teaching and learning tasks within their classrooms. Respondents select from a four-point, Likert-type response scale ranging from "weak" to "very strong beliefs in my capabilities". The instrument contains 31 items which measures six subscales – accommodating individual differences (AID), maintaining positive classroom climate (PCC), monitoring and feedback for learning (MFL), managing learning routines (MLR), motivating students (MS), and higher-order thinking skills (HOTS).

The SETAKIST-R (Pruski et al., 2013) measures efficacy and knowledge beliefs related to teaching research concepts. The measure includes 16 items and participants select from a five-point response scale ranging from "strongly disagree" to "strongly agree" with mean values approaching five, indicating high levels of efficacy and knowledge. In addition to items from the TEBS-Self and SETAKIST-R, several items were developed to measure teachers' confidence in teaching research concepts using inquiry-based methods. Respondents selected from a five-point, Likert-type response scale ranging from "not confident" to "very confident" with mean values approaching five indicating higher levels of confidence. The surveys included several open-ended questions in addition to the select-response items. These questions were designed to enhance the quantitative items in attempting to ascertain how participation in the academy supported teaching (Greene, Caracelli, & Graham, 1989). The quantitative measures provided information concerning patterns and trends within the data, while the open-ended items allowed for a more detailed analysis of individual teacher data.

Data Analyses

The data for this study were analyzed in three steps. First, in order to examine differences between mean scores for efficacy and confidence items, a RM-ANOVA was performed across two time points (pre- and post-) for all four cohorts. Second, to determine if significant mean differences on the efficacy and confidence scales were present across three time points (pre-, post-, follow-up) a repeated-measures ANOVA (RM-ANOVA) was conducted for teachers who participated in the first three years of the project ($n = 23$) as follow-up surveys have not yet been administered to the most recent Project CRESST cohort of teachers. If significant mean differences were found, post hoc comparisons were conducted utilizing Bonferroni tests. Last, teachers' narrative responses were examined using thematic analysis to supplement the findings of the quantitative survey results.

Results

Quantitative Findings

Self-Efficacy

Statistical analyses were conducted using SPSS in order to compare the mean differences between pre- and post-test items related to teacher self-efficacy. The RM-ANOVA for cohorts one through four revealed significant change in overall efficacy scores from pre- to post- test, $F(1, 62) = 39.97$, $p < .001$ (see Table 2). Composite variables on the TEBS-Self subscales were computed and exhibited reliability estimates ranging from .66 to .92.

Table 2. Repeated measures analysis of variance for efficacy beliefs
(Cohorts 1 – 4, N = 63)

Effect	*MS*	*df*	*F*	*P*
Time x TEBS-Self	2.47	1	39.97	<.001
Time x AID	3.30	1	42.32	<.001
Time x PCC	1.24	1	12.16	.001
Time x MFL	2.24	1	16.91	<.001
Time x MLR	2.82	1	19.09	<.001
Time x HOTS	4.73	1	21.97	<.001
Time x MS	2.25	1	17.10	<.001

The RM-ANOVA for cohorts one through three revealed significant change in overall efficacy scores across time as measured by the TEBS-Self, F (2, 22) = 16.52, p < .001. Post hoc analysis using the Bonferroni test revealed that teacher efficacy increased significantly from pre- to post-test (p = .002). Self-efficacy scores, however, did not differ significantly from post- to follow-up test, indicating that teachers' increased sense of efficacy had not diminished over time. Significant changes were also indicated on each of the six efficacy components within the TEBS-Self as shown in Tables 3 and 4.

Table 3. Univariate statistics for efficacy beliefs

	Means		
Construct	T1 (*n*)	T2 (*n*)	T3 (*n*)
TEBS-Self	2.82 (63)	3.15 (63)	3.30 (23)
AID	2.63 (63)	2.96 (63)	3.15 (23)
PCC	3.05 (63)	3.25 (63)	3.32 (23)
MFL	2.84 (63)	3.11 (63)	3.18 (23)
MLR	2.89 (63)	3.19 (63)	3.28 (23)
HOTS	2.44 (63)	2.83 (63)	2.97 (22)
MS	2.90 (63)	3.17 (63)	3.24 (22)

Table 4. Repeated measures analysis of variance for efficacy beliefs
(Cohorts 1 – 3, N = 23)

Effect	*MS*	*df*	*F*	*P*
Time x TEBS-Self	1.41	2	16.52	<.001
Time x AID	2.10	2	15.67	<.001
Time x PCC	0.49	2	5.15	.01
Time x MFL	1.41	2	11.57	<.001
Time x MLR	0.89	2	4.51	.02
Time x HOTS	2.07	2	6.88	.004
Time x MS	0.60	2	3.55	.045

Teaching Research Content and Skills

Of the 15 items adapted from the SETAKIST-R, seven indicated significant increases in teachers' self-efficacy and knowledge beliefs for teaching research concepts (see Tables 5, 6, and 7). For example, the mean response to "I know how to teach important research-related concepts effectively" increased across time for cohorts one through three, F (2, 21) = 22.15, p < .001. Similar to other survey results, the increased item-level means were maintained at follow-up as evidenced by the lack of statistically significant mean differences from post-test to follow-up. Scores from this item also increased significantly from pre- to post- test for all four cohorts F (1, 61) = 31.96, p < .00. An additional example includes responses to "I understand research concepts well enough to teach this content" in which mean responses increased significantly across time for cohorts one through three, F (2, 21) = 15.71, p < .001. Increased item-level means for this item were maintained at follow-up. Scores from this item also increased significantly from pre- to post- test for all four cohorts F (1, 62) = 31.71, p < .00.

A single composite variable (α = .91) was created from items developed to measure teachers' confidence in teaching research concepts using inquiry-based methods. Analyses of the pre- and post- survey results for cohorts one through four indicate that participation in the summer professional development enhanced teachers' reported levels of confidence in their abilities to teach research concepts and skills.

Table 5. Repeated measures analysis of variance for items related to teaching research concepts *(Cohorts 1 – 4, N = 63)*

Effect	*MS*	*df*	*F*	*p*
Time x I do not feel I have the necessary skills to teach about research.	7.25	1	19.47	<.001
Time x Even when I try very hard, I do not teach research content as well as I would like.	9.32	1	3.76	.007
Time x I know how to teach important research-related concepts effectively.	16.33	1	31.96	<.001
Time x I find it difficult to explain to students why experiments work.	8.78	1	12.54	.001
Time x I understand research concepts well enough to teach this content.	16.07	1	31.71	<.001
Time x I know how to make students interested in conducting research.	13.34	1	32.88	<.001
Time x I wish I had a better understanding of the research concepts I teach.	29.53	1	37.39	<.001
Time x Confidence in teaching research concepts subscale	23.66	1	65.67	<.001

There was a significant change in confidence scores for cohorts one through three across time, F (2, 21) = 22.36, $p < .001$ (see Tables 3 and 4). Bonferroni post hoc tests indicated a significant increase in teachers' confidence scores from pre- to post-test ($p < .001$). Similar to the self-efficacy scores, there was no significant change in confidence scores from post-test to follow-up ($p = .348$), indicating that the increase in teachers' confidence maintained throughout the school year. Confidence scores for all four cohorts also indicate significant change from pre- to post-test F (1, 62) = 65.67, $p < .001$ (see Tables 5, 6, and 7).

Table 6. Univariate statistics for items related to teaching research concepts

	Means		
Group	T1(*n*)	T2 (*n*)	T3 (*n*)
I do not feel I have the necessary skills to teach about research.	2.32 (62)	1.84 (62)	1.77 (22)
Even when I try very hard, I do not teach research content as well as I would like.	3.26 (62)	2.71 (62)	2.41 (22)
I know how to teach important research-related concepts effectively.	3.08 (62)	3.81 (62)	4.14 (22)
I find it difficult to explain to students why experiments work.	2.55 (62)	2.02 (62)	1.82 (22)
I understand research concepts well enough to teach this content.	3.37 (63)	4.08 (63)	4.18 (22)
I know how to make students interested in conducting research.	3.19 (63)	3.84 (63)	3.73(22)
I wish I had a better understanding of the research concepts I teach.	3.76 (63)	2.79 (63)	2.27 (22)
Confidence in teaching research concepts subscale	3.04 (63)	3.92 (63)	3.93 (22)

Table 7. Repeated measures analysis of variance for items related to teaching research concepts *(Cohorts 1 – 3, N = 22)*

Effect	*MS*	*df*	*F*	*p*
Time x I do not feel I have the necessary skills to teach about research.	1.88	2	3.90	.028
Time x Even when I try very hard, I do not teach research content as well as I would like.	3.74	2	3.76	.032
Time x I know how to teach important research-related concepts effectively.	8.94	1.57	22.15	<.001
Time x I find it difficult to explain to students why experiments work.	7.39	1.19	7.91	.001
Time x I understand research concepts well enough to teach this content.	6.38	1.30	15.71	<.001
Time x I know how to make students interested in conducting research.	4.29	2	13.42	<.001
Time x I wish I had a better understanding of the research concepts I teach.	14.74	2	15.54	<.001
Time x Confidence in teaching research concepts subscale	9.24	1.45	22.36	<.001

Narrative Survey Response Findings

Data from open ended comments on follow-up surveys further enhance findings from the self-report surveys. Selected comments reflect increase confidence, content knowledge, implementation of inquiry-based activities, and collaborative efforts. Comments selected for inclusion are exemplars that represent teacher responses.

Participants expressed feeling more confident as a result of their participation in the program. Responses included:

- "I feel more confident in my field and I feel it helped me to want to introduce different types of lessons into my curriculum and lesson planning."
- "[participation] made me a better teacher, it taught me to use more inquiry-based instruction than the typical cookie cutter models."
- "[I am now] more knowledgeable, flexible and creative.
- "I feel more comfortable talking with parents and students about science related topics, questions, and concerns."

Teachers indicated having a better understanding of how to implement inquiry-based lessons.

- "I completely changed how I taught a Biochemistry unit. Year after year, students would struggle with the concepts taught in this unit. However, the labs and materials that were presented to me allowed me the opportunity to be able to teach the concepts in a more hands-on environment. I saw much more success."
- "My participation in CRESST afforded me a learning opportunity, materials, and lesson plans to implement inquiry-based learning activities with my students, especially during the first 9 weeks. It proved to be a great way to motivate all students…"
- "[attending the academy] opened my eyes to new concepts and new ways of approaching lessons."

- “Participating in the Academy gave me an introduction to teaching research concepts and techniques in which to apply and implement research concepts and inquiry-based learning.”

Teachers also reflected on how their participation in the program resulted in increased collaborative efforts to implement inquiry-based methods.

- “[participation] broadened my knowledge base and allowed me to give and receive teaching ideas among colleagues that I would've never had the opportunity to collaborate with.”

- “I had wonderful exposure to teachers across the state who are doing great things with their students. It was so motivating to me as a new teacher with the Middle School students! I learned a lot from the Academy experience and eagerly shared these tools with other Life Science teachers as we implemented some of the CRESST activities throughout the year.”

- “…[I shared] the CRESST Curriculum with two other 7th grade Life Science teachers [in my school]. Throughout the remainder of the year, my colleagues and I focused on providing our students with additional inquiry-based activities, influenced by the CRESST activities. It was a great collaborative effort between Life Science and the Physical Ed classes!”

Discussion and Conclusion

This paper captures a first look at the impact of participation in a teacher development program on teachers’ beliefs related to self-efficacy to deliver effective instruction within the classroom context and confidence in their abilities to teach complex research content and skills using inquiry-based instructional approaches. Holding positive beliefs about their own capacity is a perquisite or stepping stone for effective change in instructional practices that apply and integrate more complex teaching strategies. The ability to affect change in teacher beliefs provides a strong foundation for the promise of a comprehensive teacher development program designed to support teachers’ development and use of inquiry in their practice. Ballone and Czerniak (2001) highlight the need for profession development programs to evaluate changes in teacher beliefs as an important outcome. As noted by Riggs (1995), higher levels of self-efficacy among science teachers have been associated with greater use of authentic and inquiry-based strategies. The results of the three administrations of the Teachers’ Efficacy Beliefs System-Self (TEBS-Self; Dellinger, Bobbett, Oliver, & Ellett, 2008) demonstrate favorable trends regarding the positive impact of the Project CRESST program. As described, the TEBS-Self was administered prior to the week-long professional development experience, immediately following the completion of the summer program, and again roughly six months following the summer program. These three administration time points allowed us to determine the immediate impact of participation on teachers’ reported levels of efficacy as well as the longer-term influence on participation.

The results indicate that teachers reported statistically significant gains across all of the subscales comprising the TEBS-Self at post-test. These data suggest the promising range of the CRESST professional development program to influence a variety of areas related to teaching and the classroom context in which teaching occurs. For example, significant efficacy gains were evident for teachers’ abilities to accommodate individual learning differences in their classroom, including planning for differentiated instruction, providing accommodations to meet the individual needs of students, and develop appropriate evaluation procedures tailored to individual students. These data suggest that the CRESST program was able to foster greater efficacy among teacher participants to provide more flexible and individualized instruction that relied on multiple teaching methods and materials. These changes in efficacy are closely associated with the essential features of inquiry-based instruction that involve supporting students to conduct scientific inquiries of their own questions using data as evidence to draw conclusions and answer initial questions (Crawford, 2000; NRC, 1996).

Among these findings related to teachers’ efficacy, teachers demonstrate improved capacity to promote and encourage higher-order thinking skills (HOTS). For example, items comprising the TEBS-Self HOTS subscale indicate that teachers reported feeling more efficacious with regard to actively involving students in instruction, soliciting questions, engaging students in critical analysis and/or problem solving. These demanding cognitive skills and process are closely aligned to the level of complex thinking and mental processes characteristics of conducting scientific inquiry or “thinking like a scientist.” Similarly, inquiry-based approaches may involve students working in ways that are similar to scientists as they conduct experiments and investigations working in small groups or teams of students. The efficacy results point to teachers’ increased abilities to foster collaboration in the classroom and to maintain a climate in which students are highly engaged and one that reflects a culture of courtesy and respect.

Most encouraging about the study findings is that teachers' reported high levels of efficacy as measured by the TEBS-Self maintained over the course of the academic year. These results suggest that the shift in teachers' belief systems evident immediately following participation in the CRESST professional development program continued at the same level throughout the school year. When the efficacy data are considered in relation to the characteristics of inquiry-based instruction, these initial findings are noteworthy and suggest the professional development program was effective in fostering long-term changes in teachers' beliefs in ways that are closely aligned with the implementation of inquiry-based instruction. The beliefs are also consistent with the new policies and standards for science education outlined in the Next Generation Science Standards, suggesting that participating teachers will be well-positioned to enact the reform-based instruction in their classrooms and may do so in ways that help to reduce existing disparities or achievement gaps that persist among minority student populations (Geier et al., 2008; Marshall and Alston, 2014).

In addition to efficacy beliefs, this study also examined teachers' general knowledge of research concepts as well as their confidence to teach research content and skills. The patterns in the confidence survey results are similar to those of the efficacy data. Statistically significant gains were evident between teachers' pre- and post-survey responses. The results indicated that teachers' reported greater levels of confidence in a variety of activities related to scientific investigations. For example, gains were evident for confidence in encouraging student interest in inquiry and ability to engage them in inquiry-oriented as well as hands-on activities. Closely related to these results are teachers' heightened levels of content knowledge and expertise to provide instruction of research content. These data demonstrate a greater comfort and confidence with teaching inquiry-related material. The reported gains in content knowledge confidence were maintained over the course of the following school year. These results complement the efficacy findings, and demonstrate a comprehensive shift in teacher beliefs across multiple and closely related areas – efficacy, content knowledge related to inquiry, and confidence. Such beliefs are closely linked to the essential features of effective implementation of inquiry-based instruction and may enable teachers to overcome the barriers associated with teaching science using this approach, such as lack of knowledge and experience with inquiry (Blanchard, Southerland & Granger, 2009).

The findings of this initial study demonstrate the promise of a professional development program that combines features known to be effective based on the literature with a sustained follow-up and continuous support. According to Capps, Crawford, and Constas' (2012) synthesis of the literature on general teacher professional development as well as professional development specific to inquiry-based instruction, the CRESST program exhibits many salient characteristics. These characteristics include: sufficient time for teachers to learn the material; support beyond the initial professional development workshop or experience; materials aligned to state and national content standards; opportunities to experience and participate in inquiry-based activities as learners; time for reflection; and support to apply what was learned in the professional development program to individual teachers' classrooms (Capps &Crawford, 2012). The survey data suggest that when best-practices in professional development are at the core of a teacher development program, profound changes in teachers' beliefs systems can occur. The survey efficacy, confidence, and content knowledge results over three different time points suggest that participation in CRESST strongly influenced teachers' fundamental beliefs about their capacity to provide effective instruction in ways that are closely connected to the features of inquiry-based instruction.

These data should be considered with the limitations of self-report survey data. Further study of the Project CRESST professional development program is needed to examine teachers' actual classroom practice and the extent to which the survey findings are consistent with direct measures of inquiry implementation. Capps and Crawford (2012) conducted a mixed-methods study of teachers' inquiry practice and found teachers' demonstrated a variety of inquiry-based practices and there was little evidence of implementing inquiry "beyond simple process skills and at times, the collection of data" (p. 520). They also concluded that many teachers believed that they were teaching in ways consistent with inquiry but were not doing so in actual practice.

Recommendations

Based on the findings of this study there are several recommendations that may inform teacher development practice as well as further research on professional development programs that are focused on inquiry-based instruction in particular. The study findings are positive and demonstrate the potential of a professional development program that when aligned with best practice can effect long-term change in teachers' beliefs systems. Concerted efforts to construct professional development programs in ways that are evidenced-based are an essential feature of effective and meaningful teacher professional development. In addition, a methodological strength of the present study was the use of survey measures aligned to features of inquiry. This approach further enhanced the nature of the conclusions drawn from the study and linked connections between changes in teachers' efficacy levels and the potential for implementing inquiry-based instruction. Similarly, these initial findings were strengthened by the use of other measures to examine complementary constructs that when considered in combination presented a robust picture of the change in teachers' beliefs. Developing an evaluation or research design in concert with the core components of the professional development programs will enable practitioners to further advance the field of professional development as well as address the critical need to support teachers' implementation of reform-based science teaching.

Acknowledgements

This material is based upon work supported by the National Institutes of Health under the Science Education Partnership Award No. R25 OD010983-03. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NIH.

References

Allinder, R.M. (1995). An examination of the relationship between teacher efficacy and curriculum-based measurement and student achievement. *Remedial and Special Education*, 16, 247-254.

Ball, D.L., & Cohen, D.K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher*, 25(9), 6-8.

Ball, D.L., & Cohen, D.K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In G. Sykes and L. Darling Hammond (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 3-32). San Francisco: Josey Bass.

Ballone, L.M., & Czerniak, C.M. (2001). Teachers' beliefs about accommodating students' learning styles in science classes. *Electronic Journal of Science Education*, 6(2), 1-43.

Bandura, A. (1994). Self-efficacy. In V.S. Ramachaudran (ed.), *Encyclopedia of human behavior* (vol. 4). New York: Academic Press.

Bhattacharyya, S., Volk, T., & Lumpe, A. (2009). The influence of an extensive inquiry-based field experience on pre-service elementary student teachers' science teaching beliefs. *Journal of Science Teacher Education*, 20, 199-218.

Blanchard, M.R., Southerland, S.A., & Granger, E.M. (2009). No silver bullet for inquiry: Making sense of teacher change following an inquiry-based research experience for teachers. *Science Education, 93*(2), 322-360.

Bruce, C.D., Esmonde, I., Ross, J., Dookie, L., & Beatty, R. (2010). The effects of sustained classroom-embedded teacher professional learning on teacher efficacy and related student achievement. *Teaching and Teacher Education*, 26(8), 1598-1608.

Capps, D.K. & Crawford, B.A. (2013). Inquiry-based professional development: What does it take to support teachers in learning about inquiry and science? *International Journal of Science Education*, *35*(12), 1947-1978.

Capps, D.K., Crawford, B.A., & Constas, M.A. (2012). A review of the empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education*, *23*(3), 291-318.

Crawford, B.A. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching*, 37,916-937.

Czerniak, C.M., & Schriver, M. (1994). An examination of preservice science teachers' beliefs and behaviors as related to self-efficacy. *Journal of Science Teacher Education*, 5(3), 77-86.

Dellinger, A.B., Bobbett, J.J., Olivier, D.F., & Ellett, C.D. (2008). Measuring teachers' self-efficacy beliefs: Development and use of the TEBS-Self. *Teaching and Teacher Education, 24,* 751-766.

Desimone, L.M., Porter, A.C., Garet, M.S., Yoon, K.S., & Birman, B.F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis*, 24(2), 81-112.

Fishman, B.J., Marx, R.W., Best, S., Tal, R.T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education*, 19, 643-658.

Garet, M., Porter A., Desimone L., Birman B., & Yoon K. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal,* 38, 915-946.

Geier, R., Blumenfeld, P.C., Marx, R.W., Krajcik, J.S., Fishman, B., Soloway, E., & Clay-Chamber, J. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching*, 45, 922-939.

Greene, J.C., Caracelli, V.J., & Graham, W.F. (1980). Toward a conceptual framework for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis*, 11, 255-274.

Haney, J.J., Lumpe, A.T., & Czerniak, C.M. (2002). From beliefs to actions: The beliefs and actions of teachers implementing change. *Journal of Science Teacher Education*, 13(3), 171-187.

Henson, R.K. (2001). The effects of participation in teacher research on teacher efficacy. *Teaching and Teacher education*, 17, 819-836.

Lakshmanan, A., Heath, B.P., Perlmutter, A., & Elder, M. (2011). The impact of science content and professional learning communities on science teaching efficacy and standards-based instruction. *Journal of Research in Science Teaching*, 48(5), 534-551.

Lee, O., & Buxton, C. (2008). Science curriculum and student diversity: A framework for equitable learning outcomes. *The Elementary School Journal*, 109(2), 123-137.

Lee, O., Buxton, C., Lewis, S., & LeRoy, K. (2005). Science inquiry and student diversity: Enhanced abilities and continuing difficulties after and instructional intervention. *Journal of Research in Science Teaching*, 43(7), 607-636.

Loucks-Horsley, S. Hewson, P.W., Love, N., & Stiles, K.E. (1998). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

Luft, J.A., & Roehrig, G.H. (2007). Capturing science teachers' epistemological beliefs: The development of the Teacher Beliefs Interview, *Electronic Journal of Science Education*, 11(2), 38-63.

Marshall, J.C., & Alston, D.M. (2014). Effective, sustained inquiry-based instruction promotes higher science proficiency among all groups: A 5-year analysis. *Journal of Science Teacher Education*. 25, 807-821.

National Center for Education Statistics. (2012). *The nation's report card: science 2011* (NCES 2012-465).Institute of Education Sciences, U.S. Department of Education, Washington, D.C.

National Commission on Mathematics and Science Teaching. (2000). *Before it's too late: A report to the nation from the national commission on mathematics and science teaching for the 21st century*. Washington, D.C: Author.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council, (2001). *Inquiry and the national science education standards*. Washington, DC: National Academies Press.

National Research Council, (2012). *A framework for K-12 science education: Practices, crosscutting, concepts, and core ideas*. Washington, DC: The National Academies Press.

National Research Council (Ed.). (1996). *National science education standards*. National Academy Press.

NGSS Lead States (2013). Next generation science standards: For states, by states. Washington, DC:The National Academies Press.

Pruski, L.A., Blanco, S.L., Riggs, R.A., Grimes, K.K., Fordtran, C.W., Barbola, G.M., & Cornell, J.E. (2013). Construct validation of the Self-Efficacy Teaching and Knowledge Instrument for Science Teachers-Revised (SETAKIST-R): Lessons learned. *Journal of Science Teacher Education*, *24*(4), 1133-1156.

Riggs, I. (1995, April). *The characteristics of high and low efficacy elementary teachers*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco.

Spronken-Smith, R., Bullard, J., Ray, W., Roberts, C., & Keiffer, A. (2008). Where might sand dunes be on Mars? Engaging students through inquiry –based learning in geography. *Journal of Geography in Higher Education*, 32(1), 71-86.

Tyler, R. (2003). A window for a purpose: Developing a framework for describing effective science teaching and learning. *Research in Science Education*, 33, 273-298.

Wallace, C.S., & Kang, N. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching*, 41,936-960.