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Email: jesehoffice@gmail.com
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CONTENTS

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A Study on Using Hands-on Science Inquiries to Promote the Geology Learning of Preservice Teachers

Ching-San Lai[1*]
[1]National Taipei University of Education

Abstract

This study aims to investigate the geology learning performance of preservice teachers. A total of 31 sophomores (including 11 preservice teachers) from an educational university in Taiwan participated in this study. The course arrangements include class teaching and hands-on science inquiry activities. The study searches both quantitative and qualitative data as the sources for the analyses. The quantitative data are taken from the results of four specimen identification tests; the respondents are required to take a pre-test before teaching and then practice the explorative hands-on science activities. Afterwards, the scores of test results are used as the foundation of the analyses. The qualitative data are the feedback from the preservice teachers in the study. The research results show the results of the four post-tests are significantly better than those of the four pre-test scores, indicating the preservice teachers' concepts of minerals and rocks significantly improved. The analysis of the qualitative data also found the preservice teachers demonstrate a good understanding on geology content during geological inquiries. According to the research results, this study believes the cultivation of and training in hands-on geology inquiries can actually enhance preservice teachers' learning performances in geology.

Key words: Geology, Geoscience education, Hands-on science inquiry, Science learning, Science teacher education

Introduction

The 21st century is an age of knowledge. In such a knowledge-based economy, knowledge has evolved into a kind of productivity and competitiveness. More and more attention is now being given to how to enhance the advantages and competitiveness of a knowledge-based economy and how to strengthen the professional development of preservice teachers in colleges. With respect to the standards required for the professional development of science teachers, the National Research Council (1996) pointed out science teachers must meet the following requirements, including: (1) Teachers of science must learn essential science content through the perspectives and methods of inquiry. (2) Teachers of science must integrate knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching. (3) Teachers of science must build understanding and the ability for lifelong learning. To summarize, substantial scientific knowledge is the first step in the professional development of science teachers. It is also the basic task for teacher preparation of preservice teachers.

Second, with respect to hands-on science inquiries, the National Research Council (2000) also emphasized the use of inquiry as the main strategy when delivering science content. Li, Yang, and Chung (2009) pointed out during a scientific inquiry, scientists can continue to raise questions from curiosity, and then use scientific methods to solve these questions. When solving questions, they will develop many ingenious ways of thinking. A hands-on science inquiry usually contains four major steps: (1) Observation: observation is the process of using one or a variety of sensory organs and instruments to acquire information from the environment. All kinds of questions come from observations. Observational results can be qualitative or quantitative. A qualitative observation does not contain figures, while a quantitative observation contains both figures and units. (2) Hypotheses and deductions: hypotheses are explanations given by scientists to observational results. One observed phenomena may have different hypotheses. These can either be correct or false. Deductions refer to the conclusions reached by logical thinking and are based on existing information. They can either be correct or false. (3) Predictions: predictions mean scientists use their imagination to predict possible results based on hypotheses and deductions. Predictions can either be correct or false. And (4) Experiment and verification:[*]

[*] *Corresponding author: clai@tea.ntue.edu.tw*

Scientists collect new information using observations or experiments to confirm whether hypotheses are proper or that their predictions are correct. In other words, scientists use the new information obtained from observations or experiments to confirm the correctness of their hypotheses and predictions. Therefore, when assisting science teachers to obtain substantial scientific knowledge, we must teach them to have good hands-on science inquiry skills.

The geology curriculum in college is an important professional curriculum for preservice science teachers, and the professional development of such teachers has a crucial influence on the science education in primary schools in the future. To promote the innovative effects of science and technology curriculums and the teaching in primary schools in Taiwan, and to foster qualified citizens in the 21st century, we need to continuously strengthen the efficiency of the training of science teachers, and enhance the career development of preservice teachers (in colleges) of primary schools. This will help to continue to enhance the learning outcomes of primary school students in the fields of science and technology.

Therefore, to enhance the efficiency of preservice teachers in science teaching, it is necessary to explore the professional abilities of preservice teachers in colleges with regards to science, and to establish a superior support system for their professional development. This will help guarantee the sufficient and necessary assistance and support for preservice teachers to acquire professional abilities in science, enable their professional development in science, and enhance the professional qualities of preservice primary school science teachers in Taiwan. They will then be able to thoroughly adapt to the new educational environment of the 21st century, which is a technological, informative, and knowledge-based economy, to achieve the goal of cultivating sound citizens for the new century.

Targeting the implementation of the geology curriculum in colleges, the study aims to investigate the learning performances of preservice teachers in colleges using hands-on science inquiry strategies and schemes. The research emphasis is to complete a hands-on science inquiry scheme by establishing the content and a model for the professional development of a geology curriculum in colleges, thus promoting the professional growth of preservice teachers' knowledge and skills in geology, and achieving the goal of enhancing the science teaching effects of primary schools.

Literature Review

Geoscience education

The curriculum and instruction of geology is generally called geoscience education at the stage of college education, and its main scope of exploration is the geosphere in the Earth system. King (2008) pointed out geoscience education focuses on cultivating learners' understanding of Earth materials, the effects of Earth activities, and Earth structure, etc.

Second, in elementary education in Taiwan, the curriculum and instruction of geology is generally included in the fields of science and technology, and the main content includes the educational connotations of the Earth system science. Dal (2009) further pointed out the core content of Earth system science education should contain discussions on the following four themes, including: (1) the structure of the Earth, (2) the dynamic evolutionary mechanism of every earth shell, (3) the role and the movement of the Earth in the planetary system, and (4) organisms on Earth.

With respect to the curriculum and content of geology, among the major items in the field of science and technology in the primary school Grade 1-9 curriculum in Taiwan, sub-themes on geology explore the substances that compose the Earth, and changes in the Earth's surface and crust, stratums and fossils, etc. (The Ministry of Education, 2008). After further examination of the learning content of geology in primary schools, it is discovered the main content includes the observation, inquiry, and appreciation of minerals, rocks, changes in the Earth's surface and crust, natural resources and energies, etc. This geological content is exactly the knowledge that primary school teachers should possess for the teaching of science and technology. Consequently, when this study discusses the professional development and knowledge ability of geology for preservice teachers in colleges, the discipline and concepts are mainly concerned with "minerals, rocks, and changes in the Earth's surface and crust".

Learning and teaching strategies of geology

According to the above, the learning content of the geology curriculum is mainly concerned with the observation, inquiry, and appreciation of minerals, rocks, and changes in the Earth's surface and crust. However, for students, the learning strategy for geology should not focus only on memorizing and reciting facts. They need to learn geology through scientific inquiry (Apedoe, 2008; National Research Council, 2000; The Ministry of Education, 2008). With respect to the cultivation of the ability for inquiry regarding geology, both Apedoe (2008) and the National Research Council (2000) emphasized strengthening learners' experiences and learning in the following five inquiry processes: (1) critical issues in applying science, (2) finding and proposing evidence, (3) using evidence to develop explanations that answer key scientific problems, (4) assessing explanations, and (5) communicating and debating the explanations.

However, many researchers have discovered students have several misconceptions about geology. These include: (1) the misconception of minerals, rocks, and fossils (Dal, 2009; Dove, 1997, 1998; Ford, 2005; Happs, 1982, 1985; Kusnick, 2002; Russell, Bell, Longden, & McGigan, 1993; Sharp, Mackintosh, & Seedhouse, 1995); (2) misconceptions of geological processes and time (Dal, 2005, 2007, 2009; Trend, 1998, 2000, 2001; Zen, 2001); (3) misconceptions of earthquakes, plate tectonics, and the structure of the Earth (Barrow & Haskins, 1996; Kali & Orion, 1996; Lillo, 1994; Marques & Thompson, 1997; Rutin & Sofer, 2007; Sneider & Ohadi, 1998); and (4) misconceptions of the water cycle (Asarraf & Orion, 2009; Bar, 1989; Kali, Orion, & Eylon, 2003). Consequently, an important topic for the geology curriculum and instruction is how to find ways to correct students' misconceptions, and establish the correct understanding of geological processes and phenomena.

To improve the students' learning regarding the concepts of different units of geology, and reduce their misconceptions of geology, many researchers have proposed different teaching methods and strategies, and such teaching has demonstrated good results (Allison, 2005; Bereki, 2000; Constantopoulos, 1994; Gibson, 2001; Kali, Orion, & Eylon, 2003; Veal & Chandler, 2008; Wellner, 1997).

With respect to mineral-themed study, Constantopoulos (1994) discovered using a jigsaw cooperative learning approach to guide students when learning about minerals could increase their mineralogy scores, class participation, learning motivation, and learning enthusiasm. Additionally, Gibson (2001) used models to create learning activities to guide students on how to conduct inquiry learning in respect to rocks and minerals. The study results show specific operations and the model inquiries for mineral crystals and rocks can increase students' recognition and understanding of rocks and minerals, and improve their ability to identify the different features of rocks and minerals. With respect to the recognition and identification of minerals, Allison (2005) pointed out adopting optimal and sub-optimal learning models of inquiry had better learning outcomes than that of mechanically memorizing the seven major features of minerals. The study results show both learning effects and the interest of students who adopt optimal and sub-optimal leaning models of inquiry are significantly improved.

With respect to the inquiry into rocks and stratums, Wellner (1997) used a spatial model of a topographic map to teach the formation of stratums. The study results show such a teaching activity contributes to students' understanding of the concepts and formation process of stratums. Second, Bereki (2000) used specimens of sedimentary rocks, metamorphic rocks, and igneous rocks to conduct a hands-on inquiry of the rock cycle. The study results show hands-on observation, inquiry, and experience can effectively promote students' understanding of the concept of the rock cycle. Additionally, the study by Kali, Orion, and Eylon (2003) discovered knowledge integration activities could effectively promote students' learning achievements in respect of the rock cycle.

Further, Veal & Chandler (2008) also pointed out the substation learning approach to science was beneficial to the understanding of the rock cycle, and training in substation science inquiries could enhance the students' skills regarding scientific inquiries in rocks. Apedoe (2008) conducted learning programs using geological experiments, and used a supportive guidance strategy for teachers and assistants. The study results show it benefits the development of students' experimental inquiry skills and their geological concepts, and the learning effects were better than that of students who adopted traditional learning methods.

With respect to the learning of other geological themes, Veal & Chandler (2008) suggested instructing students to strengthen the practice of skills in different scientific processes. For example, (1) regarding minerals and rocks, strengthen the practice of "observation, using proper tools, data analysis, and result delivery"; (2) regarding the formation of sandstone from sand, strengthen the practice of "observation, formation hypotheses, and measurement"; (3) regarding the formation of igneous rocks, strengthen the practice of "prediction and formation deductions"; (4) regarding the formation of metamorphic rocks, strengthen the practice of "modeling and observation", and (5) regarding rock identification, strengthen the practice of "observation, data collection and organizing, deduction, and developing indicating items for classification retrieval" etc., thus enhancing students' inquiry skills and improving their inquiry skills in geology.

In addition, with respect to the curriculum and instruction of geology, many researchers have developed new teaching methods and creative teaching activities for geology. The teaching implementation has also achieved quite good effects (Birnbaum, Morris, and McDavid, 1990; Hsu, Wang, and Liang, 2004; Lai, 2010; Semken and Freeman, 2008; Shen, Liu, Yi, Chen, Lin, Chao, and Liu, 2005; Su and Chiang, 2004; Tan, Liu, Mao, and Yang, 1992).

To summarize, the above teaching cases indicate, with respect to the practice of a geology curriculum and instruction, teachers can adopt multiple strategies and methods to carry out their geology teaching and inquiries. Apart from providing opportunities for students to experience and inquire by themselves, the key teaching elements is to inspire students' learning motivation and enthusiasm for geological inquiries using knowledge integration activities, and to cultivate their affection so as to appreciate the beauty of geology, while developing their own concepts of geology and inquiry skills.

Research Method

The study objects were sophomores of an educational university. The studied geology course was called Physical Geology (with experiment session) and was worth four credits (six class hours). The course lasted for one academic year, with two credits (three class hours) per semester. The text book used was Physical Geology by Plummer, Carlson, & McGeary (2007). A total of 31 students (including 11 preservice students) were involved in the study. According to the previous discussions in the literature review, as the content of geology curricula in primary schools is mainly focused on geological concepts, such as minerals, rocks, and changes in the Earth's surface and crust, the design of hands-on geology inquiries for this study mainly focuses on the discussion of minerals, rocks, and geological processes and causes. Second, the literature review also found geology teaching activities should not only pay attention to the learning of geological concepts, but also focus on the development of geology inquiry skills. Therefore, the design of hands-on geology inquiries in this study will strengthen the implementation of hands-on science activities, such as the observation, recognition, and identification of minerals and rocks. Further, with respect to course arrangements, the design of the hands-on geology inquiries integrates important factors, such as class teaching and experimental inquiry activities, with the hope of achieving the maximum promotion of professional growth in the geological knowledge of preservice teachers in colleges using limited teaching time and classes.

To summarize the above considerations, apart from the class teaching based on the physical geology course book by Plummer, Carlson, & McGeary (2007), the key elements of this hands-on geology inquiry scheme for preservice teachers also include an introduction to geology, minerals, igneous rocks, sedimentary rocks, metamorphic rocks and hands-on inquiries, geological processes and the causes, identification tests for minerals and rocks, etc. Second, apart from class teaching and discussion, the implementation of the inquiry scheme also includes conducting five different geological inquiry activities, including "Mineral Bingo", and hands-on inquiries of minerals, igneous rocks, sedimentary rocks, and metamorphic rocks. The latter four activities (10 to 18 types of specimens in each category) use specimens and the learning sheet provided by the Carolina Apparatus Supply Company of the USA (www.carolina.com) to carry out individual hands-on inquiries and identification. Eight specimen identification tests are conducted (10 to 18 types of specimens each time). They are conducted by processing different tasks in various substations, and include four pre-tests and four post-tests. Pre-tests are conducted before the teaching, and the post-tests are conducted two weeks after the teaching. The identification tests for minerals and igneous rocks are conducted in the first semester, and the identification tests of sedimentary rocks and metamorphic rocks are conducted in the second semester. Additionally, there is one off-campus geological field trip to carry out outdoor geological investigations and to collect minerals.

This study collects both quantitative and qualitative data as the main basis for the analyses. The quantitative data are the scores from four specimen identification tests, which are used as the foundation for the analyses. The qualitative data are mainly taken from the learning feedback of the preservice teachers, which are used as the main sources for data analyses. This paper uses *italic* font to present the feedback from preservice teachers as the qualitative data for the analyses. To achieve good reliability and validity for this study, three science education researchers first conducted a triangulation and cross-case inductive analysis on the qualitative data

(Bogdan & Biklen, 1982; Guba & Lincoln, 1999; Patton, 1999; Silverman, 1993, 2000), following which a validity examination was completed to confirm the reliability and consistency of the data analyses and results.

Results and Discussion

Learning performance of the hands-on practice of minerals

With respect to the mineral-themed inquiry and learning, preservice teachers conduct the pre-tests for the mineral identification tests before the teaching, and then conduct the post-tests for the mineral identification tests two weeks after the teaching. A summary of the results of the pre-test and post-test mineral identification tests and the t-test is shown in Table 1.

Table 1. Result of the Pre-tests and Post-tests of the Mineral Identification Tests and t-test for Preservice Teachers

test	*N*	*Mean*	*SD*	*t*	*p*
Pre-test	8	6.38	1.92	7.259	.000***
Post-test	8	12.50	1.41		

Note 1: *** means $p<.001$
Note 2: the maximum and minimum values of the mean values are (18, 0).

According to Table 1, the scores for the post-tests of the mineral identification tests conducted by preservice teachers are significantly higher than those of the pre-tests. The t-test shows there is a significant difference between the results of the pre-tests and post-tests of the mineral identification tests conducted by the preservice teachers (t = 7.259, $p<.001$). The study results show after receiving hands-on mineral inquiry training, the preservice teachers made significant progress in their learning of minerals and their identification. This result indicates the hands-on mineral inquiry training of this study benefits the learning and understanding of the mineral concepts of preservice teachers.

Learning performance of the hands-on practice of igneous rocks

With respect to the igneous-rock-themed inquiry and learning, the preservice teachers conduct the pre-test igneous rock identification tests before the teaching, and then conduct the post-tests two weeks after the teaching. A summary of the results of the pre-tests and post-tests of the igneous rock identification tests and the t-test is shown in Table 2.

Table 2. Result of the Pre-tests and Post-tests of the Igneous Rock Identification Tests and t-test for Preservice Teachers

test	*N*	*Mean*	*SD*	*t*	*p*
Pre-test	7	4.71	2.14	5.465	.000***
Post-test	8	9.38	1.06		

Note 1: *** means $p<.001$
Note 2: the maximum and minimum values of the mean values are (10, 0).

According to Table 2, the scores for the post-tests of the igneous rock identification tests conducted by preservice teachers are significantly higher than those of the pre-tests. The t-test shows there is a significant difference between the results of the pre-tests and post-tests conducted by preservice teachers (t = 5.465, $p<.001$). The study results show after receiving hands-on igneous rock inquiry training, preservice teachers made significant progress in their learning of igneous rocks and their identification. This result indicates the hands-on igneous rock inquiry training of this study benefits the learning and understanding of the igneous rock concepts of preservice teachers.

Learning performance of the hands-on practice of sedimentary rocks

With respect to the sedimentary-rock-themed inquiries and learning, preservice teachers conduct the pre-tests of sedimentary rock identification tests before the teaching, and then conduct the post-tests two weeks after the teaching. A summary of the results of the pre-tests and post-tests for the sedimentary rock identification tests and t-test is shown in Table 3.

Table 3. Result of the Pre-tests and Post-tests of the Sedimentary Rock Identification Tests and t-test for Preservice Teachers

test	*N*	*Mean*	*SD*	*t*	*p*
Pre-test	10	6.20	1.40	6.271	.000***
Post-test	11	9.55	1.04		

Note 1: *** means $p<.001$
Note 2: the maximum and minimum values of the mean values are (10, 0).

According to Table 3, the scores for the post-tests of the sedimentary rock identification tests conducted by preservice teachers are significantly higher than those of the pre-tests. The t-test shows there is a significant difference between the results of the pre-tests and post-tests of the sedimentary rock identification tests conducted by preservice teachers (t = 6.271, $p<.001$). The study results show after receiving hands-on sedimentary rock inquiry training, preservice teachers made significant progress in their learning of sedimentary rocks and their identification. This result indicates the hands-on sedimentary rock inquiry training of this study benefits the learning and understanding of the sedimentary rock concepts of preservice teachers.

Learning performance of the hands-on practice of metamorphic rocks

With respect to metamorphic-rock-themed inquiry and learning, preservice teachers conduct the pre-tests of the metamorphic rock identification tests before the teaching, and then conduct the post-tests two weeks after the teaching. A summary of the results of the pre-tests and post-tests of the metamorphic rock identification tests and the t-test is shown in Table 4.

Table 4. Result of the Pre-tests and Post-tests of the Metamorphic Rock Identification Tests and t-test for Preservice Teachers

test	*N*	*Mean*	*SD*	*t*	*p*
Pre-test	9	4.78	1.86	4.090	.001***
Post-test	11	8.09	1.76		

Note 1: *** means $p<.001$
Note 2: the maximum and minimum values of the mean values are (10, 0).

According to Table 4, the scores for the post-tests of the metamorphic rock identification tests conducted by preservice teachers are significantly higher than those of the pre-tests. The t-test shows there is a significant difference between the results of the pre-tests and the post-tests conducted by preservice teachers (t = 4.090, $p<.001$). The study results show after receiving hands-on metamorphic rock inquiry training, preservice teachers made significant progress in their learning of metamorphic rocks and their identification. This result indicates the hands-on metamorphic rock inquiry training of this study benefits the learning and understanding of the metamorphic rock concepts of preservice teachers.

Qualitative feedback of learning

This study not only analyzes the scores of the four specimen identification tests of preservice teachers, but also collects their learning feedback as sources for analysis. The following are the statements and analyses of the feedback from preservice teachers. Their feedback is presented in *italic* font.

First, taking the hands-on inquiry of minerals as an example, the study asked preservice teachers to answer this question. "Taking quartz and calcite as examples, how do you identify these two minerals?"

Student David answered, "*Drop hydrochloric acid on these two minerals. The one that dissolves is calcite. Or judging from cleavages, calcite has three sets of cleavages. Judging from hardness, quartz is harder than calcite. It is impossible to judge from the color, for both of them are lucent.*" As shown by David's answer, David has well-mastered the skills for mineral recognition and identification. David is able to use different surface features and properties to effectively distinguish quartz from calcite.

Student Amy answered, "*The hardness index of quartz is 7. It has a hexagonal prism and many colors. The hardness index of calcite is 3. It has three sets of cleavage, is translucent, and will emit CO_2 when you drop hydrochloric acid on it.*" According to Amy's answer, Amy has also well-mastered the different characters of quartz and calcite to effectively distinguish quartz from calcite.

Student Tony answered, "*The hardness of quartz and calcite differ. Quartz is harder than calcite. Rub the two unknown minerals against each other. The one that scratches is calcite, and the other one is quartz*." According to Tony's answer, Tony has also well-mastered the different properties of quartz and calcite to effectively distinguish them from each other.

Taking the hands-on inquiry of rocks as an example, the preservice teachers were asked to answer this question. "Take gabbro and basalt as an example. How do you identify these two rocks?"

Student Cindy answered, "*Gabbro has obvious joints, while basalt is composed of fine crystals, and its color is darker*." According to Cindy's answer, Cindy has well-mastered the different features of gabbro and basalt to effectively distinguish them from each other. Linda answered, "*Gabbro has smooth ruptured surfaces and luster, while basalt has neither*." According to Linda's answer, just as Cindy, Linda has also mastered the different features of gabbro and basalt to effectively tell them apart.

Student David answered, "*Both of the two rocks are dark colored or black. Gabbro has shining crystals, while the crystalline particles of basalt are very small*." According to David's answer, David has mastered the skills of identifying igneous rocks, and is able to use the different features of gabbro and basalt to identify them. In addition, David is also able to state some features of gabbro and basalt that are the same.

Student Amy answered, "*Both of them are basic igneous rocks. The crystalline particles of gabbro are larger than 1 mm, and dark in color. The crystalline particles of basalt are smaller than 1 mm, and are dark in color.*" According to Amy's answer, Amy also understands both gabbro and basalt are basic igneous rocks, and is able to effectively identify gabbro and basalt depending on their different features.

Student Tony answered, "*Judging by the weight percentage of SiO_2, joints, texture, and colors*." Student Peter answered, "*Compare the sizes of the crystalline particles. Gabbro is a plutonic rock that gradually cools underground. It has larger crystalline particles. On the contrary, basalt cools rapidly, and has smaller crystalline particles*." According to Tony's and Peter's answers, they have both mastered the identification features of igneous rocks.

The third question for the preservice teachers is "How did the pre-tests of the specimen tests influence your identification of minerals and rocks?"

Student Cindy answered, "*I am able to know which of my facts are incorrect or vague in advance. I can write them down when identifying the specimens in the pre-tests, and strengthen my knowledge in class*." According to Cindy's answer, the pre-tests of the specimen inquiry tests can provide Cindy with an opportunity for self-diagnosis, thus strengthening the metacognitive learning, and enhancing Cindy's understanding of minerals and rocks.

Student Mary answered, "*It provides me with an opportunity to review the knowledge I learned in high school. As I haven't seen or touched every specimen before, I am very curious, and more eager to identify minerals and rocks*." Student Amy answered, "*The pre-test applies our knowledge gained in class to the substances (specimens). We may not be able to use this knowledge directly, but it makes us more eager to know what kind of stone it is in the pre-tests*." According to Mary's and Amy's answers, pre-tests can stimulate their interest to explore further and recognize the specimens tested, indicating pre-tests can guide students' learning willingness and strengthen their sense of responsibility toward learning.

To summarize, the feedback from preservice teachers on the study of minerals and rocks show all preservice teachers have well-mastered the features of minerals and rocks, and are able to apply the identification strategies for minerals and rocks. They are able to identify the different minerals and rocks based on different features. Meanwhile, the pre-tests of the specimen identification tests can greatly enhance the willingness and responsibility of preservice teachers toward learning, and promote the learning and understanding of minerals and rocks in the subsequent hands-on inquiry activities by applying proper metacognitive skills. In addition, when comparing the qualitative feedback from preservice teachers regarding the mineral and rock learnings to the scores of the post-tests of the mineral and rock identification tests, it is discovered, after receiving training in the hands-on inquiry activities of geology, the learning performance of preservice teachers in geology is significantly enhanced.

Conclusion

Targeting the implementation of the geology curriculum in colleges, the study aim was to investigate the learning performance of preservice teachers in colleges using hands-on science inquiry strategies and schemes. The study emphasizes the cultivation and training of the hands-on inquiry skills of preservice teachers through implementing a geology curriculum in colleges, thus promoting professional growth in the geological knowledge of preservice teachers. The study results show the scores for the post-tests of the four specimen identification tests are better than those of the pre-tests, indicating the preservice teachers' concepts of minerals and rocks achieved significant growth. Second, the learning feedback from preservice teachers shows preservice teachers have a good level of knowledge regarding geological inquiries. Additionally, the pre-tests of the specimen identification tests can greatly enhance the willingness and responsibility of preservice teachers toward learning, and promote the learning and understanding of minerals and rocks in the subsequent hands-on inquiry activities by applying proper metacognitive skills. These research results indicate the cultivation and training in hands-on geology inquiries can actually enhance the professional growth in the geological knowledge of preservice teachers. Consequently, to summarize, this study believes the cultivation and training in hands-on geology inquiries benefits preservice teachers' learning of geology.

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Teaching the Future Teachers: A Teacher Educator's Self-Study in Making Science Relevant, Useful and Meaningful for New Zealand Pre-Service Teachers

Steven Sexton[1*]
[1]College of Education, University of Otago

Abstract

This self-study investigated how one teacher educator influenced his final-year pre-service teachers perceived primary science classroom learning environment. The study utilized the Nature of Science as Argumentative Questionnaire (NSAAQ) and regularly scheduled focus group interviews. These tools investigated how the learning environment the teacher educator created effectively modelled the pedagogical approaches stated in *The New Zealand Curriculum*. The initial NSAAQ results indicated where the pre-service teachers understanding of the nature of science were naïve and what aspects needed to be addressed over the course of the programme. Focus group sessions revealed how some of the student teachers' science attitudes altered over their course of study. These pre-service teachers reported they are now more confident to teach science and that their teacher educator influenced their anticipated teaching practices. This research supports the importance of self-study in initial teacher education.

Key words: Primary science, Teacher education, Self-study

Introduction

A number of challenges for the New Zealand educational system in primary science have been reported (Bull, Gilbert, Barwick, Hipkins, & Baker, 2010; Education Review Office, 2012; Gluckman, 2011). All of these reports note that while there are some noteworthy science teaching practices, there are issues regarding ineffective science teaching such as lack of confidence in teachers, perceived lack of resources and a crowded curriculum that favours English and Mathematics. Many of the challenges for New Zealand primary school science are not new (Ginns & Watters, 1995; Prenzel, Seidel, & Kobarg, 2012).

Teacher quality is one of the main means to address the challenges in primary science education (Gluckman, 2011). But how is a quality primary school teacher prepared for education in science? It has been noted that how teachers are prepared for the classroom during their university education is a good indicator of how well they may eventually teach (Darling-Hammond, 1999; Education Review Office, 2010; Rice, 2003). Within initial teacher education (ITE) programmes, two influences need to be considered when evaluating future teacher quality: the teacher educator (Cochran-Smith, 2003); and, if the pre-service teachers practice teaching using the pedagogy learned during their coursework (Hudson & Skamp, 2002).

Teacher educators create the classroom learning environments in which pre-service teachers experience learning and teaching. How then do teacher educators and their classroom learning environments contribute to the multi-faceted educational picture of primary science teacher preparation? Does the teacher educator's practice and created learning environment influence how final-year student teachers may eventually teach primary science?
The purpose of the present study was an investigation into how the researcher, as teacher educator, and his final-year undergraduate pre-service teachers understood the programme's targeted primary science. The research scrutinized which aspects of the researcher's classroom practices influenced the pre-service teachers' pedagogical understandings of primary science to include modelling classroom activities, adapting activities to accommodate a range of student abilities and including students' topics of interest. The study explicitly sought to identify the extent to which the student teachers' perceived how the classroom modeled *The New Zealand Curriculum*'s (Ministry of Education, 2007) effective pedagogy approaches.

* Corresponding Author: *Steven Sexton*, steven.sexton@otago.ac.nz

Theoretical Framework

This self-study draws on what could be described as a theorisation of equality and identity informed by social constructivist (Skamp, 2012) and post-colonial theories (MacFarlane, MacFarlane, Savage & Glynn, 2012). This paper explores equality issues in the teaching of science education and scrutinizes a common view of teaching as inclusive and egalitarian (Biklen, 2011; Whyte, 2011). Specifically, it builds on the tradition of teachers as researchers, which has informed self-study as a practice-based approach leading to teacher educator research (Lunenberg, Zwart & Korthagen, 2010).

Why Teacher Educators?

Who teaches the teachers how to teach? This task is given to teacher educators (Cameron & Baker, 2004). Even though teacher educators are an important aspect of teacher education, research literature indicates we are an often-neglected group in research studies. Little research has focused on the quality or expertise of teacher educators (Loughran, Berry, & Mulhall, 2012; Hume & Buntting, 2014).

The present study focused on the practice of one teacher educator, the researcher, and how he worked to develop science pedagogical understandings in seventeen final-year undergraduate pre-service teachers. As teacher educators are responsible for providing pre-service teachers with strong foundations of professional teaching knowledge, the researcher wanted to inform not only his own teaching practice but also the development of formal knowledge on teacher education (Lunenberg, Zwart, & Korthagen, 2010). Therefore, this study sought to investigate the research question: How does conducting a self-study of a teacher educator influence initial teacher education primary student teachers' understanding in science education?

Why Effective Pedagogy As Defined In *The New Zealand Curriculum*?

The New Zealand Ministry of Education introduced a dramatically revised integrated curriculum document in 2007 compared to the previous curriculum documents (Benade, 2009). Included in the 2007 curriculum are seven pedagogical approaches that teachers are encouraged to incorporate into their own teaching practice (see, http://nzcurriculum.tki.org.nz/The-New-Zealand-Curriculum). The curriculum document notes that these pedagogies are based on a wide body of evidence about what positively impacts student learning (Ministry of Education, 2007). Pre-service teachers, therefore, need first authentic exposure to and then practical experience in these approaches in order to be able to incorporate them into their own teaching practice.

As part of this revised curriculum, the Nature of Science was position as the overarching strand of science. It is through this Nature of Science strand that the content areas of the Living World, Material World, Physical World and Planet Earth/Beyond are explored to expand the student's understanding of their world (Sexton, 2011). Specifically for this study, *The New Zealand Curriculum's* seven pedagogical approaches were linked explicitly to science activities as a means to promote positive student teacher learning.

Methodology

To address the research question, this self-study research project used a mixed method framework (Lunenberg, Zwart, & Korthagen, 2010; Russell, 2010). Mixed method is a methodology often used in learning environment studies and has proven to be effective (Aldridge, Fraser, Taylor, & Chen, 2000; Pickett & Fraser, 2002). The advantages of mixed method are that it provides a depth and breadth of both understanding and corroboration that may not be attainable by either qualitative or quantitative methods alone. Mixed methods allows researchers to use all of the tools of data collection necessary rather than being limited by those associated with either qualitative or quantitative methods (Creswell, 2009).

Nature of Science as Argument Questionnaire

The researcher selected the Nature of Science as Argument Questionnaire (NSAAQ) for the present study, see Appendix. The NSAAQ developed by Sampson and Clark (2006) measures key aspects of participants' epistemological understanding of the nature of scientific knowledge. The NSAAQ provides information on four specific aspects of the nature of science. These are the nature of scientific knowledge; how scientific knowledge is generated; how that knowledge is evaluated; and science as a socially and culturally embedded practice. The questionnaire has proven validity both in design (Sampson & Clark, 2006) and implementation in New Zealand (Rice, 2013).

The NSAAQ was chose as it allowed the researcher to gather quantitative data as to how these student teachers understood science and what areas needed to be addressed. While this survey measure aspects of how the participants understand the nature of science and not how to implement *The New Zealand Curriculum*, it did provide a means to measure how the teacher educator was able to influence the student teachers' understanding of science over the course of the programme.

The survey was administered by the researcher at the beginning of the first session of the programme to establish an understanding of what these final year pre-service teachers understood about the nature of science. For this ITE programme, student teachers are required to take a compulsory introductory course in science in their first-year of their undergraduate programme. As part of their final-year of study, student teachers are required to take Literacy and Numeracy plus two additional curriculum learning areas of their choice, of which science is one option. This programme is delivered over ten two-hour tutorials.

Focus Group Sessions

Focus group sessions were used to elicit pre-service teachers' understandings of Shulman's (1986) theoretical constructs of pedagogical content knowledge (PCK). PCK is generally seen as a combination of general pedagogical knowledge and subject matter knowledge (Gess-Newsome, 1999). Content knowledge (CK) by contrast, is defined as the subject matter that is taught and how it is organised in the teacher's mind (Shulman, 1986). Teacher educators need both knowledge types to develop in pre-service teachers as teachers draw on these knowledge constructs to know what to teach and how to teach it. As the NSAAQ examined what aspects of the nature of science these pre-service teachers understood, the focus group sessions explored how the pedagogy was understood from the course and how it reflected the effective pedagogy approaches from *The New Zealand Curriculum*. The focus group sessions were a regular part of their university coursework and each averaged 25 minutes of the two-hour tutorials.

The researcher conducted all sessions, as these were a part of their science education course. The transcripts were continuously reviewed for themes that emerged by analytic induction (Erickson, 1986). Analytic induction is a way to sift through the narrative data, first coding for general themes. One of the themes the transcribed interviews were coded for were indications of how the researcher's/teacher educator's primary science course was impacting on pre-service teachers' pedagogy. After coding for general themes, each general theme was then analysed again until a more detailed pattern emerged. The detailed themes that emerged from the data were then linked, when possible, to *The New Zealand Curriculum's* effective pedagogy to formulate an overall understanding of what was taught by the teacher educator and what was perceived by pre-service teachers.

Participants

Participants for this study were from one undergraduate programme of study at a large university in New Zealand. All 17 student teachers enrolled in the 2014 final-year science curriculum studies course voluntarily participated in this study. The ten two-hour sessions were face-to-face tutorials. Participants were 18-years or older, of which 15 were female and two male, see Table 1:

Table 1: Participants' Self-Identified Demographic Data from NSAAQ

Total surveys	17
Female	15
Male	2
NZ European	17
18-20-years	2
21-25-years	10
26-29-years	4
30 + years	1

Science Education Programme

The present study's science programme was a ten-session course of study in the first semester of 2014. These student teachers were informed that they would be required to create a unit of study on a primary science topic as the assessment requirement for this course. During this final-year of study, the student teachers spent one-day a week in a school as part of their professional learning experience. At the completion of this course, the student teachers had two weeks to prepare for a three-week block placement of sustained control teaching of this same class. It was anticipated that the student teachers would use their unit of work while on this sustained teaching placement.

On the first day of the science education course, the teacher educator informed the student teachers that the course science content would be determined by their input. As this course requires the student teachers to build a unit of work based on the interests and abilities of their teaching placement classroom, their science education facilitator would model this. The student teachers brought to the second tutorial the science topics they wanted the course to include. Then as a class, the following topics were chosen; see Table 2.

Table 2. Teaching and Learning Schedule

Week	Course Content	Explicit Nature of Science – New Zealand Curriculum	Explicit Nature of Science pedagogy	Explicit effective pedagogy - *The New Zealand Curriculum*
1	Agar jelly dishes: using science to explain school/class rules	Reviewing *The New Zealand Curriculum*'s science learning area: Nature of Science and the four Content Strands	The nature of scientific knowledge	Creating a supportive learning environment
2	Cool bombs: common kitchen ingredients	How Investigating in Science and Understanding about Science link	How scientific knowledge is generated	Encouraging reflective thought and action
3	Mini-beasts: how to investigate the Living World, ethics of science	The importance of students being able to use the correct vocabulary to talk about science	How scientific knowledge is evaluated	Enhancing the relevance of new learning
4	Change of State: how the Physical World is different from the Material World	Relating the science to students' everyday world	How scientific knowledge is generated	Facilitating shared learning
5	Gardening	Using both Living World and Planet Earth to demonstrate Participating and Contributing	Science as a culturally and socially embedded practice	Making connections to prior learning and experience
6	Space	Effective and models to Investigate in science using Planet Earth and Beyond	The nature of scientific knowledge	Providing sufficient opportunities to learn
7	Planet Earth: Volcanoes, Tornados, Weather	How Earth behaves and how to incorporate appropriate vocabulary for students	Science as a culturally and socially embedded practice	Encouraging reflective thought and action; Making connections to prior learning and experience
8	Games	Types of fun that facilitate student learning about their world	How scientific knowledge is evaluated	Facilitating shared learning; Providing sufficient opportunities to learn
9	Electricity	Integration of all four elements of the curriculum's Nature of Science	How scientific knowledge is generated	Teaching as inquiry
10	Explosions	Integration of all four elements of the curriculum's Nature of Science	Science as a culturally and socially embedded practice	Teaching as inquiry

Results

Each question of the NSAAQ presents two contrasting views of the nature of science, a naïve and an informed perspective. A five-point scale separates the two statements (Sampson, 2006). The NSAAQ survey includes at least five questions addressing each of the four identified aspects. Quantifiable data from the NSAAQ surveys was analysed using the Statistical Package for the Social Sciences (SPSS) version 21.0. The consistency of the responses among the participants' responses to the individual NSAAQ items was calculated by using Cronbach alpha coefficient as 0.64 for the initial test and .71 for the second test that indicated that the questionnaire had sufficient internal consistency (Gliem & Gliem, 2003).

NSAAQ and Scoring Descriptions

In scoring the responses to the NSAAQ survey, a naïve view was taken as a response of 1, 2 or 3, while an informed view was taken as a score of 4 or 5 (Rice, 2013). This decision was based on the premise that participants who selected 3 for their response to any of the NSAAQ questions were unable to make a distinction between the two views (Sampson, 2006). The mean, standard deviation and percentage of respondents who selected 1, 2 or 3 for each question was calculated (see Table 3, below). The range of the means for the initial-test questions was from 1.51 to 4.55, while the range of the second-test was 2.59 to 4.94.

Table 3. Student Teachers' views of Nature of Science

NSAAQ	M	SD	% answering 1, 2, or 3	M	SD	% answering 1, 2, or 3
		Initial-test			Second-test	
1	2.3	1.27	82.3	2.59	.64	70.6
2	2.89	1.19	47.1	3.71	.64	35.3
3	3.75	0.97	29.4	4.06	.49	0
4	4.21	0.41	0	4.41	.56	0
5	2.22	0.92	88.2	2.88	.75	58.8
6	3.93	1.22	29.4	4.94	.73	0
7	3.01	0.89	82.4	3.47	.66	47.1
8	4.42	0.49	0	4.53	.50	0
9	2.56	0.67	100	2.88	.83	82.3
10	1.90	0.71	100	2.59	.92	88.2
11	2.48	0.85	100	3.17	.96	70.6
12	1.51	0.67	100	3.29	.80	58.8
13	3.32	0.78	70.6	3.24	.84	70.6
14	3.08	0.77	82.4	3.94	.40	41.2
15	3.63	1.23	29.4	4.88	.39	0
16	2.85	1.16	82.4	3.18	.97	58.8
17	3.01	0.89	70.6	4.12	.85	11.8
18	3.92	0.83	23.5	3.35	.59	17.6
19	4.13	0.72	23.5	4.24	.46	0
20	2.71	1.19	70.6	2.76	.78	64.7
21	2.72	0.94	70.6	3.29	.89	58.8
22	2.63	0.66	100	2.94	1.22	64.7
23	3.76	1.00	29.4	4.41	.67	0
24	2.91	0.83	70.6	3.00	1.00	58.8
25	4.11	0.87	17.6	4.71	.46	0
26	4.55	0.50	0	4.94	.30	0
Overall	3.15	0.87		3.67	.70	

The researcher decided to calculate the percentage of respondents who indicated 1, 2, or 3 for each question as this provided an indication of the percentage of respondents holding naïve views. The range for the percentages for the initial test was from 0 to 100%. This identified the five questions where all of these student teachers held naïve views, see questions 9, 10, 11, 12 and 22.

Overall, these student teachers held naïve views for 12 of the 26 pre-test questions. This indicated what the teacher educator needed to prepare in the course material that would address both the student teachers' pedagogical content knowledge in effective science education and the nature of science aspects covered by questions 9, 10, 11, 12 and 22. At the completion of this programme, these student teachers held naïve views for only 6 of the 26 questions which included questions 9, 10 and 22.

Effective Pedagogy Approaches

As *The New Zealand Curriculum* highlights seven effective pedagogical approaches, the researcher wanted to investigate how well these teaching approaches were reflected in the data analyses. Creating a supportive learning environment recognises that learning is social and cultural process. Students learn better when they part of a positive classroom environment (Ministry of Education, 2007). This approach was noted by almost all the student teachers as one of the strengths of the course. One student noted, "I have really enjoyed science and have particular liked how you designed the course so that what we learnt was relevant for our teaching practice." These student teachers really appreciated the amount of control they had over course content. This was commented upon by most of these student teachers, for example, "it was helpful to be able to choose the topics we covered in the classes." When asked to explain how this was helpful, this student teacher added, "these are topics that are useful to us as these are what our mentor [classroom teacher hosting the student teacher] want us to teach."

As part of the learning environment, these student teachers had multiple opportunities to develop and reflect on their own and others' ideas in scaffold opportunities of reflective thought and action (Ministry of Education, 2007). The teacher educator, using both small group and whole group discussions, supported these approaches as classes developed the language of teaching as well as the language used in science by engaging in hands-on science activities. These student teachers commented that the classroom was a learning environment that not only encouraged them to question the teacher educator's plans, methods and ability to explain concepts but also to develop their own ideas with each other. For example in the fifth week of the programme the topic was gardening, many student teacher were surprised to have what they thought as correct information challenged. In an activity (see, http://www.nourishinteractive.com/system/assets/free-printables/133/kids-garden-activity-produce-plants-matching-activity.pdf?1310694858) every student teacher in the class stated, "apples and bananas grow on trees." After being asked to justify why they all thought this was true, the student teachers after some debate came to the understanding that, "bananas do not grow on trees but on an herbaceous perennial plants with fleshy stalks known as pseudostems." They acknowledged that much of their misunderstanding centred on the fact that, "the banana plant looks like a tree" and is generally referred to as a 'banana tree.' Further investigations into banana plants lead to the discovery that, "the banana plant is the biggest plant in the world without a woody stem." The teacher educator asked why was all of this extra information discussed when the question was only which of these fruits grow on trees. The student teachers noted that this lesson was designed to make explicit their connections to prior learning and experiences, "but you did not just tell us we were wrong, we found out on our own." This was then further expounded upon by another student teacher, "the other stuff was a teachable moment and was like last week's shared learning," and a third student teacher added, "we were all trying to one up [do better than] the last [person]."

Support for the targeted pedagogical approaches was observed during the hands-on science activities used in class sessions that then had the student teachers reflect and discuss what they thought they knew and what actually occurred. It should be noted that some activities elicited significantly more reflection and frustration than others did. For example, it was anticipated that many of these student teachers would find it difficult to use models to demonstrate the orbit of the Moon and explain how a near total lunar eclipse was going to be visible from New Zealand on April 15th, 2014. The Moon's orbit provided these student teachers an opportunity to reflect critically on how activities are able to lead to deeper thinking. Using material to model the Sun, Earth and Moon, student teachers were grouped into four groups and asked to demonstrate a full moon, new moon, and both a solar and lunar eclipse. After only a few minutes, the student teachers felt confident to model how the Earth orbits the Sun and then how the Moon orbits the Earth. Only one of the four groups demonstrated the Moon's orbit that would not result to a monthly solar and lunar eclipse as three groups demonstrated an orbit of Sun, Earth and Moon in the same horizontal plane. After the groups discussed their demonstrations, one student teacher noted, "why is everything I was taught wrong!" This student teacher like many of her colleagues was experiencing a dissonance with what she believed to be correct with what she was actually experiencing. As effective and appropriate use of models to stimulate critical reflective thought and discussion is an area where these student teachers needed more support, they were informed that they would need to include in their unit plans how and where they were going to encourage their students to engage in critical reflection.

In an attempt to provide a more positive learning opportunity, the student teachers had the opportunity to go to the local observatory for an evening a week prior to the lunar eclipse. The intent was to explore how a lunar eclipse occurs but other opportunities arose. For many students, it was “seeing the rings of Saturn was the coolest thing ever, I actually saw them!” or, “so that is why we sing called twinkle, twinkle, little star” in seeing how the light of the star interacts with the atmosphere to appear to twinkle.

Students’ learning is supported when new knowledge is incorporated with what they already know and connections can be made to other learning areas (Ministry of Education, 2007). This teaching approach was supported with pre-service teachers commenting on how science could be ordinary things from their everyday life. They noted how to use activities that students would be able to connect to their own lives, such as batteries, aluminum foil and light bulbs make a circuit; and how to use toothpicks, marshmallows and trays of jelly to demonstrate the effects of earthquakes on buildings.

Students’ deeper learning is facilitated when they understand what, why and how they could use their new learning; that is enhancing the relevance of new learning having the opportunities to learn (Ministry of Education, 2007). This was best represented when one student commented that after the session on weather (see session 7, Table 2) he now understood how and why thunder occurs. Even better, in the focus group session for session 8, he talked about doing the previous week’s thunder activity with his teaching experience class and how with a piece of paper he showed his students and mentor in less than 30-minutes, “how cool science can be.” As stated, in this programme student teachers were explicitly involved in making their own learning decisions. More than one student teacher was pleased that what was being taught was what they could use in their own unit planning or weekly teaching; for example, “I liked how each class covered a different aspect of science, based on what anyone needed or was going to need in their upcoming practicum.” But most rewarding to the teacher educator was the comment, “I feel much more confident in teaching science now.”

In New Zealand, teachers should use relevant, useful and meaningful science content to expand their students’ worlds through science education. Teachers, therefore, need to provide the opportunities to allow students to ask questions about the science they are doing, use the appropriate vocabulary necessary to talk about the science they are doing and understand how this science relates to their world. As one student teacher commented, “I found it [this course] very helpful in the sense that you learnt how to teach science.” When asked to clarify what she meant, she went on to state, “science is students using the correct words to questioning each other, to question the science and question me as the teacher.” In this same focus group session, another student teacher remarked that she found out that it was, “ok for a teacher not to know everything” and that one can, “learn from your students” which were attitude shifts from how she learned science in school.

The teacher educator modelled in the course and made explicit examples of how the programme content was reviewed and adjusted using evidence-based strategies. This was done so the student teachers were aware of when the teacher educator was implementing inquiry into the teaching and learning relationship (Ministry of Education, 2007). As stated, the student teachers’ assessment for this programme was to plan a science unit for the school setting in which they were placed for sustained teaching. They were instructed that as part of their planned unit they would be critiqued on how well they linked lessons and built on the conceptual understandings of their students. This was done to support the pre-service teachers need for structured assistance to understand how to challenge ideas and assess student learning. Not all of the student teachers appreciated this emphasis on modelling what, how and why in learning.

One student teacher rated the course very well and noted that, “Steve always put 100% into ever lesson, which was interesting and hands on for us the students.” This same student teacher then commented that I was supportive and helpful with the assessment tasks, but not as helpful and supportive in class. It would appear for at least this one student teacher a ten-week course was not long enough in showing her the importance of challenging what she thought she knew about science. Not only did see comment negatively on having her ideas challenged by the course but also she did not alter her naïve position for NSAAQ questions 9, 10, 11, 12 or 22.

Conclusions

The NSAAQ was used to measure the student teachers’ concepts of the nature of science, and to provide a tool that could be used to discriminate between how the nature of science is viewed. In addition to identifying participants' nature of science understanding, the individual questions provided a tool to highlight the specific nature of science concepts to explore within the tutorials in an attempt to enhance each individual's understanding.

Semi-structured focus group sessions would seem to support how these student teachers' perceptions changed over the course. Overall, these student teachers did move to a more positive attitude towards how to teach primary science than when they started the course and linked this to the teacher educator's enthusiasm and passion for the topic. As teacher dislike of science is a reason why some students are not taught science (Sexton, Atkinson & Goodson, 2013), the shift to a more positive attitude towards science by these student teachers is encouraging.

During the focus group sessions, the student teachers commented on how the teacher educator modelled the science teaching practices they were expected to use. The student teachers, however, indicated that more work on their part was required before they would feel as confident in their teaching practice. This supports research that student teachers need to experience effective pedagogy for it to be incorporated in their own PCK (Stofflett & Stoddart, 1994).

One aspect of the primary science course that these student teachers commented on was that after being introduced to effective pedagogy through science education, they wanted more practice in using it. Many of these student teachers felt much better prepared by this course to teach science. However, once student teachers are in a teaching position, research indicates it was difficult for them to implement the pedagogy they learnt at university as they coped with full-time responsibilities of a classroom (Sexton, Atkinson & Goodson, 2013).

Hands-on activities were used during the coursework and the use of activities like these was stated as a key pedagogical approach that shaped how many of the student teachers would begin to teach science in their own classrooms. This is a positive outcome as it indicates these student teachers intend to implement a more student centred approach to hands-on science. However, how well and how often these student teachers will actually use hands-on activities once they are classroom teachers is not known. As the reality of limited school resources, teacher preparation and setup time, as well as scheduling time for science teaching impacts beginning teachers (Education Review Office, 2012), follow-up research is required to indicate if high quality hands-on activities are actually used.

Another concern that might affect the student teachers' science pedagogy is the emphasis on literacy and numeracy. This emphasis on literacy and numeracy is a reason given in the 2010 Education Review Office report as to why primary science teaching time has waned in schools. Other researchers have reported that when science is not considered important by teachers or is assigned a low priority compared to other subjects like literacy and numeracy, little time is spent teaching it (Education Gazette, 2009; Roden, 2000).

Effective pedagogies should be taught not only in science but also across all subject areas during the pre-service teachers' education. ITE providers should review what is taught throughout the teaching degree programmes and evaluate if effective pedagogies are taught, linked and explicitly made known to student teachers. As New Zealand's Ministry of Education is interested in having these approaches utilised by its teachers, more research into the application of the approaches as well as student and in-service teacher professional development in the use of the approaches would be required. As these effective pedagogical approaches are not just for the curriculum area of science, educational opportunities in how to use them effectively is necessary.

Recommendations

Teachers are the key to a quality education as they are the link between curriculum, pedagogy, assessment, and social and learning outcomes (Jones & Baker, 2005). Primary school teachers who can effectively develop these links in the learning area of science are needed (Gluckman, 2011). But it is difficult to achieve a positive link for New Zealand primary students when many of their primary school teachers are uncomfortable with teaching science (Education Review Office, 2010, 2012; Lewthwaite, 2000). One solution here in New Zealand that has been shown to be effective in addressing primary teachers teaching science is the Sir Paul Callaghan Science Academy, see http://www.scienceacademy.co.nz/. This intervention seeks to support in-service primary teachers, in much the same way that this paper reports on how the teacher educator as researcher sought to support student teachers.

An important element in teacher education is the teacher educator. Teacher educators convey all aspects of *The New Zealand Curriculum* to include both necessary content knowledge and pedagogical content knowledge. Therefore, teacher educators should explicitly incorporate self-study to know which parts of their practice are influencing pre-service teachers. Teacher educators should not assume that the concepts taught and modelled during primary science coursework are understood, nor that in the future they will be integrated into the teaching pedagogy of the student teachers once they are in a classroom situation.

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Examination of the Teacher Candidates' Environmental Attitudes via New Environmental Paradigm (NEP) Scale in terms of Different Variables

Emine Hande Aydos*, Esed Yağcı
Hacettepe University

Abstract

In today's world, the importance of environment education that is one of the most important issues is increasing rapidly. In the basis of the education, families and teachers take role together. It is aimed to grow up individuals who have positive attitudes and are sensitive the environment at every level of education. In order to achieve this goal, there is need for teachers giving importance to environment education and having adequate equipment. It will be beneficial to learn the environmental attitudes of teacher candidates who grow up elementary students after a few years. Because of this reason, in this study, it is aimed to examine the environmental attitudes of teacher candidates in terms of different variables. In the research, quantitative research methods were used. Sample is consisted of 1th and 3rd grade students from different department of science in Faculty of Education at Hacettepe University. In order to collect the data, New Environmental Paradigm (NEP) Scale was used. In the finding of the research, it was investigated that there is a difference in environmental attitudes of teacher candidates in terms of department of science, grade level, region lived during their childhood and get the status of environment education course variables and there is no difference in term of also, some suggestions were given.

Key words: Teacher candidate; Environment education; NEP; Attitude

Introduction

It is not possible to think the environment separate the effect of people because environment is not only the world outside of our skin, it is also a place that we affect, affected, shaped and as the same time a place where we realize ourselves (Uşak, 2006). It is very crucial that individuals benefit from the living area and they avoid the behaviors which can be reverse the natural balance of it (Uzun & Sağlam, 2005). At this point, it is crucial that all individuals should gain the conscious and ability in order to protect the environment and to have better living conditions. The main goal of environment education is to protect the nature and natural resources. Besides of giving information, environment education should affect the behavior of the individual. In order to be gained positive and persistent behavior change and provide the individuals to participate actively are the main aim of environment education (Şimşekli, 2004).

In today's world, one of the most salient problems is environmental problems. Changing living conditions, developing technology, rapid population increase, industrialization and also urbanization increase the environmental problems. In this regard, it is very crucial to provide the environmental conscious in national and international areas. Environmental problems and its results make environment education a current issue. It is necessary that environment education programs should be varied for every age and education level in order to increase the environmental conscious. In this regard, examination of educational applications and programs provide the environmental education activities to become realistic and goal directed (Gülay & Ekici, 2010).

When the substantial effects of environmental problems are seen clearly, as a reaction, it is widely increase environmental protection conscious and environmental sensibility. Before it is thought that environmental conscious is related to the people that live in developed countries, in recent years, it is clearly asserted that people in developing and underdeveloped countries have an important environmental conscious (Dunlap, Gallup & Gallup, 1993; Furman, 1998). It is impossible to think young people without the education in all countries all over the world. Education must be concerned with more than simply the transmission of knowledge and more than formal education. It must think about all the influences on young people's attitudes and behaviors.

* Corresponding Author: *Emine Hande Aydos, handeaydos@yahoo.com.tr*

Throughout this education, young people are also gained attitudes and behaviors of environment education (Yencken, Fien & Sykes, 2005).

Because of the reasons that are emphasized strongly it is crucial that environmental education need to take place in every level of education systematically from early childhood to high school in years. It is important to give place environment education activities in national education programs (Gülay & Ekici, 2010). In order to provide the development of individuals' attitude and behavior, both formal and informal environment education can be used by the educators. All these affect the environmental education progress and for a qualified environment education, there are various and contemporary ways (Palmer, 1998).

Education faculties are one of the important parts of the system and every year, lots of young people are graduated from there. Therefore, if the educators provide to increase the sensitivity of young people in education faculties and start to move actively, it could be a big step to prevent the environment problems developed multifaceted. As a result of this, it is provided that young people behave consciously for a balanced, safe, healthy and livable world (Maskan, Efe, Gönen & Baran, 2006).

Importance of the Research

As known one of the most important issue of educational program is environment education and its importance is increasing every day. The main aim of environment education is to protect the nature and natural sources. Families and teachers compose the fundamentals of this education together. It is necessary to aim of growing up individuals who are sensitive to the environment and have positive attitudes at every level of elementary education. It can be reached to this aim with the teacher giving importance to environment education and having enough information about this issue. It is necessary to give effective and qualified education to every level of elementary education students by teacher candidates graduated with qualified environment education. It can be beneficial to examine the environmental attitudes of teacher candidates who will graduate in a few years and educate elementary education students. Because of all these reasons, it is aimed to examine the environmental attitudes of teacher candidates in terms of different variables. Throughout this aim, research questions are given above:

1. Do teacher candidates internalize eco centric or anthropocentric approach for the environmental attitudes?
2. Is there any difference between the environmental attitudes of teacher candidates according to the department of science?
3. Is there any difference between the environmental attitudes of teacher candidates according to the grade level?
4. Is there any difference between the environmental attitudes of teacher candidates according to the region lived during their childhood?
5. Is there any difference between the environmental attitudes of teacher candidates according to the environment education course taken?

Method

In the research, descriptive method was used. According to Kaptan (1998), descriptive method describes and clarifies the events, objects, creatures, institutions, groups and different areas. The most important limitation of the research is to select probable based randomized sample group. At the same time, with the use of simple randomized sample, area study was conducted in a short time at different department in Hacettepe University. At this framework, it is aimed to examine the environmental attitudes of teacher candidates in terms of different variables such as department of science, gender, classroom level, the region lived during their childhood and environment education course taken.

Sample of the Research

In the study, 282 teacher candidates are placed from different departments in Faculty of Education in Hacettepe University. 84% female and 16% male teacher candidates have participated in the research (see Table 1). Study group of the research is from Elementary Science-Technology Education, Elementary Mathematics Education and Elementary Classroom Education Departments in Hacettepe University. When the classroom level of them is examined, 50.4% of them are 1st grade and 49.6% of them are 3rd grade. When the region lived in during childhood feature of the sample is examined, 14.5% of teacher candidates lived in village, 12.4% of them lived in town and 73% of them lived in city during their childhood. 41.5% of them have stated that they attended ‘Environment Education’ course and 58.5% of them did not.

Table 1. Demographic features of sample group

Demographic Features		N	%
Gender	Female	237	84.0
	Male	45	16.0
	Total	282	100.0
Department	Elementary Science-Technology Education	133	47.2
	Teacher	65	23.0
	Elementary Mathematics Education Teacher	84	29.8
	Elementary Classroom Education Teacher	282	100.0
	Total		
Grade Level	1stgrade level	142	50.4
	3rd grade level	140	49.6
	Total	282	100.0
Region lived in during their childhood	Village	41	14.5
	Town	35	12.4
	City	206	73.0
	Total	282	100.0
Environment Education Course taken	Taken	117	41.5
	Not taken	165	58.5
	Total	282	100.0

Data Collection Tool

In the original version of NEP scale, all 15 items have strong item-total correlations and yield an Alpha of 83 when combined into a single measure, and it is appropriate to treat them as continuing a single (revised) NEP Scale (Dunlap, Van Liere, Mertig & Jones, 2000). Demirel et al. Found the Cronbach Alpha as 0.72, Taşkın found the Cronbach Alpha as 0.46, Sam et al. Found the Cronbach Alpha as 0.53, Furman found the Cronbach Alpha is 0,60, Günden and Miran found the Cronbach Alpha as 0.62, Erdoğan found the Cronbach Alpha as 0.62. Inthisstudy, the version of Alnıaçık and Koç was used and they found the Cronbach Alpha as 0.68. Alnıaçık and Koç (2009) have conducted the study with 222 university students. Reliability analysis was conducted with Cronbach’s Alpha, and validity test was applied by explanatory factor analysis. The Ecological Paradigm Scale was handled in various validity and reliability studies other than Recreation area. This scale evaluates the attitude of people in order to understand their internalizing anthropocentric attitude with 15 Likert type judgments and a lot of researchers have used it (Dunlap et. al., 2000). At first, there is only one factor in the scale (Dunlap & Van Liere, 1978). However, after a few studies, it is revealed that the scale has more factors (Albrecht, et al., 1982; Arcury, 1990; Geller & Lasley, 1985; Noe & Snow, 1990; Scott & Willits, 1994, Furman, 1998).

Dunlap and other have revised the scale in a research in 2000. P-NEP Scale has 15 items and it is five point Likert type scale. 8 items of the scale (1,3,5,7,9,11,13,15) support ecocentric attitude and other 7 items (2,4,6,8,10,12,14) support anthropocentric attitude. Alnıaçık and Koç (2009), in the research, have stated that there are four factors but there is only one dominant factor and they have not divided the scale into factors. The scale is formed two parts. In the first part, there are questions related to demographic features (Department of science, grade level, region lived in during their childhood and Environment Education course taken or not) and in the second part, there are items in order to determine environmental attitudes level of teacher candidates in the scale. Questions related to the environmental attitude provide opportunity ecocentric and anthropocentric approaches.

Data Collection Process

As data collection tool an attitude scale was used. On the scale form, there are questions related to the demographic features of sample group and items of R-NEP. Scale was applied with the help of four instructors in March-April 2014 and totally, 282 teacher candidates were participated. Sample group has read and answered the items individually.

Data Analysis

In the study, data was acquired throughout the R-NEP scale and analyzed using SPSS 21.0 (Statistical Program for Social Sciences). For the data analyze, t test was used grade level and Environmental Education course taken variables and also One-way ANOVA was used for the department of science and region lived during their childhood variables. Meaning level was determined as p<0.05.

Results and Discussion

This research is conducted to examine the environmental attitudes of teacher candidates in different departments, grade level, region lived in during their childhood and Environment Education course taken. When the answers of teacher candidates are examined in general, it can be clearly seen that ecocentric attitude is wide. Eight items of the scale (1,3,5,7,9,11,13,15) support ecocentric attitude and answers of them mostly change from mildly agree to strongly agree. Other seven items (2,4,6,8,10,12,14) support anthropocentric attitude and answers of them mostly change from mildly disagree to strongly disagree. Findings of t test and One-way ANOVA results are given in Table 2.

Table 2. Mean and standard deviation results of environmental attitudes of teacher candidates according to department of science

	Department of Science	n	$\overline{X}$	sd
Ecocentric Attitude	Department of Elementary Science-Technology	133	33,69	2,92
	Education Department of Elementary Mathematics	65	31,63	5,04
	Education Department of Elementary Classroom Education	84	33,93	3,56
	Department of Elementary Science-Technology Education	133	21,48	3,20
Anthropocentric Attitude	Department of Elementary Mathematics Education	65	21,94	3,64
	Department of Elementary Classroom Education	84	21,95	4,19

When mean and standard deviation values of environmental attitude were examined for ecocentric attitude according to department of science variable of teacher candidates, mean of Department of Elementary Science-Technology Education is 33.69; mean of Department of Elementary Mathematics Education is 31.63 and mean of Department of Elementary Classroom Education is 33.93 (see Table 3).When mean and standard deviation values of environmental attitude were examined for anthropocentric attitude according to department of science variable of teacher candidates, mean of Department of Elementary Science-Technology Education is 21.48; mean of Department of Elementary Mathematics Education is 21.94 and mean of Department of Elementary Classroom Education is 21.95.

Table 3. One-way ANOVA results of environmental attitudes of teacher candidates according to department of science

	ANOVA	Sum of Squares	df	Mean Square	F	p
Ecocentric Attitude	Between Groups	234.66	2	117.33		
	Within Groups	3805.07	279	13.64	8.60	.001
	Total	4039.73	281			
Anthropocentric Attitude	Between Groups	15.21	2	7.60		
	Within Groups	3656.77	279	13.11	.58	.560
	Total	3671.98	281			

p<0.05

When Table 3 is examined there is significant difference between department of science of teacher candidates and ecocentric attitude (p<0.05). According to this result, it can be said that ecocentric attitudes of teacher candidates change according to department of science of teacher candidates. In order to examine which groups have difference “Tukey” was applied. According to this result, between Department of Science-Technology Education, Department of Mathematics Education and ecocentric attitude, there is a difference on behalf of Department of Science-Technology Education. Between Department of Elementary Classroom Education, Department of Mathematics Education and ecocentric attitude, there is a difference on behalf of Department of

Elementary Classroom Education. Also, there is no significant difference between department of science of teacher candidates and anthropocentric attitude (p=0.560). Kahyaoğlu, Daban and Yangın (2008) have also found in their research that teacher candidates from Department of Elementary Social Sciences Education and Department of Elementary Classroom Education have higher environmental attitudes than Department of Science-Technology Education and Department of Mathematics Education teacher candidates (see Table 4).

Table 4. t test results according to grade level of teacher candidates

	Grade level	N	X	SS	df	t	p
Ecocentric Attitude	1st level	142	32.81	3.57	280	-2.14	.033
	3rd level	140	33.77	3.96			
Anthropocentric Attitude	1st level	142	22.35	3.75	280	2.97	.003
	3rd level	140	21.09	3.37			

$p<.05$

When table 4 is examined, there is a significant difference in ecocentric and anthropocentric attitudes according to the grade level of teacher candidates. For the ecocentric attitude, mean of 1st grade level teacher candidates is 32.81 and mean of 3rd grade level is 33.77. According to this result between the grade level, there is a difference on behalf of 3rd grade level (p=0.033). For the anthropocentric attitude, mean of 1st grade level teacher candidates is 22.35 and mean of 3rd grade level is 21.09.

Also, according to this result between the grade level, there is a difference on behalf of 3rd grade level (p=0.003). Işıldar (2009) has found that for ecocentric attitude there is a difference on behalf of 4th grade students. However, there is no significant difference for anthropocentric attitude. Ek, Kılıç, Öğdüm, Düzgün and Şeker (2009) have examined the relationship between environmental attitude and grade level of students in high school and found the mean of 4th grade students is higher.

Despite of this research, Aydın (2010); Sam, Sam and Öngen (2010) stated that there is no significant difference between the grade levels of students on environmental attitudes of them. Sever and Yalçınkaya (2012) have found in their research that grade level has a significant effect on both ecocentric and anthropocentric attitude. For the ecocentric attitude, there is a difference on behalf of 1st grade students and for the anthropocentric attitude; there is a difference on behalf of 2nd grade students. Although students take Environment Education course at 2nd grade, they have anthropocentric attitude than 1st grade. Therefore, it can be said that 2nd grade students have lower environmental consciousness than 1st grades (see Table 5).

Table 5. Mean and standard deviation results of environmental attitudes of teacher candidates according to region lived in during their childhood

	Region Lived in during Their Childhood	n	$\overline{X}$	sd
Ecocentric Attitude	Village	41	33.49	3.69
	Town	35	33.94	3.82
	City	206	33.14	3.81
Anthropocentric Attitude	Village	41	20.88	4.10
	Town	35	21.06	3.45
	City	206	22.01	3.52

When mean and standard deviation values of ecocentric attitude were examined according to region lived in during their childhood variable of teacher candidates, mean of village is 33.49; mean of town is 33.94 and mean of city is 33.14.When mean and standard deviation values of anthropocentric attitude were examined according to region lived in during their childhood variable of teacher candidates, mean of village is 20.88; mean of town is 21.06 and mean of city is 22.01.

Table 6. One-way ANOVA results of environmental attitudes of teacher candidates according to region lived in during their childhood

	ANOVA	Sum of Squares	df	Mean Square	F	p
Ecocentric Attitude	Between Groups	21.41	2	10.71	.743	.476
	Within Groups	4018.32	279	14.40		
	Total	4039.73	281			
Anthropocentric Attitude	Between Groups	61.72	2	30.86	2.385	.094
	Within Groups	3610.26	279	12.94		
	Total	3671.98	281			

p<0,05

When Table 6 is examined, there is no significant difference between region lived in during their childhood of candidate teachers and ecocentric attitude (p=0.476). Also, there is no significant difference between region lived in during their childhood of candidate teachers and anthropocentric attitude (p=0.094). According to this result, it can be said that environmental attitudes of candidate teachers does not change according to region lived in during their childhood of teacher candidates. Despite of this research, Ek and others (2009) have found that there is a significant difference between regions lived in during their childhood of candidate teachers and scores gained from Environmental Attitude Scale on behalf of students lived in city (p=0.005). Şama (2003) has also found that there is a significant difference between regions lived in during their childhood of teacher candidates and there is a positive effect of going from the village to the city with the life period (see Table 7).

Table 7. T test results according to taking the environment education course

	Environment Education Course	N	X	SS	df	t	p
Ecocentric Attitude	Taken	117	34.35	3.27	280	4.07	.000
	Not taken	165	32.53	3.96			
Anthropocentric Attitude	Taken	117	20.97	3.51	280	-3.02	.003
	Not taken	165	22.27	3.60			

p<.05

When table 7 is examined, there is significant difference in ecocentric and anthropocentric attitudes according to taking the Environment Education Course and not variable. For the ecocentric attitude, mean of teacher candidates who takes Environment Education course is 34.35 and mean of teacher candidates who does not take Environment Education course is 32.53. According to this result between taking Environment Education course, there is a difference on behalf of teacher candidates who takes the course (p<0.05). For the anthropocentric attitude, mean of teacher candidates who takes Environment Education course is 20.97 and mean of teacher candidates who does not take Environment Education course is 22.27. For the anthropocentric attitude, it is expected that teacher candidates who take Environment Education course have low mean. Also, according to this result, between taking Environment Education course, there is a difference on behalf of teacher candidates who takes Environment Education course (p=0.003).

Sever and Yalçınkaya (2012) have found in their research that between taking Environment Education course and anthropocentric attitude, there is a significant difference on behalf of teacher candidates who takes the course (t=3,166 p<,05). However, items in anthropocentric factor show low environmental conscious. Because of this reason, low score is expected in items that determine anthropocentric attitude and in this research; anthropocentric attitude is high in the group of students who take Environment Education course as an interesting finding. In order to prevent environmental problems, there is need for effective ways and one of them is Environment Education course. In their research, they have also found significant difference between taking Environment Education course variable on behalf of teacher candidates who take Environment Education course parallel with this research (Ek et al., 2009). Despite of this research, Kahyaoğlu, Daban and Yangın (2008) have found that there is no significant difference between environmental attitudes of teacher candidates and taking the Environment Education course. Also, Erol and Gezer (2006) in their research have found that there is no significant difference between environmental attitudes of teacher candidates and taking the Environment Education course.

Conclusion

Average of the scale item shows us that ecocentric attitude is higher between the sample groups in the research. When the analysis is done, it has been seen that there is significant difference between department of science of teacher candidates and ecocentric attitude. Between Department of Science-Technology Education, Department of Mathematics Education and ecocentric attitude, there is a difference on behalf of Department of Science-Technology Education. Between Department of Elementary Classroom Education, Department of Mathematics Education and ecocentric attitude, there is a difference on behalf of Department of Elementary Classroom Education. Also, there is no significant difference between department of science of teacher candidates and anthropocentric attitude.

There is a significant difference in ecocentric and anthropocentric attitudes according to the grade level of teacher candidates. For the ecocentric attitude, mean of 1st grade level teacher candidates is 32.81 and mean of 3rd grade level is 33.77. According to this result between the grade level, there is a difference on behalf of 3rd grade level. For the anthropocentric attitude, mean of 1st grade level teacher candidates is 22.35 and mean of 3rd grade level is 21,09. Also, according to this result between the grade level, there is a difference on behalf of 3rd grade level.

There is no significant difference between region lived in during their childhood of candidate teachers and ecocentric attitude. Also, there is no significant difference between region lived in during their childhood of candidate teachers and anthropocentric attitude. It can be said that environmental attitudes of candidate teachers does not change according to region lived in during their childhood of teacher candidates.

There is significant difference in ecocentric and anthropocentric attitudes according to taking the Environment Education Course and not variable. For the ecocentric attitude, mean of teacher candidates who takes Environment Education course is 34.35 and mean of teacher candidates who does not take Environment Education course is 32.53. Between taking Environment Education course, there is a difference on behalf of teacher candidates who takes the course ($p=0.000$). For the anthropocentric attitude, mean of teacher candidates who takes Environment Education course is 20.97 and mean of teacher candidates who does not take Environment Education course is 22.27. For the anthropocentric attitude, it is expected that teacher candidates who take Environment Education course have low mean. Also, according to this result, between taking Environment Education course, there is a difference on behalf of teacher candidates who takes Environment Education course. Environment Education course provides students to understand how the environmental knowledge and attitudes are being formed. This education can be added to the curriculum from early childhood to high school in a formal way. Also, Environment Education course should be taken part in every level of education parallel with the development of students (Meydan & Doğu, 2008).

Recommendations

In the light of findings, these can be suggested above:

- In education faculties, effective environment education should be given, education environments should be prepared in order to provide the students' learning by doing and activities should be prepared for students' gaining environment conscious.
- For teacher candidates, Environment Education should be active and programs should be prepared in the light of this point.
- In order to develop ecocentric attitude of teacher candidates, education activities should be revised.
- Environment Education should start from early childhood to high school at every level of education and it should be continue with interdisciplinary approach.
- In education programs, Environment Education should be given step by step and development level of the students should be considered.
- There should be interaction between the societies in order to bring up conscious individuals on environmental issue.

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Identifying the Factors Affecting Science and Mathematics Achievement Using Data Mining Methods

S. Ahmet KIRAY[1*], Bilge GOK[2], A. Selman BOZKIR
[1]Necmettin Erbakan University, [2]Hacettepe University

Abstract

The purpose of this article is to identify the order of significance of the variables that affect science and mathematics achievement in middle school students. For this aim, the study deals with the relationship between science and math in terms of different angles using the perspectives of multiple causes-single effect and of multiple causes-multiple effects. Furthermore, the study examines and reveals how the reading skills, problem solving skills, cognitive and affective variables influence the math and science achievement. The data was collected from the results of Turkish students who participated in three international examinations; TIMSS 1999, PISA 2003 and PISA 2006. We analyzed the data using two data-mining methods (decision trees and clustering). The findings show that science or mathematics achievement is not influenced by the course-specific variable alone but also by other related variables. The following variables are the most important; the students' reading and problem-solving skills affected both mathematics and science achievement; the mathematics achievement affected the science achievement; and the science achievement affected the mathematics achievement. It is also found that the affective variables have almost equally significant effects on the science and mathematics achievement.

Key words: Integrated science and mathematics; data mining; TIMSS; PISA

Introduction

The relationship between science and mathematics has been significant throughout the history of science (Kıray, 2012). Sometimes the work of a mathematician has been the basis of a great scientific invention, and scientific study has led to a new mathematical domain. Until the beginning of the 1700s, both subjects were combined under the heading of natural philosophy (Cahan, 2003) but as a result of the accumulation of knowledge over time, they became independent disciplines. However, since the fields of science and of mathematics are closely related thinking systems (McBride, 1991), an implicit relationship has always naturally existed between them (House, 1990; Berlin, 1991; Kurt & Pehlivan, 2013). "Science provides rich contexts and concrete phenomena demonstrating mathematical patterns and relationships. Mathematics provides the language and tools necessary for deeper analysis of science concepts and applications." (Basista & Mathews, 2002). Therefore, in science and mathematics instruction, in order to achieve the goals of the science course, mathematics should be used, while similarly science topics should be employed in order to make the mathematics topics more concrete (Taşdemir & Taşdemir, 2008). This connection between science and mathematics is inevitably reflected in school curriculums. Courses based on science offered by most schools depend on mathematical skills (Basson, 2002). On the other hand, the mathematics course is supported by the science course in integrating knowledge with everyday experiences.

Science and mathematics courses are usually designed independently but there are many visible attempts to make connections between them in various countries, including in Turkey. This recent attempt is largely a result of the reactions to the achievement levels Turkish students in international examinations such as TIMSS and PISA, which lag behind the international averages. Such examinations provide the participating countries with the opportunity to compare themselves with other countries in terms of science, mathematics and reading scores (Aypay et al, 2007). The overall goal of TIMSS is to improve science and mathematics instruction in different countries by providing data on which instructional programs, instructional activities and school environments lead to higher levels of student achievement (Gonzalez & Miles, 2001). PISA examinations, on the other hand, are administered in order to measure the levels of reading, mathematics and science as well as problem-solving literacy (Shelley & Yildirim). This examination focuses not on the access levels of school curricula but on the knowledge and skills necessary for effective participation in social life (Berberoğlu & Kalender, 2005). At the

* Corresponding Author: *S.Ahmet KIRAY, ahmetkiray@gmail.com*

same time, PISA measures the levels of students in regard to use of the information and skills acquired in the school in the real-life situations (EARGED, 2005). International examinations deal with the scores of science, mathematics, reading and problem solving that are a part of the cognitive domain as well as with some basic characteristics related to achievement. As is widely known, the factors that have impacts on student achievement can be cognitive and/or affective. Research on this topic indicates that student achievement is related to affective characteristics (Oliver & Simpson, 1988; Güngör et al., 2007). Some of the affective characteristics are identified as; interest, self-concept/confidence, self-efficacy, belief, anxiety, self and motivation (Gömleksiz, 2003; Dede & Yaman, 2008).

As stated above, interest is one of the affective characteristics. It is commonly assumed that a prerequisite for learning is being interested in the subject to be learnt. Therefore, the higher the interest in the subject matter, the higher the level of learning achieved (Dewey, 1933; Hizarcı et al., 2005; Erten, 2008). Moreover, interest is known to affect both cognitive and affective processes (Yaman et al., 2008). Interest develops over time and influences the attitude of the individual. In order for a tendency to be a full attitude, the individual should exhibit it for a long period of time (Tavşancıl, 2006). One of the significant goals of science and mathematics education is to develop in students positive attitudes towards science and mathematics. The major reason for students having negative attitudes towards these two courses seems to be lack of interest and motivation (Bilgin, 2006). Both interest and motivation are significant factors in improving the concentration and achievement levels of students. Individuals' interest, attitude, motivation and achievement as well as self-belief are in close interaction with one another.

Self-belief is significantly related to science and mathematics achievement (House, 2004). One aspect of self-belief is self-concept. Self-concept is about how one person perceives himself. "Academic self-concept and school performance strongly interact. When learning experiences are positive, self-concept is enhanced; when they're negative, it suffers" (Eggen & Kauchak, 2001, p.100). On the other hand, self-concept is closely related to self-efficacy. High achievers feel self-efficacious and personally responsible for control of their academic learning process (Zimmerman et al., 1996; Girasoli & Hannafin, 2008). "Efficacy beliefs influence how people think, feel, motivate themselves and act" (Bandura, 1995). A person's level of arousal, whether perceived positively as anticipation or negatively as anxiety, can influence his or her self-efficacy beliefs (Tschannen-Moran & McMaster, 2009). It is commonly argued that anxiety is a multi-dimensional construct (Bursal, 2008) and that it is related to negative attitude, avoidance, background, instructor behaviors, level of achievement, lack of confidence and negative school experiences (Bursal & Paznokas, 2006; Harper & Daane, 1998; Hembree, 1990; Sloan et al., 2002).

Chaos, Fuzzy Logic and Data Mining

Lorenz developed the idea of the butterfly effect as a result of computer-assisted weather forecast calculations in 1963. The idea, a metaphor for chaos theory, is that the flutter of a butterfly in China in March leads to changing the nature of a hurricane that will occur in the Atlantic Ocean in August (Gleick, 1987). Following this idea, scientists today deal with the reasons for the hurricane occurring in the Atlantic Ocean and mathematicians with the mathematical models accounting for the variables leading to the hurricane. Given that the variables leading to the hurricane interact with one another, it is quite clear that such a cause-effect relationship cannot be linear. Furthermore, such a relationship cannot be understood following double logic. "Fuzzy logic" developed by Zadeh (1965) is an alternative approach in that it suggests that almost none of the systems in real life are linear. A fuzzy set is the most basic element of fuzzy systems. A fuzzy set is one in which there are elements with varying levels of membership or of belonging. The membership value of the elements that do not belong to the set is 0 while the membership value of those elements that are full members of the set is 1. For those elements whose membership status is not clear, membership values ranging between 0 and 1 are assigned (Altaş, 1999). Advances in computer science have made it possible for the theory of the fuzzy set depending on fuzzy logic to be used commonly.

One of these areas is data mining, in which chaos theory and fuzzy logic are employed to identify the relationships among data (Alataş & Akın, 2004). Data mining is a multidisciplinary tool that helps scientists to discover the designs, relationships, modifications, irregularities, rules and statistically significant patterns within the data and aims at predicting the results as well as implicit relationships within the data sets (Mitra et al., 2002; Alataş & Akın, 2004). Data mining is the process of exploration and analysis, by automatic or semi-automatic means, of large amounts of data in order to find out useful patterns and rules (Berry & Linoff, 2000). In essence, data mining is the center of KDD (Knowledge Discovery in Databases). KDD is the overall process that involves all the stages of distilling data into information, and is better known by the more popular term 'data mining' (Miller & Han, 2001). KDD contains some important steps, as shown in Figure 1. This process consists of a series of transformation steps, from data preprocessing to evaluation/interpretation of data mining results. The purpose of preprocessing is to transform the raw input data into an appropriate format for subsequent analysis. The stages involved in data preprocessing include fusing data from multiple sources, cleaning data to remove noise and duplicate observations, and selecting records and features that are relevant to the data mining task at hand (Tan et al., 2005). The KDD process is given below.

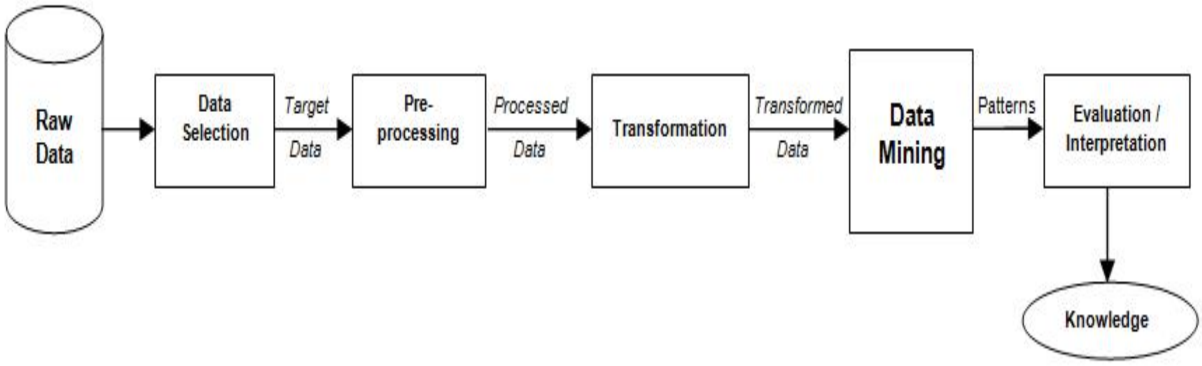

Figure 1. The KDD process (adapted from Mitra et al., 2002)

Aim of the Study

"Philosophically and theoretically, there is strong support for the integration of science and mathematics teaching and learning as a way to improve and enrich the science and mathematics learning experiences" (Berlin 1991). If teachers are aware of which variables affect students' science and mathematics achievement, they may be able to tackle some of the causes of underachievement. Sometimes these effects can be seen with the linear models that emerge from positivist philosophy. However, human beings and their learning processes are very complex. Hermeneutic philosophers (suh as Kuhn) are opposed to linear thinking processes, arguing instead for chaos and fuzzy logic (Perla & Carifio, 2005). In regard to accounting for levels of achievement/underachievement in science and mathematics courses, Lorenz's (1963) idea of the butterfly effect means that all variables, including those that have been regarded as irrelevant and those that have very minimal effects on student achievement, should be taken into consideration. If the flutter of a butterfly causes many events, or the reasons for the hurricane are various not single, then can the same reasoning be valid for educational situations? In this context, a student's math anxiety may affect his science achievement, or the efficacy problems experienced by a student in regard to science may influence his mathematics achievement. Similarly, positive attitudes towards mathematics developed as early as the elementary education years may have an impact on later science achievement. In the same vein, high levels of motivation towards science may positively affect later mathematics achievement (Kıray, 2010).

On the other hand, the reason for underachievement may be a student's poor reading and problem-solving skills. Furthermore, science achievement may be a result of mathematics achievement. If we are to improve the science or mathematics achievement levels, can we realize it by focusing on just the content of one of these courses? Considering both courses in a parallel way may guide our attempts to improve the achievement levels in these two courses. If there is a non-linear relationship between science and mathematics leading to the butterfly effect, variables belonging to the affective domain and basic skills such as reading and problem solving may significantly affect this relationship. In order to uncover these relationships, not the classical logic but fuzzy logic should be employed. Understanding these relationships can benefit from the administration of examinations at different time periods in terms of the variable of time. Large-scale data that represent country samples can contribute to these relationships in terms of the variable of position. In the current study, we used data on international examination results that offer large-scale data about Turkey and that were obtained at different time periods. This study is limited to courses in science and mathematics, which have been considered to be closely related to each other historically and in terms of their nature and the factors affecting the achievement levels in these courses. The aim of the study is to determine the order of significance of the factors influencing the achievement levels in science and mathematics courses using data mining methods. Given that changes in the initial conditions of one variable affect the other variables, it is assumed that this relationship is non-linear. The data obtained from three distinct international examinations are used to identify the significance order in the non-linear relationship. Therefore, the study has been designed at two distinct patterns in order to search for single cause-multiple effects and multiple causes-multiple effects. The research questions that we will attempt to answer through the study are as follows:

1-When only the science achievement is considered as a predictable variable, what is the significance order of the variables having an impact on this achievement?
2-When only the mathematics achievement is considered as a predictable variable, what is the significance order of the variables having an impact on this achievement?
3-When both the science and mathematics achievement is considered as a predictable variable, what is the significance order of the variables having an impact on this achievement?

Method

The data used for the study were collected from the TIMSS 1999, PISA 2003 and PISA 2006 examinations that were administered to Turkish students in the 15-year age group. The variables examined in the study are given in Table 1. The variables given in Table 1 are analyzed through the use of data mining methods.

Table 1. Variables examined in the whole study

Exam Name	Variable name	Description
TIMSS 1999	Bsmmat01	Mathematics achievement
TIMSS 1999	Bsssc01	Science achievement
TIMSS 1999	Bsbmgood	Motivation to math
TIMSS 1999	Bsbsgood	Motivation to science
TIMSS 1999	Intscie	Interest, importance and value science
TIMSS 1999	Intmat	Interest, importance and value math
TIMSS 1999	Bsdmcmai	Index of confidence in math ability
TIMSS 1999	Bsdscsai	Index of confidence in science ability
TIMSS 1999	Bsdmpatm	Attitude to math
TIMSS 1999	Bsdspats	Attitude to science
PISA 2003	Pv1mat	Mathematics achievement
PISA 2003	Pv1scie	Science achievement
PISA 2003	Pv1prob	Problem solving achievement
PISA 2003	Pv1read	Reading achievement
PISA 2003	Mateff	Math self-efficacy
PISA 2003	Anxmat	Math anxiety
PISA 2003	Intmat	Interest in math
PISA 2003	Scmat	Math self-concept
PISA 2006	Pv1scie	Science achievement
PISA 2006	Pv1read	Reading achievement
PISA 2006	Pv1mat	Mathematics achievement
PISA 2006	Intscie	General interest in learning science
PISA 2006	Scieff	Science self-efficacy
PISA 2006	Scscie	Science self-concept

Data Preparation and Applying Data Mining Methods

The understanding and the preparation stages are among the most important steps in the data mining applications (Delen et al., 2005). At the start of this study, three datasets which contain the data of TIMSS 1999 and PISA 2003/2006 exams were exported to SQL Server database from SPSS. At the same time, unnecessary variables in the dataset were excluded. The TIMSS 1999 data that we used in the analysis consisted of eight inputs and two predictable variables as well as 7163 records. These variables and their properties are listed in Table 2.

Table 2. Types and usage parameters of variables included in the TIMSS 1999 dataset

Variable Name	Type	Model 1 Usage	Model 2 Usage	Model 3 Usage
BSMMAT01	Numeric	Predict Only	Input	Predict
BSSSCI01	Numeric	Input	Predict Only	Predict
BSBMGOOD	Discrete	Input	Input	Input
BSBSGOOD	Discrete	Input	Input	Input
BSDMCMAI	Discrete	Input	Input	Input
BSDSCSAI	Discrete	Input	Input	Input
INTMAT	Discrete	Input	Input	Input
INTSCIE	Discrete	Input	Input	Input
BSDMPATM	Discrete	Input	Input	Input
BSDSPATS	Discrete	Input	Input	Input

Likewise, the PISA 2003 dataset has six inputs, two predictable variables and 4855 records. Similarly, the PISA 2006 dataset has four inputs, two predictable variables and 4942 records. PISA 2003/2006 variables and their properties are given in Table 3 and Table 4 respectively.

Table 3. Types and usage parameters of variables included in the PISA 2003 dataset

Variable Name	Type	Model 1 Usage	Model 2 Usage
Anxmat	Numeric	Input	Input
Intmat	Numeric	Input	Input
Matheff	Numeric	Input	Input
Pv1math	Numeric	Predict Only	Predict
Pv1prob	Numeric	Input	Input
Pv1read	Numeric	Input	Input
Pv1scie	Numeric	Input	Predict
Scmat	Numeric	Input	Input

In order to carry out the research, Microsoft SQL Server 2008 Analysis Services software is chosen as the analyzing platform as it supports regression trees (the continuous variable version of decision trees). Since the goal of this data mining study is to develop models that can be used to discover the relationships of science and mathematics achievement, a decision tree, a well-known classification technique, and clustering, a descriptive data mining technique, were used simultaneously during the analysis. In addition, Microsoft SQL Server Analysis Services employs its own decision tree algorithm (Microsoft Decision Trees) and clustering algorithm (Microsoft Clustering). The Microsoft Decision Trees algorithm supports both discrete and continuous valued variables/attributes as the predictable variable. Another reason for selecting this algorithm and software is that these can build dependency network graphs which indicate the influences of independent variables on predictable variables. The dependency network graphs display the relationships among variables derived from the content of the decision tree model. Each node in the graph represents one variable, and each edge represents the relationship between two nodes (Tang & MacLennan, 2005).

Table 4. Types and usage parameters of variables included in the PISA 2006 dataset

Variable Name	Type	Model 1 Usage	Model 2 Usage
Scieeff	Numeric	Input	Input
Pv1math	Numeric	Input	Predict
Pv1intr	Numeric	Input	Input
Pv1read	Numeric	Input	Input
Pv1scie	Numeric	Predict Only	Predict
Scscie	Numeric	Input	Input

The decision tree is a data mining approach that is often used for classification and prediction. Although different techniques, such as neutral network, can also be employed for classification purposes, decision tree methodology has the advantages of easy interpretation and understanding for decision makers to compare with their domain knowledge for validation and to justify their decisions (Chien & Chen, 2008). In addition, there are a few advantages of using decision trees over using other data mining algorithms, for example, decision trees are quick to build and easy to interpret and prediction based on decision trees is efficient (Tang & MacLennan, 2005). Hence, the decision tree models shown below are created for each dataset for the purpose of this study, and then the results were converted into tables.

As the purpose of analysis of the TIMSS data is to discover the factors influencing achievement in science and math, we produced three models for different goals. The first model focuses on factors that affect math achievement, so only the Bsmmat01 variable was marked as predictable. Similarly, the second model is focused on science achievement. Therefore the Bsssci01 variable was marked as “predictable” the same as in the first model. However, the third model’s aim is to investigate science achievement as a factor influencing mathematics and vice versa. Hence the Bsmmat01 and Bsssci01 variables were both marked as “predictable” in the third model. All the other variables are used as input variables and all the initial parameters of Microsoft Decision Trees algorithm are kept in default settings, so no special manipulation is done over the dataset and pure results are revealed. After the stage of model creation, we created seven decision tree models. We obtained the order of influencing factors (variables) on the predictable variables via dependency network graphs. We used a similar approach in analysis of the PISA 2003 and PISA 2006.

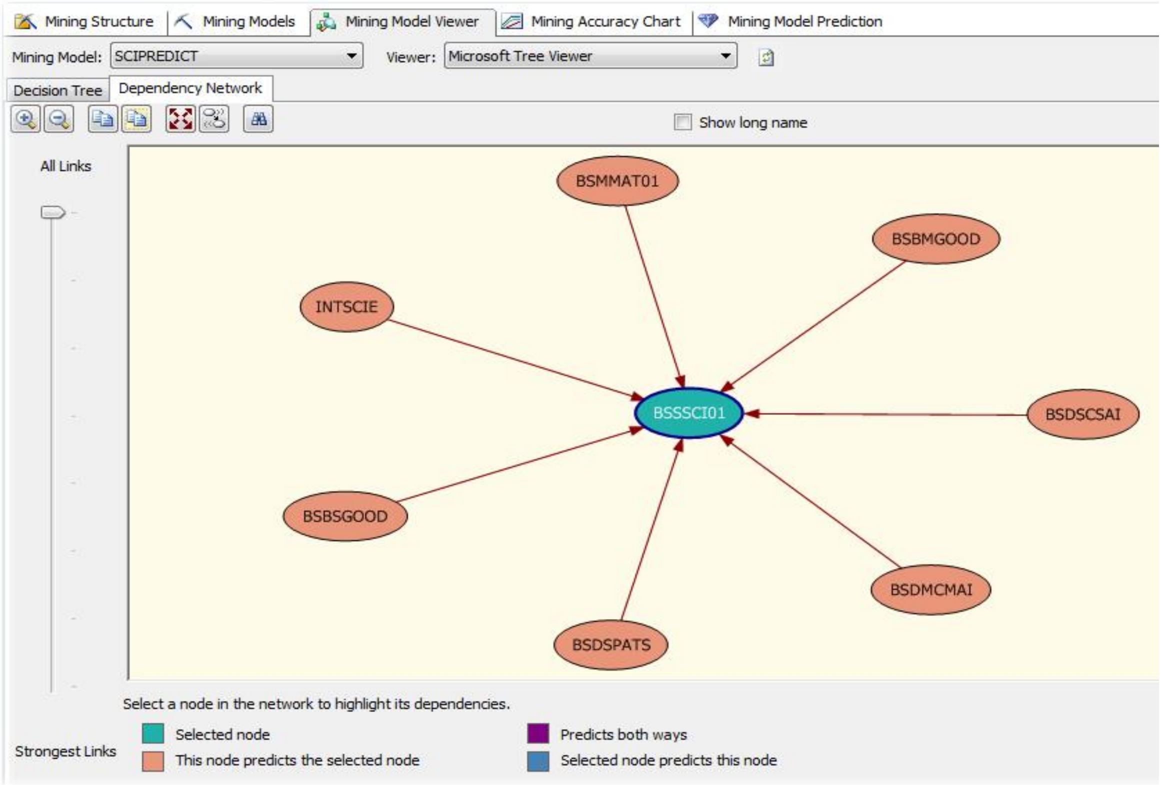

Figure 2. Variables affecting the science achievement

On the other hand, the aim of clustering is to find groups of closely related observations so that observations that belong to the same cluster are more similar to each other than observations that belong to other clusters (Tan et al., 2005). Clustering is a useful technique for the discovery of some knowledge from a dataset. It is an exploratory method for helping to solve classification problems. Its use is appropriate when little or nothing is known about the category structure in a body of data. The objective of clustering is to sort a sample of cases under consideration into groups such that the degree of association is high between members of the same group and low between members of different groups (Chiu et al., 2009). Assigning cases to clusters is one of the most significant differentiators in clustering algorithms. The Microsoft Clustering algorithm serves two distinct techniques in clustering; *K-means* and *expectation maximization* (EM). In the K-means method, every case is assigned to one and exactly one cluster, whereas the EM method uses a probabilistic approach to assign clusters. Thus, a case does not have to be a member of a single cluster (soft clustering) as in the K-means approach (hard clustering) (Tang & MacLennan, 2005).

The data we used in both the decision trees and clustering studies is TIMSS 1999, PISA 2003 and PISA 2006 data from Turkey. In the clustering phases of study, we employed the EM algorithm. To gain natural clusters, we set the "Cluster_Count" parameter of the algorithm to "0", meaning automatic and natural clustering. During the clustering phase, ten clusters were derived from the PISA 2003 and TIMSS 1999 datasets, and nine clusters from the PISA 2006 dataset.

Results

The variables used in the study are taken as predictable variables together either with only the science score or with only the mathematics (or math) score or with both scores based on the properties of the related exams and were then analyzed by means of both decision tree and clustering techniques. The results obtained are given below in chronological order of the examinations.

TIMSS 1999 Examination

Predictable Variable: Science (TIMSS 1999)

Table 5 was completed using a dependency network together with a decision tree, and shows the most dominant variables as well as the most recessive ones. This order of significance is given in Table 5. With the science achievement score (Bsssci01) taken as the single predictable variable, the order of significance for the variables having an impact on it is given in Table 5. It can be seen that the most dominant variable on the science achievement score is the mathematics achievement score (Bsmmat01). Although the math interest (Intmat) and math attitude (Bsdmpatm) values are considered to be variables, they are empty in Table 5 and no effect of them on the science achievement score is observed.

Table 5. Order of significance for the variables affecting only science achievement score in TIMSS 1999

Predictable Variable	Order of Predictors									
	BSM-MAT01	BSS-SCI01	BSB-MGOOD	BSB-SGOOD	BSD-MCMAI	BSD-SCSAI	INT-MAT	INT-SCIE	BSD-MPATM	BSD-SPATS
BSSSCI01	1		5	3	4	2		7		6

Predictable Variable: Mathematics (TIMSS 1999)

Table 6 was completed using a dependency network together with a decision tree, and shows the most dominant variables as well as the most recessive ones. This order of significance is given in Table 6. With the math achievement score taken as the single predictable variable, the order of significance for the variables having an impact on it is given in Table 6. Although science interest (Intscie), math attitude and science attitude (Bsdspats) values are considered to be variables, they are empty in Table 6 and no effect of them on the math achievement score is observed.

Table 6. Order of significance for the variables affecting only math achievement score in TIMSS 1999

Predictable Variable	Order of Predictors									
	BSM-MAT01	BSS-SCI01	BSB-MGOOD	BSB-SGOOD	BSD-MCMAI	BSD-SCSAI	INT-MAT	INT-SCIE	BSD-MPATM	BSD-SPATS
BSMMAT01		1	3	4	2	5	6			

Predictable Variables: Science and Mathematics (TIMSS 1999)

Table 7 was obtained using a dependency network together with a decision tree and shows the most dominant variables as well as the most recessive ones. This order of significance is also given in Table 7. When the science and math achievement scores are taken as the single predictable variables, the order of significance for the variables having an impact on them is given in Table 7. This table clearly indicates that the math achievement score is the dominant variable on the science achievement score. It is also seen that there is no empty column except for where both achievement scores overlap. When both achievement scores are regarded as predictable variables, all of the variables appear to be significant. In addition to the order of significance for variables extracted from dependency networks derived from the decision trees, the common characteristics of the students who participated in the exams are studied as well as the correlations among variables, which are analyzed via the clustering study. In the clustering study, the students are grouped considering the same input variables as in the decision tree analysis phase. The clusters of student characteristics can then be analyzed with the help of the "clustering profile viewer" of the Microsoft Analysis Services program (Figure 2).

Table 7. Order of significance for the variables affecting both science and math achievement score in TIMSS 1999

Predictable Variables	Order of Predictors									
	BSM-MAT01	BSS-SCI01	BSB-MGOOD	BSB-SGOOD	BSD-MCMAI	BSD-SCSAI	INT-MAT	INT-SCIE	BSD-MPATM	BSD-SPATS
BSSSCI01	1		16	10	15	5	14	6	8	9
BSMMAT01		2	3	7	4	13	12	18	17	11

When TIMSS 1999 clustering results and Bsmmat01 providing the math achievement status as well as Bsssci01 providing the science achievement status are taken into consideration, it is seen that high and low achievers in the fields of science and math are members of the same clusters (see Fig. 3). Although the other variables belonging to this dataset are used as inputs, they are not given in the results since they are not metrics that can be used as measures of achievement.

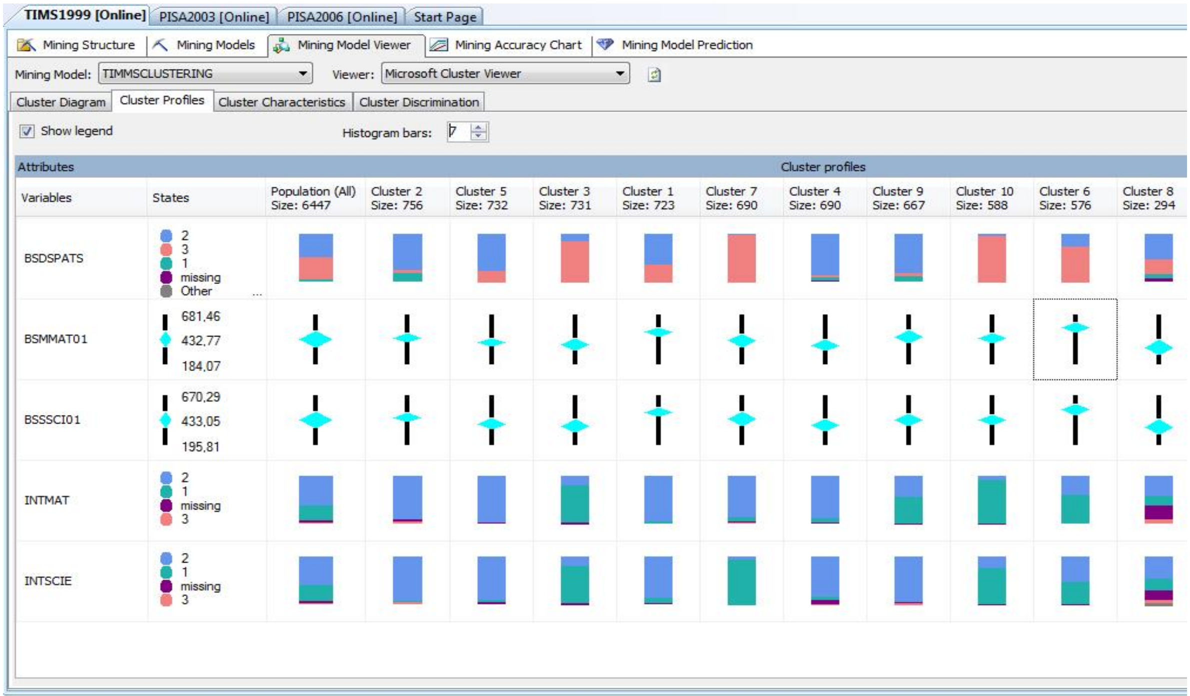

Figure 3. TIMSS 1999 clustering technique outcomes

PISA 2003 Examination

Predictable Variable: Mathematics (PISA 2003)

Table 8 was completed using a dependency network together with a decision tree and shows the most dominant variables as well as the most recessive ones. The math achievement score (Pv1math) is taken as the predictable variable in the model. The order of significance for the other variables affecting it is given in Table 8. The PISA 2003 examination focuses largely on the capability of students in regard to the mathematics course. Therefore, the exam includes only those cognitive and affective variables that are considered to be related to mathematics. In regard to the science course, only the achievement score is included but the other related variables are not covered. Table 8 indicates that the most dominant variable affecting the math achievement score is the math self-concept score, while the other variables included by the exam coverage as well as in the current study appear to be significant in accounting for the math achievement.

Table 8. Order of significance for the variables affecting math achievement score in PISA 2003

Predictable Variable	Order of Predictors							
	Pv1prob	Pv1math	Pv1read	Scmat	Matheff	Anxmat	Pv1scie	Intmat
Pv1math	2		3	1	6	4	5	7

Predictable Variables: Science and Mathematics (PISA 2003)

Table 9 was completed using a dependency network together with a decision tree and shows the most dominant variables as well as the most recessive ones. When both math and science achievement scores are taken as the predictable variables in the decision tree model, the order of significance for the other variables affecting them appears as given in Table 9. It is clearly shown that the most dominant variable on science achievement is the variable of problem-solving skill. It is also seen that there is no empty column except for where both achievement scores overlap in Table 9. When both math and science achievement scores are taken as the predictable variables, all variables included in the study appear to be significant in accounting for the achievement levels.

Table 9. Order of significance for the variables affecting math and science achievement in PISA 2003

Predictable Variable	Order of Predictors							
	Pv1prob	Pv1math	Pv1read	Scmat	Matheff	Anxmat	Pv1scie	Intmat
Pv1scie	1	2	3	13	6	11		14
Pv1math	5		7	4	10	8	9	12

In addition to the order of significance for variables developed through dependency networks which are derived from the decision trees, using clustering technique we analyzed which variables have correlations. When natural sets of the students are analyzed, there appears no direct, linear correlation between math achievement/underachievement and science achievement/underachievement.

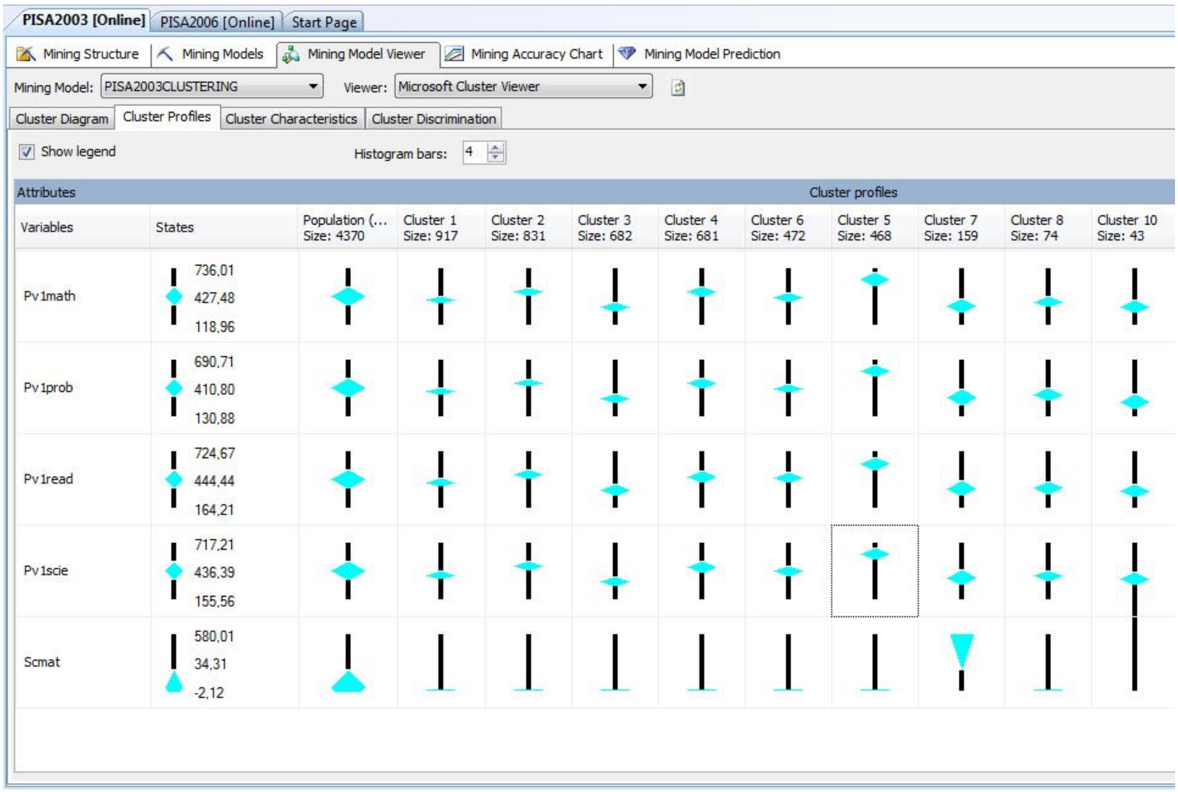

Figure 4. PISA 2003 clustering technique outcomes

The clustering study for the PISA 2003 examination data indicates that the level of achievement has the same trend in the highest achievement and lowest achievement sets both in math and science (see Fig. 4). The highest achievers in math appear to be the highest achievers in science also (Cluster 5). Similarly, other sets also show the achievement correlation between math and science. Additionally, the input variables of Pv1prob and Pv1read are also found to be parallel with the math and science achievement. Although other input variables are used in the dataset, these variables appear not to lead to significant differences from one set to another so that these inputs are excluded from the findings.

PISA 2006 Examination

Predictable Variable: Science (PISA 2006)

When science achievement (Pv1scie) is used as the predictable variable, the order of significance for the other variables affecting it appears as given in Table 10. The PISA 2006 examination focuses largely on the capability of the students in regard to the science course. Therefore, the examination includes only those cognitive and affective variables that are considered to be related to science. In regard to the math course, only the achievement score is included but the other related variables are not covered. It is clearly shown in Table 10 that the most dominant variable on the science achievement score is that of reading score. All of the other variables included by the exam coverage as well as in the current study also appear to be significant in accounting for the science achievement.

Table 10. Order of significance for the variables affecting science achievement in PISA 2006

Predictable Variable	Order of Predictors				
	Pv1read	Pv1math	Scscie	Scieeff	Intmat
Pv1scie	1	2	3	4	5

Predictable Variables: Science and Mathematics (PISA 2006)

Table 11 was completed using a dependency network together with a decision tree and shows the most dominant variables as well as the most recessive ones. In this study, both math and science scores are considered as predictable variables. The order of significance for the other variables affecting them is given in Table 11. Table 11 shows that the most dominant variable on the science achievement score is that of reading skill, whereas the variable of science interest is the least significant variable on the math achievement score. However, it is also seen that there is no empty column in Table 11 except for where both achievement scores overlap. When both math and science achievement scores are taken as the predictable variables, all variables included in the study appear to be significant in accounting for the achievement levels.

Table 11. Order of significance for the variables affecting math and science achievement in PISA 2006

Predictable Variable	Order of Predictors					
	Pv1read	Pv1math	Scscie	Scieeff	Pv1scie	Intscie
Pv1scie	1	2	3	4		9
Pv1math	5		7	6	8	10

As in the studies already discussed, at this stage students are grouped and the correlation between achievement and underachievement levels of those in the same set is analyzed. The findings obtained from the PISA 2003 dataset are also found in the PISA 2006 dataset when analyzed in a clustering study (see Fig. 5). When the variables of reading skill (Pv1read), science achievement (Pv1scie) and math achievement (Pv1math) are taken into consideration, it appears that there is a significant correlation between them. Furthermore, achievement and underachievement in regard to mathematics, science and reading are parallel (see Cluster 7 at Fig. 5).

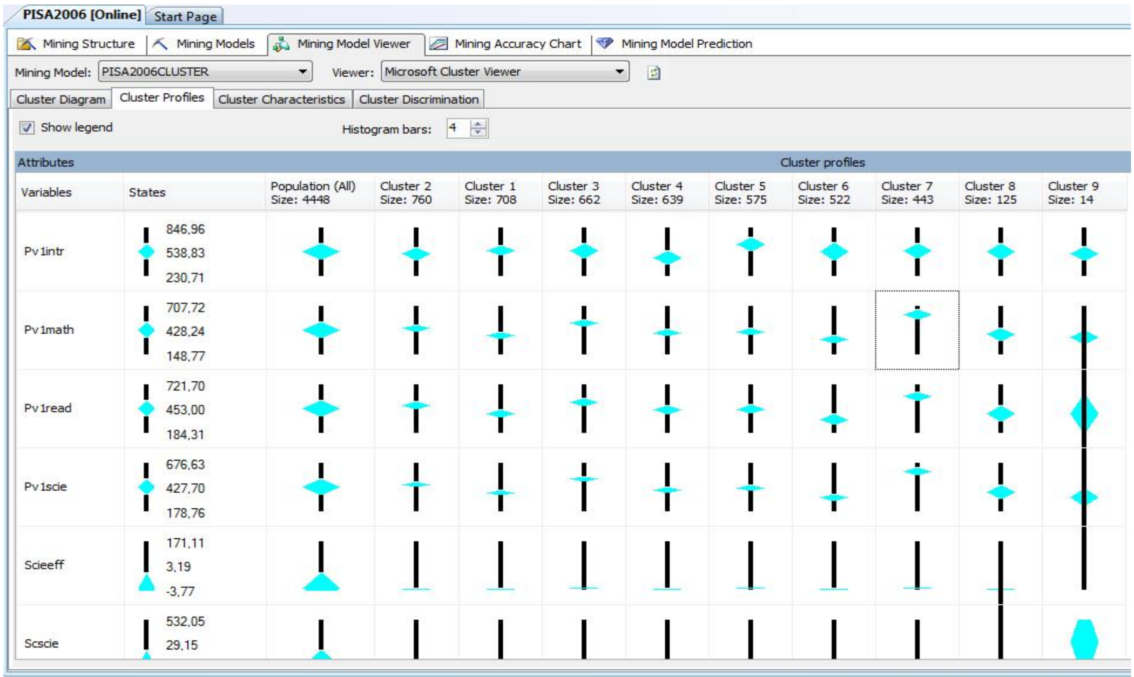

Figure 5. PISA 2006 clustering technique outcomes

Discussion

Correlation among Variables Related to Cognitive Domain and Skills Covered in the International Examinations

Correlation between Science Achievement and Math Achievement

When the findings obtained from the three examinations mentioned above are analyzed, it is seen that there is a close correlation between science achievement and math achievement. Clustering outcomes indicates strongly that this correlation is interactive, suggesting that if any student is an underachiever in either of the courses, he or she is also an underachiever in the other, or that if any student is successful in either of the courses, he or she is also successful in the other. These findings are consistent with those of the other studies, such as Wright and Corin (1999), Güleç and Alkış (2003), Wang (2005), Taşdemir and Taşdemir (2008) and Uzun, Bütüner and Yiğit (2010), suggesting that there is a strong, positive correlation between science achievement and math achievement. However, when the findings of the dependency network developed through the decision tree study are analyzed, it is found that the effect of the math achievement on the science achievement is higher than the effect of the science achievement on the math achievement. Nevertheless, one of the most dominant variables on the math achievement is the variable of science achievement, whereas one of the most dominant variables on the science achievement is the variable of math achievement. One of the potential reason for this finding seems to be the fact that a successful math student may also be successful in the science course since the latter is closely related to and depends on the math course. On the other hand, in regard to science achievement, some subfields in science (biology, earthscience etc.) may require more use of reading skills, interpretation and inference skills than the use of mathematical skills. Therefore, since these subfields in science have different structures, science achievement may have less significance in accounting for math achievement. In the same vein, Sloutsky, Kaminski, and Heckler (2004, 2005) and Kıray and Kaptan (2012) conclude that integrating and using abstract math concepts within concrete science topics increases student achievement. They also conclude that the transfer of abstract concepts into concrete concepts is much more effective than the transfer of concrete concepts into abstract concepts and that the transfer of abstract concepts into concrete concepts does not have any negative outcome. They also report that math achievement is much more effective in accounting for science achievement. In other words, science achievement is found to be less effective in explaining math achievement. One of the potential reasons for this finding is that, since mathematics has an abstract structural nature whereas the nature of science is largely concrete (Bassok & Holyoak, 1989), the transfer of abstract into concrete is much more influential than the transfer of concrete into abstract. Another possible reason is that mathematics is necessarily employed in the science course and therefore it affects the learning of mathematics. Recent science and mathematics programs used in Turkey and in other countries indicate the fact that many subfields of mathematics are extensively employed in the science course, particularly in physical sciences (Mehmetlioglu & Ozdem, 2014). The other relevant point is related to the development of math and science programs. Since math programs are usually developed based on the assumption that the content of the math course is learnt first, and then it is transferred into the science course, the math achievement is able to be much more influential in accounting for the science achievement.

Correlation between Science/Math Achievement and Reading Skills

The analyses of the PISA 2003 and PISA 2006 datasets clearly indicate that science/math achievement and reading skill are closely related. Clustering outcomes strongly suggest that this correlation is interactive, suggesting that if the reading score of a student is higher, then he or she will be successful in either of the courses, but if the reading score of a student is lower, then he or she will not be successful in either of the courses. On the other hand, when the findings of the dependency networks developed through decision tree studies are analyzed, it is found that the effects of the reading skills on science achievement are much more influential, in contrast to their effects on the math achievement. Thus, it is safe to argue that reading skill is the most significant predictor of science achievement. This finding is consistent with that of Ireland’s study (1987), which proposes that there is a high positive correlation between reading performance and science achievement.

These findings of the current study clearly suggest that reading skill is much more significant for science achievement in comparison with both math achievement and problem-solving skill. These findings seem to be consistent with the finding of Friend (1985), who argues that the reading score is much more influential in predicting science achievement than is the math achievement score.

When the science and math items of the PISA examinations are taken into consideration, it is seen that students are largely asked to answer the science questions using a text provided in the exam paper and also to justify their answers using their own reasoning (EARGED, 2005). Therefore, the skills of understanding what they have read and of developing interpretations become much more significant in answering the questions in science examinations. Moreover, some science items, especially given in the form of reading text could be offered as language items instead of being science items. Therefore, because of the nature of the science items, reading skill may be one of the critical predictors of science achievement. The overall goal of the Turkish science and technology program is to provide students with new information acquired through reading and discussions. This program contains four distinct learning areas that are all concerned with the cognitive domain (MEB, 2005). Reading skills are significant in all of these areas of the science and technology program, but the skills of understanding what they read and of developing interpretations seem to be much more critical in the learning areas of “living beings and life” and “the earth and the universe”. The possible reason for reading skills being the most critical predictor of science achievement may be the fact that reading skills are the basic skills for learning all of the other subject matters and that these skills are dominant capabilities in two learning areas of the science program. The first step towards solving problems is to understand correctly the problem to be solved (Polya, 1945). Math items included in the PISA examinations, on the other hand, require the students to understand the problems correctly. Thus, reading skills may be strong predictors for math achievement. However, the problems in math items are not written as text so they depend more on problem-solving skills than reading ability. Therefore, although reading skills are also strong predictors of math achievement, reading skills are much stronger predictors of science achievement.

Correlation between Science/Math Achievement and Problem-Solving Skills

The findings obtained from the PISA 2003 examination dataset clearly indicate that both science and math achievement are closely related to problem-solving skills. Clustering outcomes further suggest that both math scores and science scores change depending on changes in the scores for problem-solving skills. In other words, a student with a higher score for problem-solving skills appears likely to be successful in both courses, whereas a student with a lower score for problem-solving skills appears likely to be an underachiever in both courses. This finding of the current study seems to be consistent with the findings of previous studies suggesting that such skills as problem-solving and reasoning are the common skills necessary for both science and mathematics (Berlin & White, 1994; Davison et al., 1995; Lederman & Niess, 1998; Kıray, 2010). On the other hand, the findings obtained from the dependency networks that are derived from decision tree study clearly indicate that the effect of problem-solving skill on science achievement is much more influential in comparison with its effects on math achievement. Therefore, although problem-solving skill is one of the most dominant predictors for mathematics achievement since it is among the basic skills for the mathematics course, it is also the strongest predictor for science achievement. This specific finding of the current study is consistent with that of Kıray's study (2003), which found that those students who known the problem-solving steps developed by Polya in science course were much more successful in solving problems than those students who did not know these problem-solving steps. Math problems can be categorized as follows: ordinary problems that are commonly included in the math textbooks and that require the use of four basic math operations, and real-life problems that require the skills of organizing and classifying the data and the skill of recognizing the relationships and that express a real-life situation or a potential real-life event (Altun, 2008; Mataka, Cobern, Grunert, Mutambuki, & Akom, 2014). The PISA 2003 examination includes real-life based problems not ordinary math problems. Therefore, it asks the students to use related problem-solving skills for real-life problems. Such skills put emphasis on the skills of decision making when facing a complex real-life problem, as well as reasoning skills (EARGED, 2005). Given the nature of the Turkish science and technology programs, such item types seem to be more appropriate for eighth- and ninth-grade science contents. Thus, level of problem-solving skills appears to be a much more significant predictor for science achievement rather than for math achievement.

Correlation between Affective Variables Covered by the International Examinations and Science/Math Achievement

Self Concept

The findings of the dependency networks developed through decision tree studies in which math achievement is taken as the predictable variable suggest that the most significant affective predictor for math achievement is math self-concept (Scmat), whereas the effect of science self-concept (Scscie) on math achievement is less significant. This finding of the current study is consistent with that of Wang (2007), who analyzed the findings of the TIMSS 1995, 1999 and 2003 examinations and found that "there was a non-monotonic change in the reciprocal relationship between mathematic self-concept and mathematics achievement" and correspond with that of Manger and Eikeland (1998), and Barkatsas, Kasimatis and Gialamas (2009), who found that mathematics self-concept/confidence is an important variable accounting for mathematical achievement. The national report issued by EARGED (2003) states that students who believe that they are underachievers in the math course develop feelings of helplessness and increase in the level of such feelings causes decrease in the level of achievement. One of the reasons math self-concept is influential on achievement levels may be the students' past experience which leads to their feelings of helplessness.

The findings of the dependency network in which science achievement is taken as the predictable variable suggest that science self-concept is the most significant affective predictor for science achievement while math self-concept has an average effect on it. Various studies such as Oliver and Simpson (1988), Byrne (1996), Guay, Marsh, and Boivin (2003), Wilkins (2004), and Aypay, Erdoğan, and Sözer (2007), also reach a similar conclusion that there is a positive correlation between students' science achievement and their science self-concept. The national report on the TIMSS 1999 examination also argues that both math and science self-concept\confidence variables seem to be the most influential factor in accounting for the achievement levels (EARGED, 2003). The findings of the current study also support this argument.

The findings of our study in regard to the TIMSS and PISA examinations suggest that the achievement level in any subject is most strongly influenced by the related self-concept, which is an affective variable. Additionally, self-concept in science and in mathematics, respectively, appear to be strong predictors of achievement both its own field and in the other one. However, the effect on the other is less in the three examinations in regard to the effect of the field's own self-concept. The finding of the current study in regard to the effects of the math self-concept on science achievement and also the effects of the science self-concept on the math achievement is consistent with the argument of Marsh (1992) that self-concepts in different areas have impacts on the performance in different areas. Based on this finding, it is possible to argue that self-concept/confidence in one course affects not only the achievement level in that course but also affects the achievement level in other related courses.

Brookover, Thomas, and Peterson (1964) identified a positive correlation between self-concept and achievement in specific subject matter (cited in Labenne & Greene, 1969). "Although researchers find a moderate relationship between academic self-concept and achievement, the strongest correlations exist between specific academic self concepts and their corresponding subject matter areas" (Eggen & Kauchak, 2001, p.100). Although the findings of the dependency networks suggest that a specific self-concept is the most significant predictor for achievement in the related subject matter, the analysis of the clustering findings based on the association rule shows that the relationship between self-concept and science or math achievement is less significant than the relationship between reading and problem-solving skills and science or math achievement. This may be a result of the fact that self-confident students either in science or in mathematics encounter a different examination pattern in the international examination that is largely distinct from the nature of examinations administered in their schools. It may be argued further that although self-concept is a very significant predictor for achievement; it may be affected by changes in the positional and temporal conditions. Thus, students with higher self-concept scores may not be successful when the conditions are significantly changed or students with lower self-concept scores may be successful when the conditions are significantly changed.

Interest

Analysis of affective variables clearly indicates that among the affective variables, the one that has least effect on the achievement levels is the variable of interest. However, since one of the prerequisites for learning is interest in the subject matter, it may account for achievement in the related course. The finding of this study is consistent with the argument of Güngör, Eryılmaz, and Fakıoğlu (2007) that there is a positive relationship between interest and achievement. On the other hand, in the current study the variables of interest in mathematics and interest in science that refer to interest towards mathematics (Intmat) and interest towards science (Intscie), respectively, are excluded in the single cause-multiple effects relationship since they appear to have minimal effects on the achievement levels due to the specific nature of the program employed in the study.

The findings of the dependency networks related to the TIMSS 1999 and PISA 2006 examinations in which both science achievement and mathematics achievement are taken to be the predictable variable show that science interest is the least effective predictor for mathematics achievement. The findings of the dependency network related to the TIMSS 1999 and PISA 2003 examinations in which both science achievement and mathematics achievement are taken to be the predictable variable, on the other hand, display that mathematics interest is one of the less effective predictors for science achievement. Again this chaotic situation may be a result of the fact that when the findings are analyzed from the perspective of multiple causes-multiple effects depending on the fuzzy reasoning, those variables remain implicit because the interactions of variables seem to have influences on the achievement levels.

In regard to sources of interest, Wilson (1971) proposes the element of "feel need" while Dewey (1969) offers the element of "needs of organism". The reasons for mathematics interest to be one of the variables accounting for science achievement seem to be as follows: mathematics is the basis of all the other subject matters; it is related to all of the other subject matters; mathematics is an integrated part of everyday experiences and students in the science course need to use their mathematics knowledge. Furthermore, since science is also integrated with everyday experiences, leading to the use of its contents in the math courses to attract the students' attention, then interest towards science may be an influential predictor for the math achievement. Additionally, the analysis of the subcategories of the interest variable (namely: I enjoy learning math/science; math/science is boring; math/science is important to everyone's life; math/science is an easy subject; I would like a job that involved using math/science; etc.) indicates that if for some students math is an easy subject and they enjoy it, then the same positive attitudes are also reflected towards the math content covered in the science course and therefore their interest in math may have an impact on their science achievement, even though their level of math interest is low. Given that science activities are also used in the math course, the science interest may have effects on the math achievement too. Another reason could be that since in the math courses the instructional methods of the science courses are extensively used (inquiry, discovery, learning cycle etc.) and similarly, in the science courses, skills of the math courses are commonly employed (problem-solving, reasoning, modeling etc.), the interest in either of the courses may become a common interest in both. Interest is generally identified with intrinsic motivation. Given that interest is the key element of motivation (Dotterer et al., 2009), the effects of interest on achievement also point to the effects of motivation on achievement.

Motivation

The findings of the dependency network related to the TIMSS 1999 examination, in which the mathematics achievement is taken to be the predictable variable, suggest that the second most significant affective variable after the self-concept score in regard to math achievement is the score of the motivation towards math (Bsbmgood). This is followed by the score of the motivation towards science (Bsbsgood). The findings of the dependency network related to the TIMSS 1999 examination in which the science achievement is taken to be the predictable variable similarly indicates that the score of the motivation towards science, after the science self-concept, is the second most significant affective predictor for science achievement, followed by the scores for math self-concept and motivation towards math. The finding that motivation is one of the significant predictor for achievement is consistent with Hendrickson (1997) and Gardner and Tamir (1989), suggesting that student motivation increases the levels of achievement. As stated by Eggen and Kauchak (2001), individual needs are the basic elements in the cognitive theories of motivation. Most children younger than 15 years receive a general education without election of subjects in Turkey. Education at this level is not based on training for specific occupations. The analysis of subdimensions of the motivation category shows that the variable of motivation is consisted of mostly those items on the future expectations (to get the job I want; to get into the school I prefer, to please my parents, to please myself). For those students whose future expectations are closely related to the vocational use of science and math, intrinsic motivation towards these courses is probably higher. The need and desire to learn science and math may make these students more successful in these courses. On the other hand, for those students who do not perceive any need to learn science and math the motivation levels may be lower. Accordingly, their achievement levels in these courses may also be lower. Considering the perspective of the single effect-multiple causes, the reason for motivation being one of the significant predictors of achievement may be that it seems to reflect the future expectations of the students.

The findings of the dependency network in which both mathematics achievement and science achievement are taken to be the predictable variables suggest that motivation towards science as well as motivation towards math seems to have less effect on science achievement in contrast to other variables, whereas the motivation scores in regard to math achievement appear to have nearly the same order of significance. When this finding is analyzed following the perspective of multiple causes-multiple effects, it appears that the effects of both motivation scores on math achievement are higher than their effects on science achievement. This finding is consistent with the findings of Oliver and Simpson (1988), and Akbaş and Kan (2007), who argue that there is low correlation between motivation and science achievement. These differential effects of motivation in regard to science achievement and math achievement may result from the distinctive nature of science and math. School science courses in general and primary school science courses in particular include everyday experiences in Turkey. Since the science course offers students scientific explanations for everyday events, students may naturally become more motivated towards the science course. Having a natural prior motivation towards the science course may decrease the discrimination power of the score of the motivation toward science. It may be results from the multiple causes-multiple effects perspective that cannot be seen following one cause and one effect. However, for the math course the situation may be different. In other words, students may not have a natural prior motivation towards the math course, which is much more abstract in comparison with the science course. Given that, the measurement approaches, this lack of natural prior motivation due to the nature of the math course could be more significant on the effects of the motivation scores on the math achievement rather than their effects on science achievement. Because of this fact, the search for the relationship between single effect-multiple causes and multiple causes-multiple effects may not affect the order of the math motivation score. These findings suggest that attention should be paid to the motivation towards the math course to increase motivation among the students. On the other hand, these findings also indicate that the motivation towards science has much higher effects on the math achievement in contrast to its effects on the science achievement. This finding resulted from the multiple causes-multiple effects relationship is interesting from the perspective of chaos theory. This may stem from the fact that the content of the science course is employed for reinforcement in making connections between the math course and everyday experiences. On the other hand, as stated by McBride and Silverman (1991), science activities that display mathematical concepts using examples appear to increase the motivation to learn math. Examples of everyday experiences are transferred into the math course to attract the students' attention, to motivate them towards the course contents and to make the abstract mathematical contents more concrete for the students. However, in science instruction there are no such attempts since the science subject itself is a real-life topic. Given that the source of the motivation towards science is the everyday experiences of the students, the fact that the effects of the motivation towards science on the math achievement are higher than its effects on the science achievement seems to be reasonable. However, the clustering outcomes indicate that the motivation scores do not change depending on the change in the achievement scores. The outcomes of clustering are compatible with the findings of Zakaria and Nordin's study (2008), indicating that there is low correlation between math achievement and motivation, and also with the conclusions of Oliver and Simpson (1988), and Akbaş and Kan (2007) who found that there is low correlation between motivation and science achievement. Therefore, it can be argued that motivation is the prior preparation stage for learning. Accordingly, higher or lower motivation alone cannot predict higher or lower levels of achievement for the course but higher motivation can be one of the most significant conditions that lead to higher levels of the achievement.

Efficacy

The findings of the dependency networks related to the PISA 2003 and 2006 point out that the variable of math efficacy (Mateff) score is significant in accounting for math achievement while the variable of science efficacy score (Scieff) is significant in accounting for science achievement. These findings are consistent with those of Demir and Kılıç's study (2009) which deals with the PISA 2003 examination. Specifically, the authors argue that those students with higher math self-efficacy have higher levels of math achievement. On the other hand, Basista and Mathews (2002) state that inefficient learning of the contents of both math and science leads to lower levels of self-efficacy in these courses. This situation may be a result of the fact that those students who do not have sufficient knowledge and skills for problem-solving have lower levels of self-efficacy scores. When both science and math are regarded as the predictable variable for the PISA 2003 examination, it appears that the effects of math efficacy on science achievement are higher than its effects on math achievement. However, the findings obtained from the dependency network based on the PISA 2006 data for science achievement suggest that science self-efficacy is much more significant in accounting for the science achievement in contrast to in accounting for the math achievement. Math self-efficacy is much more significant than science self-efficacy in accounting for science achievement, while science efficacy is much less significant than math efficacy in accounting for math achievement. This may suggest that those students with higher levels of science achievement have higher levels of self-efficacy in regard to both science and mathematics. Although a similar pattern occurs for math achievement, it is not as strong as that observed for science achievement. One of the variables with lower effects on math achievement is science self-efficacy. The fact that, although math self-efficacy is one of the significant variables in accounting for science achievement, science self-efficacy is not very significant for explaining math achievement may reflect that the dependency of the science course on the math course is greater than the dependency of the math course on the science course. The math content used in the science course is an inevitable, integrated part of the science course according to Turkish science curriculum. As stated by Blanchette and Dunbar (2002) and Sousa (2006), the content of the math course may difficult to be transferred into the science course to solve problems for unsuccessful student, so they may feel low self-efficacy toward math. The transfer skill may be related to the sense of self-efficacy. Hence the students felt low self-efficacy to math may fail to math, they may not transfer to math content into the science course.

Anxiety

The findings of the dependency network related to the PISA 2003 data on math achievement indicate that the significance of math anxiety (Anxmat) occurs in the middle position. The sources of the math anxiety are math achievement and mathematical background (Bekdemir, 2007; Belbase, 2013). Therefore, the math anxiety may be one of the most significant variables in explaining math achievement. When both the science achievement and the math achievement scores are taken to be the predictable variables, it appears that the anxiety score has effects on both math achievement and science achievement. As a result, math anxiety is among the significant predictors for math achievement even though it is not the most significant variable in this regard. Math anxiety seems to be less significant in accounting for science achievement in contrast to its effects in explaining math achievement, but it has a much more significant effect on science achievement than variables such as math interest and math self-concept. Various research studies have identified a negative correlation between math achievement and math anxiety (Sherman & Wither, 2003; Yüksel-Şahin, 2008; Zakaria & Nordin, 2008). These findings are consistent with the current finding that the anxiety score is a significant variable in accounting for the achievement. Furthermore, math anxiety has equally significant effects on science achievement as on math achievement. As stated Sousa (2006) and Kıray (2010) that since those students with math anxiety have negative feelings towards math, they may avoid meeting the requirements to learn math. Those students with math anxiety may experience difficulty in their science courses, since the science courses extensively include mathematical contents, leading to underachievement in the science examinations. On the other hand, Baloğlu (2001), states that math anxiety may occur not only due to cognitive factors but also due to the lack of self-concept and the lack of self-efficacy related to math. In the current study, these two affective variables are found to be influential on the achievement levels. Thus, it is safe to argue that those students with math anxiety as a result of their lack of math self-efficacy may avoid certain science contents that include intensive use of mathematical concepts.

Attitude

The TIMSS 1999 examination dataset suggests that attitude towards science (Bsdspats) appears to be the second last variable in accounting for science achievement. On the other hand, attitude towards math (Bsdmpatm) does not have any impact in accounting for science achievement, and attitude towards math and attitude towards science are not significant predictors for math achievement. However, when both science achievement and math achievement are taken as the predictable variables, the findings of the dependency network developed through the decision tree models appear to suggest that attitude towards math and attitude towards science have average effects in accounting for science achievement. On the other hand, attitude towards science in regard to accounting for math achievement again has an average effect while attitude towards math in this regard appears to be last in order of significance.

The findings of the study indicate that among the variables included in the analysis the variable of attitude is the one with the least significant effects. Serin (2004) and Papanastasiou and Zembylas (2004) concluded that there is low positive correlation between the attitude towards science and science achievement, while Caston (1986) concluded that it is not possible to argue that the attitude towards math is significantly correlated with math achievement. The findings of the current study support the argument that there is low correlation between attitudes towards a subject and achievement in the subject. However, it should be noted that those studies suggesting that there is no correlation between attitude and achievement often employ the perspective of single cause-single effect derived from positivist science philosophy. In fact, following such a perspective may inhibit the correlation between attitude and achievement. Thus, fuzzy logic and its derivative techniques are needed to uncover the potential correlation between math/science attitudes and math/science achievement.

The beliefs and attitudes may be related to each other through a cause-effect relationship (Tavşancıl, 2006). Each attitude includes beliefs but each belief does not lead to an attitude (İnceoğlu, 2004). Attitudes develop over long periods of time and are stable. When the findings are analyzed from the perspective of single cause (science or math achievement)-multiple effects, it appears that all the other variables affecting the achievement are influenced by the beliefs, whereas these beliefs may not lead to the formation of the attitudes. The students who participated in these international examinations belong to the 15-year age group. In accordance with the theory of Piaget on educational development, these students have learnt abstract math and concrete science content during the concrete operations period and they have not yet experienced their period of abstract operations. In the same vein, since these students make better sense of the concrete science content, their beliefs in regard to science have become more stable leading to attitude formation. One of the reasons for the science attitude to have effects on science achievement could be this developmental feature proposed by Piaget. Additionally, since students have not fully experienced the period of the abstract operations, hence their beliefs in regard to the math contents that may be largely abstract have failed to cause them to form strong attitudes towards math at this stage. Instead of following the perspective of single cause-multiple effects to analyze the variables that have influences on the science and math achievement, the perspective of multiple causes-multiple effects to analyze these variables suggests that these variables are all influential in accounting for science and math achievement. More interestingly, the math attitude has more effect on science achievement in contrast to the science attitude, while the science attitude has more effect on math achievement in contrast to the math attitude. At this point, a chaotic effect like Lorenz's butterfly effect is observed. In other words, the mathematical content used in the science courses may contribute to the formation of the math attitude. As a result, it is only when both science achievement and math achievement are considered together that the math attitude may become more influential. Similarly, the use of the mathematical content that is made concrete in the science content may lead to the stronger role of the science attitude in accounting for math achievement. On the other hand, all of the variables interact with one another, leading to chaotic non-linear relationship and as a result, those variables that seem to have no effect may become very influential in this interaction. It is also suggested that the age of the participants is significant because they are at the beginning of attitude formation and the interaction of all the variables produces the effects of this pre-abstract operations period. It may be considered as evidence, at the same time, that the effects of attitude can be more clearly seen and the entity that is measured in such studies is the strong beliefs towards either science or math, or the maturing phase of attitudes. It may be interpreted as follows: when science and math courses are considered together, or when there is full integration between these two courses, the attitude variable becomes more important.

Conclusion and Recommendations

The results of the study indicate that science achievement and math achievement are affected not only by the variables belonging to the cognitive domain and related to the cognitive skills but also by the affective variables. Specifically, the study concludes that: 1- Achievement or underachievement in science and math courses affect each other; 2- The effect of the math achievement in accounting for the science achievement is much greater than that of the science achievement in accounting for the math achievement; 3- Science achievement and math achievement are both influenced by the skills of reading and of problem-solving; 4- The affective variables such as self-concept, interest, motivation, self-efficacy, anxiety, and attitude are all influential on science and math achievement; 5- Science achievement is affected by both affective variables related to the science course and the other affective variables related to the math course; 6- Math achievement is affected by both affective variables related to the math course and the other affective variables related to the science course; 7- The variables of the math/science achievement and of the skills of problem-solving and of reading interact one another.

We also found that there were very close relationships between math/science achievement and the skills of problem-solving and of reading. Therefore, these four variables should be taken into consideration immediately, rather than the other variables. The skills of reading and of problem-solving should be given importance in school programs since they are basic skills for each learning area. Given that such skills develop lifelong, they should not be regarded as the elements of a specific subject. Instead, they should be distributed to all areas of learning throughout the program and the development of these skills should be considered to be a major goal of any program.

The results of the study were obtained through the use of data mining techniques, providing the opportunity to employ chaos theory and fuzzy logic in regard to an educational research context. The study also indicates that, in the field of educational research, the determinist approach that is dominant in this line of research and that is based on the linear relationships is inefficient. It is all chaotic in that, when an individual come across a problem to be solved, he/she chooses those data that are available, analyzes and synthesizes them, interprets them, and develops a totally new body of information. New information recorded by the human brain may totally change the process due to the changes in the starting conditions. In this process of developing new information, all data interact with one another. Therefore, instead of using binary logic for science and mathematics, both courses should be approached by fuzzy logic. From this point of view, the study concludes as follows: 1- The skill of problem-solving, which traditionally has been considered to be a math skill, is much more influential in accounting for science achievement than it is in accounting for math achievement; 2- An affective variable, such as the math efficacy, that has been defined as belonging to the math area appears to be more significant in accounting for science achievement than it is in accounting for math achievement; 3- The motivation to learn science may have higher effects in accounting for math achievement in contrast to its effects in accounting for science achievement; 4- The variable of the math attitude appears to be ineffective when only the science or math achievement is taken into consideration, but it became a significant predictor for the achievement levels of both courses when both science achievement and math achievement are considered; 5- The significance of math anxiety is as evident in science achievement as it is in math achievement; 6- It is found that reading skills, which are not regarded as an integrated part of either science or math programs in the Turkish education system, is one of the most significant predictors for the achievement levels of these subject courses. This result suggests that Lorenz’s chaos theory and fuzzy logic are proper to deal with educational topics. Although each course is independent in subject matter, the lack of math efficacy and the negative attitude towards math that occurs in the math courses may also have significant effects on students’ underachievement in science courses, and such an interaction may not be predicted by the teachers. Similarly, the possibility of being underachiever for a student with poor problem-solving skills may be greater for the science course than for the math course.

In sum, the order of significance for the variables that are traditionally defined as pertaining to a specific subject matter changes when science and math variables are regarded as integrated. Such chaotic interactions suggest that these two courses should be considered and designed together. While designing the learning process, math teachers and science teachers should give importance to these cross relationships. In conclusion, program developers and practitioners should consider these two subjects together, or integrate them, or develop strong connections between the courses focusing on the cognitive and affective characteristics and skills. If science teachers and math teachers are to improve students' achievement levels and to reduce, if they cannot eliminate, reasons for underachievement, they should not focus only on their own courses. They should cooperate to realize these goals. Science instruction strategies (inquiry, discovery, learning cycle etc.) as well as math skills (problem-solving, reasoning, mathematical modeling, developing relationships etc.) should be regarded as an integrated part of teachers' pre-service and in-service courses and should be taught to student-teachers as well as teachers in a full manner.

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An Analysis of the Learning Activities Covered in the 5th Grade Science Textbooks Based on 2005 and 2013 Turkish Science Curricula

Cemil Aydoğdu*, **Şahin İdin**
Hacettepe University

Abstract

The aim of this study is to analyze the learning activities covered in 5th grade elementary science textbooks which depend on 2005 and 2013 elementary science curricula. Two elementary science textbooks depends on 2005 science curriculum and two elementary science textbooks depend on 2013 science curriculum were researched. The study is a qualitative research and the data were analysed through the document analysis technique. The findings revealed that textbooks based on 2005 science curriculum includes more activities. In addition, these activities were found to be designed to evaluate student learning. There was no preparation for workbooks in 2013 science curriculum. Based on the findings obtained some suggestions are developed about the design of the textbooks.

Key words: Science education; textbook activities; qualitative research

Introduction

Science textbooks are significant teaching and learning materials which introduce science and related concepts to students and guide their learning. The textbooks play important roles to increase students' interests and understanding related to science and to improve their knowledge about subjects. Based on advances in science and technology, textbooks should be updated. MEB (ministry of Turkish education) is center to identify educational policies and therefore textbooks are selected by MEB in Turkey. MEB controls the consistency between textbooks and curriculum.

In 2005, science curriculum was changed by MEB (MEB, 2005). The new curriculum depended on constructivist approach. Therefore, the content of the science textbooks was developed depending on this new program, too. In addition, workbook was also prepared. The ultimate goal of this workbook was to increase students interests and their motivation related to the course. In 2013 the MEB changed the content of the science education course. The course's name was science and technology and new name is science (MEB, 2013). In addition, new curriculum is based on inquiry-based learning method and workbooks are not used no longer. Moreover, MEB also banned the recommendation of any supplementary material or book to the students in all courses (MEB, 2014). Therefore the importance of textbooks are increased. In this context, the experimental activities and other learning activities covered in the textbooks are major ways and tools for students to learn the subjects .

Review of the Literature

There are various points to be considered in the development of the textbooks for the science and technology course. For instance, pre-studies should be conducted in regard to the analysis, visits, observations or experiments. In regard to the activities and experiments necessary steps should be taken, the steps to be followed in the procedures should be given and necessary warning should be given in order to realize time and equipment savings. It should be also emphasized that the communication between teacher and students is significant to achieve the course objectives. All these points should be given in guide books (Kaptan, 1998).

In the study which analysed the effects of the learning activities covered in elementary science and technology textbooks on student learning, it was found that five of sixteen teachers reported partly positive effects of the learning activities on student learning whereas eleven teachers regarded them totally effective. Those teachers who reported partly positive effects of the learning activities indicated that the reasons for such a partial effect

* Corresponding Author: *Cemil Aydoğdu, caydogdu@hacettepe.edu.tr*

are due to irrelevancy of the activities, not being totally understood by students and not being interesting (Aydın and Çakıroğlu, 2010).

Classical experimental work is the best known form of practical work and is most commonly used for teaching science and chemistry in elementary schools (Herma, Grmek & Dinevski, 2014). Science teaching in primary schools is based on the understanding of physical, chemical, and biological contents. So the starting-point for realizing these objectives during the teaching and learning of science is experimental and problem research-based learning. Most of the scientific concepts and their connections, especially chemical because of their triple nature can be illustrated or deduced from experimental work (Glažar, Devetak, Strgar & Naji, 2006). In the delivery of the course material to students experiments are of great importance. Therefore, those experiments and learning activities covered in the textbooks should be carefully designed. Experimental activities in the textbooks developed for students and teachers should be designed based on the laboratory usage techniques (Aydoğdu and Candan, 2012).

Importance of the Research

As stated above the MEB also banned the recommendation of any supplementary material or book to the students in all courses. The idea behind it; textbooks including science textbooks are necessary for students' learning. Is the idea really as it is planned by MEB?

This study analysed the learning activities covered in the science textbooks, which are reviewed and regarded as suitable for the science course by MEB. Based on this analysis relevant suggestions are given. The study is important since it reveals the insufficient parts for activities in science textbooks. The aim of this study is to analyze the learning activities covered in 5^{th} grade elementary science textbooks which depend on 2005 and 2013 elementary science curricula in Turkey. In parallel to the aim given above, the study tries to answer the following research questions:

1. What are the major deficiencies in the learning activities of MEB science textbooks which were used in 2012?
2. What are the major deficiencies in the learning activities of science textbooks developed by the private (Semih) Publication, which were used in 2012?
3. What are the major deficiencies in the learning activities of MEB science textbooks which were used in 2013?
4. What are the major deficiencies in the learning activities of science textbooks developed by the private (Evren) Publication, which were used in 2012?

Method

The study was designed as a qualitative research. In qualitative research the data are mostly collected through observations and document analysis. In the study the data were analyzed through document analysis. In the document analysis, course materials can be examined which contain information about the facts to be studied (Yıldırım and Şimşek, 2011). In document research, the issues involve locating materials, often at sites far away and obtaining permission to use materials (Creswell, 2007).

In the study four textbooks were analysed in terms of the learning activities. Two of them were used for the 5th grade in the science and technology course during the school year of 2012-2013. These two textbooks were written based on the science curriculum published in 2005. One of the textbooks was written by MEB and the other one by a private publisher. Both textbooks were regarded as suitable for use in the course. The other two were used for the 5th grade in the science course during the school year of 2012-2014. These two textbooks were written based on the science curriculum published in 2013.

Results

This part presents the findings of the study and answers the research questions given above.

Findings about the first research question

In MEB science and technology textbook there are seven units. This number is consistent with the number mentioned and required in the educational program. As can be seen from Table 1, there are different numbers of activities in each unit. Similarly, the number of the objectives varies in each unit. The total number of activities in the textbook is 76. It is 107 in the study guides (see Table 1).

Table 1. 2012 Science and technology textbook written by MEB

Unit number	Unit title	Number of sections in the unit	Number of objectives	Number of activities	Number of the learning activities in the book
1	Let's solve the problem of our body	4	22	4	8+3+1+3=15
2	Recognising the change of matter	4	46	20	8+3+2+9=22
3	Force and movement	3	21	10	1+2+4=7
4	Electricity in our Life	2	16	5	2+7=9
5	The world, the sun and the moon	3	19	6	4+3+4=11 (1 activity)
6	Let's visit and know the world of living being	6	33	13	1+ 8+ 3+ 3+ 1+ 10=26 (1 activity)
7	Light and sound	7	39	18	3+1+3+2+2+1+5=17
	Total	29	196	76	5+102=107

In each activity, safety symbols are given at the beginning. The rules to be followed are included in the instructions. However, there is no instruction about how to use various equipment such as protective gloves, nitric acid, eye glasses among the others. The learning activities are numbered. However, the thermometer used in the activites is not specified. It is not stated that a pair of scissors used in the activity should not be extremely sharp and rusty. The length of equipment such as connection cable and meter is not given. In addition, it is not indicated that protective aprons should be used and that connection cables should be touched by hand.

Findings about the second research question

Tablo 2 shows that in the science and technology textbook written by Semih publishers and used in 2012, there were seven units. This number is consistent with the number mentioned and required in curriculum. There are different numbers of activities in each unit. Similarly, the number of the objectives is 196 as mentioned in curriculum. The total number of activities in the textbook is 70 whereas it is 130 in the workbook.
The dimensions and amount of the materials used in the learning activities are not explained. Although safety symbols are included, there is no mention of caution while using the chemicals. The question of who (whether students or teacher) should carry out the activities is not answered. In those learning activities, which should be carried out by the students, it is not specified whether they are conducted individually or in a group. In addition the thermometer to be used is not specified in terms of its type. There is no caution of the likely danger of using a pair of scissors. The capacity of becherglas is not specified such as 50ml, 100ml, 250ml. and it is not indicated that it should be refractory.

Table 2. 2012 Semih publications data of Science and Technology textbook

Unit number	Unit title	Number of sections in the unit	Number of objectives	Number of activities	Number of the learning activities in the book
1	Let's solve the problem of our body	3	22	7 21	
2	Recognising the change of matter	4	46	19	30 (29+1)
3	Force and movement	3	21	5	9
4	Electricity in our Life	2	16	5	9
5	The world, sun and moon	3	19	4	11
6	Let's visit and know the world of living being	7	33	18	29
7	Light and sound	6 (A+B)	39	12	21(20+1)
	Total	28	196	70	130 (128+2)

Findings about the third research question

As can be seen from Table 3, in the science textbook written by MEB and used in 2013 for the 5th grade students there are seven units. Each unit has different number of sections. The number of objectives was reduced and it is 44 in the textbook analysed. There are 58 learning activities in textbook. In the units there is no explanation about the concept of experiment. The rules to be followed are given in the introduction part. The learning activities do not include safety symbols. Warnings about materials are not well and fully specified. The amount of the materials required is not given. The materials used in producing the test tubes are not given, too.

Table 3. 2013 Science textbook written by MEB

Number of units	Unit title	Sections covered in the unit	Number of objectives	Number of activities
1	Let's solve the problem of our body	3	13	16
2	Measuring the magnitude of the force	2	2	5
3	Change of the matter	4	6	11
4	Light and sound	5	7	10
5	Let's visit and know the world of living being	2	3	6
6	Electiricity in our daily life	2	3	2
7	Mysteries of the Earth's crust	4	10	8
	Total	22	44	58

Findings about the fourth research question

In Evren publishers' science textbook based on new science curriculum in 2013, there are seven units. As can be seen from Table 4 there are 44 objectives and each unit has different number of sections. There are 37 learning activities. Both safety symbols and safety warning are given incompletely. The order of the references to the materials is random. The experiments are not numbered. It is observed that the safety symbols given and the materials used in the activity are not consistent. There is also some misconceptions in the definitions of the materials used in the activity (i.e., it is stated that there are four weights with 50 gram; the word weight should be mass. The amount of the materials used in the learning activity and experiments is not specified (for instance, 10 N dynamometer). It is not mentioned about who (students or teacher) will carry out the experiment. In regard to the group work in the process of experiment the number of student groups is not specified. There are incomplete instructions about the experiments and the learning activities. The types of the thermometers used in the experiments are not specified (for instance, whether a mercury thermometer or an alcohol thermometer will be employed).

Table 4. 2013 Science textbook developed by Evren Publishers

Number of units	Unit title	Sections covered in the unit	Number of objectives	Number of activities
1	Let's solve the problem of our body	3	13	2+3+2=7
2	Measuring the magnitude of the force	2	2	1+3=4
3	Change of the matter	4	6	1+2+1+4=8
4	Light and sound	5	7	2+0+1+3+5=11
5	Let's visit and know the world of living being	2	3	2+1=3
6	Electiricity in our daily life	2	3	2+2=4
7	Mysteries of the Earth's crust	4	10	0+0+0+0=0
	Total	22	44	37

Comparison of the learning activities in the textbooks used in 2012 and in 2013

Table 5: A comparison of the contents of the textbooks used in 2012 and in 2013

Program	Differences in units	Sections	Topic
2012	The world, the sun and the moon (This unit is not covered in the textbooks used in 2013)	All sections are covered in the book,	All topics are covered only in the textbooks used in 2012
	Force and movement	* Forces requires contact and contact-free forces * Magnetism	Gravity Force, Magnetic force
2013	Mysteries of the Earth's crust (This unit is not covered in the textbooks used in 2013)	All sections are covered in all textbooks,	All topics are covered only in the textbooks used in 2013
	Measuring the magnitude of the force	Measuring the magnitude of the force	Force meter: Dynamometer
	Light and sound	Shadow	There is no topic of partial shadow

As can be seen in Table 5 the textbooks written in 2012 and in 2013 were compared in terms of unit differences, sections and topics covered. In the textbooks used in 2012 there is the unit of the world, sun and moon, which is not covered in the textbook used in 2013. Even though the unit of force and movement is covered in the textbooks used both in 2012 and in 2013, the content of the unit is different. Because in the textbooks used in 2012 the topics about the forces, which require contact and contact-free forces as well as magnetism are covered, but these topics are not covered in the textbook used in 2013. The unit of mysteries of the earth's crust is not covered in the textbooks used in 2012, but it is included in the textbook used in 2013. Although the unit of light and sound is covered the textbooks used both in 2012 and in 2013, the content of the unit is different. The textbooks used in 2013 do not cover the topic of partial shadow.

Discussion

In 2012 two science textbooks were used for the 5th grades in all public schools in Turkey. One of the textbooks was written by MEB and the other one by a private publisher. These textbooks were written based on the science and technology curriculum, which was developed in accordance with the principles of the constructive approach. The number of units and objectives in both textbooks is found to be the same. However, the number of sections in them varies. More specifically, it is twenty-nine in the textbook by the MEB while it is twenty-eight in the textbook by the private publisher. In addition, the number of the learning activities in both textbooks is also different in that in the textbook written by MEB there are a total of seventy-six learning activities while there are seventy learning activities in the textbook written by a private publisher. The number of the learning activities in the workbooks also differs. In MEB workbook, there are 107 learning activities whereas there are a total of 130 learning activities in the workbook by the private publisher.

In 2013 two science textbooks were qualified to be used for the 5th grades in Turkey. It was found that the textbooks one of which was written by MEB while the other one by the private publisher have the same titles for the units and the same number of units, sections as well as objectives. However, the number of the learning activities covered in the textbooks varies. More specifically, in the textbook written by the MEB there are a total of fifty-eight learning activities while there are thirty-seven learning activities in the textbook written by a private publisher.

The textbooks used in 2012 and in 2013 differ in terms of the number of the learning activities. It can be argued that, those textbooks used in 2012 which were written in accordance with the constructive principles are richer in terms of the learning activities covered. In addition these textbooks are accompanied with workbooks which are not given with the textbooks used in 2013. It is reported that some of the learning activities covered in the textbooks for the science and technology course are not fully carried out (Yangın and Dindar, 2007, Yıldız-Duban, 2013). There are some changes in the science textbooks written in 2012 and in 2013 in terms of topics covered. Some of the units and topics are left for the sixth grade.

In the textbooks used both in 2012 and in 2013 the rules to be followed during the learning activities and the experiments are generally given in the introductory sections. However, the rules for the specific learning activities and the experiments were found not be specified. In other words, some significant characteristics such as the amount of the materials to be used, their type, how to use them were not given in a required manner. It can be argued that the learning activities covered in the textbooks analysed were not developed following the necessary techniques for the lab use.

In the textbooks used in 2012 there were some misconceptions related to the process of the learning activity and the process of experiments. Such misconceptions were not observed in the textbooks used in 2013. However, in the textbooks used in 2013 it was found that there was inconsistency between the picture of the material to be used in the activity and its visual representation in some of the learning activities. Science textbooks in subjects such as biology should provide students with scientifically sound information so that they learn correct basic knowledge for making informed decisions (Kim and Kim, 2013).

In the interviews with the science and technology teachers it was found that only a few of them (three out of sixteen participants) well prepared for the learning activities whereas most of them (thirteen participants) partly prepared for the activities (Aydın & Çakıroğlu, 2010). The reasons for partial preparation were given by the teachers are as follows: "sometimes objectives and the learning activities are inconsistent; there are problems about the procurement of the materials used in the activity; and there are time constraints in order to complete the activity." (Aydın & Çakıroğlu, 2010). On the other hand, a common trend in the textbooks used in 2012 and in 2013 was that who would carry out the activities was not specified. In addition, the number of students in the groups was not specified in the experiments which required group work. It is significant that some of the learning activities included in the textbooks should be designed taken into consideration the processes out of school environment.

In the science textbooks which will be used in the future that some significant characteristics such as the amount of the materials to be used, their type, how to use them are given in a required manner. It is significant that some of the learning activities included in the textbooks should be designed taken into consideration the processes out of school environment. In the textbooks used in 2013 it was found that there was inconsistency between the picture of the material to be used in the activity and its visual representation in some of the learning activities. Arrangements can be made again for the solution of this problem in the science textbooks. Mismatch between the materials to be used in activities with the image itself. It is suggested that safety sembols can be used cautiously in every activities and experiments in the science textbooks. There is no workbook for the textbooks used in 2013 as a result of the decision of MEB mentioned above. The lack of study guides is a disadvantages for students. Because such guides provide the students with the opportunity to consolidate their learning through various learning activities. So it is suggested that workbooks can be prepared which has activities and experiments for science textbooks.

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Concept Mapping Strategy: An Effective Tool for Improving Students' Academic Achievement in Biology

John Sakiyo*, Kawu Waziri
Modibbo Adama University of Technology

Abstract

The study investigated the use of concept mapping teaching method on secondary school students' academic achievement in biology. Two hypotheses tested at 0.05 level of significance guided the study. The design of the study was quasi-experimental design with 122 Senior Secondary students selected purposively from two senior secondary schools in Adamawa state. Instrument used for data collection was an achievement test tagged Biology Students' Achievement Test (BSAT) adapted from WAEC tests 2005 to 2010. The instrument was content validated by three experts and Cronbach alpha formula was used for testing its reliability. The reliability coefficient of 0.78 was obtained. The treatment lasted for six weeks and data were analyzed using one-way Analysis of Covariance (ANCOVA). The result revealed that, concept mapping method enhanced students' academic achievement in biology. Furthermore, there was no significant difference between male and female students in the experimental group. It was recommended that, concept mapping method should be incorporated in the teaching of biology for meaningful learning and that workshops should be organized for in-service and practicing teachers on how to use concept mapping strategy.

Key words: Concept Mapping, Gender, Achievement, Secondary School, Biology

Introduction

Over the years, researchers have been investigating why some learners acquire a deep, meaningful understanding of materials studied, whereas others have only a superficial grasp of the information presented. Often the latter kind of students may have high school grades and high standardized test scores. What appeared to underlie the differences in these two groups of students according to Novak (2010) was the differences in the way they approached learning of subject matter. Novak developed concept mapping strategy based on the theoretical foundation laid down by educational psychologists. The underlying basis of the theory is that meaningful (as opposed to rote) human learning occurs when new knowledge is consciously and purposively linked to an existing framework of prior knowledge (Novak, 2006). Furthermore, Novak mentioned that the mind organizes information in a hierarchical top-down fashion from higher level skills to the lower level skills. While, in rote (or memorised) learning, new concepts are added to the learner's framework in an arbitrary and verbatim way, producing a weak and unstable structure that quickly degenerates. The result of meaningful learning is a change in the way individuals experience the world. It is seen that the students who learn by rote according to Novak (2006) are able to recall the new information but they cannot apply the knowledge in other situations. To give an organized body of content in a meaningful way, keeping in mind the cognitive map of the learner simple ideas are presented first to the students followed by complex ideas joined in hierarchical manner so that proper learning can take place in sequential and integrated manner.

Concept mapping is a graphical tool for organizing and representing knowledge in networks of concepts and linking statements about a problem or subject (Novak & Canas, 2006). Concept mapping includes concepts, usually enclosed in circles or boxes of some type and relationships between concepts are indicated by a connecting line linking words. Concepts are graphical or pictorial arrangements that deal with a specific subject matter. They are useful tools in representing the structure of knowledge in a form that is psychologically compatible with the way in which human beings construct meaning. Mouton (1996) defines a concept as the most elementary symbolic construction by means of which people classify or categorise reality or make sense and attribute meaning to their world. Novak and Gowin (1994) demonstrated that, the label for most concepts is a single word, although sometimes symbols such as + or % are used. The core element of a concept mapping is a proposition, which consists of two or more concepts connected by a labeled link.

* Corresponding Author: *John Sakiyo*, jsakiyo@yahoo.com

Propositions according to Novak (2010) are meaningful statements about some object or event. In a concept mapping, propositions are connected to each other to form a hierarchical and branching structure, with the most inclusive, most general concepts at the top of the mapping and the more specific, less general concepts arranged below, that represents the organization of knowledge in long-term memory.

One of the important characteristic of Concept Mapping is the inclusion of "crosslink." Cross-links show how a concept in one domain of knowledge represented on the mapping is related to a concept in another domain shown on the mapping. In the creation of new knowledge, cross-links often represent creative leaps on the part of the knowledge producer (Novak, 2000). A final aspect of the structure of Concept Mapping is the inclusion of specific examples of events or objects. These can help to clarify the meaning of a given concept. Normally these are not included in ovals or boxes, since they are specific events or objects and do not represent concepts. Summarily, Novak (2004: 154) identified six procedures to follow in constructing concept mapping.

- i. Identify the key concepts in a paragraph, research report, and chapter; or simply think of the concepts of a subject area and list them. Some people find it helpful to write the concept labels on separate cards or small pieces of paper, so that they can be moved around
- ii. Rank the concepts by placing the broadest and most inclusive idea at the top of the map. It is sometimes difficult to identify the broadest, most inclusive concept. It is helpful to be aware of the context of the concepts we are dealing with or to have some idea of the situation for which these concepts are arranged.
- iii. Work down the paper and add more specific concepts.
- iv. Connect the concepts by lines. Label the lines with action or linking words. The linking words should define the relationship between the two concepts so that it reads as a true statement, or proposition. The connection creates meaning. When you can hold together a large number of related ideas, you can see the structure of meaning for a given subject area.
- v. Specific examples of concepts can be added below the concept labels. (e.g., golden retriever is a specific example of a dog breed.
- vi. Perhaps you can already see ways that the concept map could be made differently.

Remember there is no one way to draw a concept map. As one's understanding of relationships between concepts changes, so will the mapping. This is what gives the concept mapping power and flexibility. For example, using the topic plant cell. The major concepts may include:

- i. Cell Wall
- ii. Protoplasm
- iii. Cytoplasm
- iv. Nucleus
- v. Vacuole

After listing these major concepts they are then arranged hierarchically from lowest to highest. The most general concepts are on the top in the hierarchy while the specific concepts are placed below. The concepts are then connected with lines or arrows to indicate relationships.

The idea of concept mapping is to determine how meaningful learning increases students' achievement. Concept mapping as a strategy in education is parallel with the movement from teacher to learner and as a result has the power to improve academic achievement (Peterson & Snyder, 2008). Today, educators and researchers are convinced that, most students learn best through personal experience and by connecting new information to what they already believe or know. For this reason students need to personally construct their own knowledge. Sakiyo and Jebson (2008) suggested learner-centred teaching methods provide adequate learning outcomes rather than teacher-centred approaches which are dominated by the teacher. Sakiyo and Jebson also pointed out that, student activities are better than teacher activities in promoting authentic students learning in secondary school. Therefore, the recommendations of researchers to involve students in the construction of their knowledge, paved the way to look at concept mapping teaching method as it relates to students' meaningful learning and achievement.

Concept mapping increases recall of information in instructions in biology subject (Hall, 2002). Kinechin (2000) recommended the use of concept mapping on instruction and learning in secondary school biology education. The important point is that the beginning stage of drawing concept maps not only needs active participation of the learner in the learning process but also paves the way on their understanding of a specific learning area. As a result, such information about learners' understanding empowers facilitators to determine learners' cognitive deficiencies and provide corrective feedback (Nowruzi, Khiabani & Nafissi, 2010). Lambiotte and Dancereau (2001) stated that the students that made concept maps have a broader knowledge base and therefore more able to solve problems compared to those students that learned by rote memorization. Lambiotte and Dancereau also found out that, the students with low prior knowledge learned better with concept mapping than those taught with lecture method. Concept mapping has also been shown to increase the learners' writing ability (Gorjian, Pazhakh, & Parang, 2002). This improvement has been demonstrated in terms of the quantity and quality of producing, arranging and relating ideas (Pishghadam & Ghanizadeh, 2006). In science education, concept mapping has been widely recommended and used in a variety of ways. It has been used to help teachers and students build an organized knowledge based on a given discipline or on a given topic (Blackwell & Pepper, 2008). It has also, been used to facilitate middle level students' learning of science content (Novak & Gowin, 1994; Adlaon, 2002; Dhaaka, 2012). Findings from these studies indicate that concept mapping is an effective tool for aiding students' comprehension of science materials.

Moreover, giving students more chance to get involved in the learning process through the use of concept mapping skills makes them perform significantly better than their counterparts who have been exposed to the teaching using the usual traditional lecture method (Nnamdi & Okechukwu, 2006). It has also become clear that for students who have some concept mapping experience, there exists a correlation between their concept mapping ability and performance in achievement test (Chee & Wong, 1996). Concept mapping has also proved to be a useful vehicle to fill the usual gap between theories and practice (Sutherlang & Katz, 2005). Access of representation at a given situation in learning is also helped through concept mapping (Bruillard, 2000). Concept mapping has also proved as useful tools in lesson design, and can determine the key concepts and their relationship, and build the whole curriculum as a content analysis tool in itself (Kaszas & Turcsanyi-Szabo, 2003).

Significant researches have indicated that gender plays a role in students' academic achievement particularly in biology and science in general. Okeke (2007) observed that the consequences of gender disparity cut across social, economic, political and educational development, especially in the areas of science and technology. Offor (2007) identified some reasons for gender disparity in science education to include; opportunity cost of education, early marriage among girls, lack of female role models, poor self concept, inherent sex differences, teaching methods and gender stereotyping among students and teachers. However, limited studies have been conducted on the effect of concept mapping teaching methods on secondary school students' achievement in biology in Nigeria.

Statement of the Problem

Educational researchers have sought to find out why some learners acquire a deep, meaningful understanding of materials studied, whereas others have only a superficial grasp of the information presented. Generally, pupils memorize the content and reproduce the same to pass the examination (Dhaaka, 2012). In such an environment students' academic achievement, cannot be attained. Often this kind of learning leads to students' poor academic achievement. Students' poor academic achievement has been a focus of many studies examining the effects of interaction pattern on learning outcomes (Orji & Ebele, 2006). Many factors were reported to contribute for the students' poor academic achievement in biology, but Orji and Ebele attributed students' poor performance to ineffective methods of biology instruction adopted by Nigerian secondary school teachers. Concept mapping could be a strategy to motivate students to promote their academic achievement in biology.

Purpose of the Study

This study determined the effect of concept mapping teaching strategy on secondary school students' academic achievement in biology in Adamawa state. Specifically the study sought to establish the following specific purposes:

1. To determine the effect of concept mapping teaching method on secondary school students' academic achievement in biology
2. To determine the influence of gender on secondary school students' academic achievement when taught biology using concept mapping method of teaching in biology.

Hypotheses

Two hypotheses test at 0.05level of significance, guided the study.
HO_1. There is no significant mean difference on secondary school students' academic achievement in biology when biology is taught using concept mapping and lecture methods.
HO_2. There is no significant influence of gender on secondary school students' academic achievement in biology when biology is taught using concept mapping method of teaching.

Method

The study adopted the quasi-experimental pre-test, post-test non-equivalent control group design. The study was conducted in Adamawa State, Nigeria. The target population of the study was all Senior Secondary two (SSII) students in senior secondary schools in Adamawa state offering biology. The reason for using SSII students was because the class is stable. It is neither facing the problem of being freshly introduced to senior secondary biology (as is the case with SS1) nor preparing for any end of course or terminal examination (as is the case with SSIII). The sample for the study consisted of 52 male and 70 female SSII biology students from two public co-educational senior secondary schools in Girei local government area of Adamawa State. Purposive sampling technique was used to select the co-educational schools for the study. Two intact classes were chosen randomly from each of the schools. The intact classes in each of the schools were then assigned randomly to one experimental and control group. The experimental group was concept mapping group while the control group was the lecture method group.

The instrument for data collection was an achievement test tagged the "Biology Students' Achievement Test" (BSAT). The BSAT is a 60-itemed multiple-choice objective test items with four options. The instrument was adapted from West African Examination Council (WAEC) biology tests from 2005 to 2010. The items covered six cognitive domains of educational objectives (Knowledge contains 25% of the items, comprehension 25%, application 15%, analysis 15%, synthesis 10%, while evaluation takes 10%). The instrument was pilot tested on 30 students from a non-participating school. The BSAT yielded a Cronbach alpha reliability index of 0.78 which was a good reliability index.

The pre-test was administered in the first week of the research to both experimental and control groups before the treatment. The treatment was done strictly on selected topics drawn from senior secondary school II syllabus which included: Nutrition, Habitat and Nutrient cycle. The experimental group was subjected to treatment of concept mapping method, while the control group was taught using the lecture method. The class teaching was done by one of the researchers. Posttest was administered to both the experimental and control groups after six weeks of instruction. The hypotheses were tested at 0.05 level of significance using one-way Analysis of Covariance (ANCOVA).

Results and Discussion

HO_1. There is no significant mean difference on secondary school students' academic achievement in biology when biology is taught using concept mapping and lecture methods.

Table 1. ANCOVA of the Experimental and Control Groups

Source	Type III sum of square	Df	MS	F	P-value	Partial eta
Corrected Model	2966.1	2	1483.088	40.982	0.00	0.408
Pretest	5461.1	1	5461.164	0.093	0.12	0.031
Teaching Methods	431.7	1	431.794	2.567	0.00	0.398
Error	4306.4	119	2843.233			
Corected Total	7272.5	121	36.188			

From the Table 1, there is significant mean difference between the experimental and control group. Since the computed p-value (0.00) is less than the f-value (2.567) at 0.05 level of significant, the null hypothesis of no significant effect is rejected. This means there is significant difference of students' academic achievement between experimental and control group in favour of concept mapping group.

HO_2. There is no significant influence of gender on secondary school students' academic achievement in biology when biology is taught using concept mapping method of teaching.

Table 2. Male and Female ANCOVA in the Experimental Group

Source	Type III sum of square	Df	MS	F	P-value	Partial eta
Corrected model	244.7	2	122.3	7.546	0.001	0.212
Pretest	241.2	1	214.2	1.087	0.00	0.210
Gender	1.5	1	1.50.09	0.766	0.002	
Error	907.9	56	16.2			
Corrected total	1152.6	58				

From the Table 2, there is no significant mean difference between male and female students in the experimental group. Since the computed p-value (0.766) is greater than the f-value (0.09) at 0.05 level of significant, the null hypothesis of no significant effect is accepted. This means there is no significant difference of students' academic achievement between male and female in the concept mapping group.

Discussion and Conclusion

The study found out that, Students taught biology concepts using concept mapping method performed better than those taught with lecture method. This means students' performance significantly differed based on the teaching methods used in the study. This finding agrees with findings of Akeju, Simpson, Rotimi and Kenni (2011) that found significant difference between experimental and control groups in favour of concept mapping group. Dhaaka (2012) recommended the use of concept mapping as an effective tool for biology teaching. Along the same vein Yezka and Nasrabadi (2004) maintained that, concept mapping strategy promotes meaningful learning as well as students' academic achievement.

The study also found no gender difference in students' achievement in biology. This finding agrees with the findings of Sakiyo (2008) who reported no gender difference in the acquisition of science process skills when students are taught using student-centred teaching methods. Sakiyo (2007) suggested that, gender differences can be eliminated when teachers used certain teaching strategies that can bring about gender equity in science education.

This study shows that, Concept mapping strategy promotes students' academic achievement in biology. Students' academic achievement cannot be translated in terms of acquiring knowledge to pass examinations, but to acquire dip meaningful understanding of the materials presented to the students. There was no gender difference in students' academic achievement in biology, the increase in students' academic achievement does not depend on gender, and this means concept mapping is an effective to tool for both male and female students.

Recommendations

From the result of this study, the following recommendations are made:

1. It is evident that, concept mapping teaching is effective in promoting meaningful learning and improving students' academic achievement in biology. Therefore, teachers should use this teaching method to teach biology teaching lessons.
2. Workshops should be organized and made compulsory for practicing teachers so that they can embrace the skills of concept mapping teaching method.
3. Pre-service teachers should be exposed to the concept mapping teaching method
4. Concept mapping teaching method should be suggested for some biology content areas in the curriculum.

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