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ABSTRACT

The Mathematics, Science, and Technology Educators and Researchers of The Ohio State University (MSaTERs-OSU) is a student organization that grew out of the former Ohio State University Council of Teachers of Mathematics (OSU-CTM). Papers from the fourth annual conference include: (1) "Technology Education Curriculum Models in Michigan Secondary Schools" (Phillip L. Cardon); (2) "Inquiry-based Teaching in Urban Schools" (Anita Roychoudhury); (3) "Discovering Pi with Geometry Software While Accommodating Different Levels of Technological Literacy in a Student Population" (Lloyd Hugh Allen); (4) "Visual Perception of Small Living Organisms by Nonmajor Biology Students at The Ohio State University" (Robert Day); (5) "Answering the Creationists: The Importance of Religiously-Neutral Science Education" (Alexander Glass); (6) "Designing Instructional Tools Using the Tenets of Constructivism" (Beth D. Greene and Marlena F. Herman); (7) "The Development of a Rubric to Evaluate Effective Thematic Units in Science" (Tracy L. Huziak); (8) "Instructional Effects of Multiple Analogies on Understanding the Concept of Chemical Changes" (Hyeoksoon Kwon); (9) "A Comparative Study of U.S. and Korean Science Curriculum Reforms" (Hyeoksoon Kwon and Youngsun Kwak); (10) "An Analysis of the Teaching and Learning Theories of the New National Science Curriculum in Korea" (Gyoungho Lee and Hyonyong Lee); (11) "What Do the 'New Standards' Look Like in Action? Practical Examples from Algebra II" (Nancy Schaefer and Sharon Kail); (12) "Conceptions-based Radioactivity Curriculum" (David Torick); and (13) "Science Education in Korea: New Curriculum and Challenges" (Hyonyong Lee, Roseanne W. Fortner, and David L. Haury). (ASK)

Proceedings of the
Fourth Annual Spring Conference
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The Mathematics, Science, and Technology Educators & Researchers of The Ohio State University

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Saturday, May 6, 2000

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Mission Statement

The ***Mathematics, Science, and Technology Educators & Researchers of The Ohio State University*** (*MSaTERs-OSU*) is dedicated to improving the teaching and learning of mathematics education, science education, and technology education through the following objectives:

- to promote improved teaching practices and research in mathematics education, science education, and technology education;
- to encourage commitment to professional growth and continued professional improvement;
- to promote unity and communication between and among students in mathematics education, science education, and technology education;

Membership is open to all those interested in the advancement of mathematics education, science education, and technology education.

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Technology Education Curriculum Models in Michigan Secondary Schools

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Over the past decade, tremendous changes have occurred in curriculum models for technology education. The transition from industrial arts to technology education brought new curriculum models and techniques for implementing the new ideas and concepts of teaching about technology (Herschbach, 1996). These curriculum models have been implemented in the Michigan public schools (Michigan Department of Education, 1996), but the type of model used in each school is not known. The purpose of this study is to learn the type of technology education curriculum model that exists in each of the public schools within Michigan.

As a first step to understanding technology education curriculum models, there must be understanding about the definition of technology education. Technology education is defined as the study of the transportation, manufacturing, construction, and communication fields of industry (Herschbach, 1992, p. 4). Also, technology education can be defined as the study of "human innovation in action. It involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities" (International Technology Education Association, 1996, p. 16).

Another definition was found in the *Jackson's Mill Industrial Arts Curriculum Theory* document by Snyder & Hales (1981). This definition states that

> Technology [education] is considered as the knowledge and study of human endeavors in creating and using tools, techniques, resources, and systems to manage the manmade and natural environment for the purpose of extending human potential and the relationship of these to individuals, society, and the civilization process. (p. 2)

In addition to the definition of technology education, the purpose of the field must also be clear before a discussion about the various curriculum models can occur.

Importance

A knowledge of the types of technology education curriculum models implemented in schools throughout the state of Michigan is very important for the following reasons. First, this knowledge will help first year teachers to locate themselves at a school that shares similar philosophies. Second, the information from this research would result in an increase in federal and state funding to all Michigan technology education programs. And third, future research regarding the promotion of technology education would be greatly enhanced.

Statement of the Problem

The promotion of technology education curricula in technology education programs throughout the state of Michigan is generally accepted. However, the curriculum model in each program is unknown, and may vary between schools. The research question to be considered is:

> How are technology education curriculum models implemented at the secondary school level in the state of Michigan?

Definition of Terms

> Technology Education - A field that satisfies the needs and wants of people by developing the knowledge and processes necessary to generate systems of communication, transportation, construction, manufacturing, and biological systems for the solution of problems and the extension of human capabilities (International Technology Education Association, 1996, p. 2,16)

Literature Review

Purpose of Technology Education

The purposes of technology education, as written by Zuga (1986), are focused toward production but can be used to form purposes for technology education in general. The purposes of technology education are to:

- Assist students in assessing and preparing for future careers and technical occupations.
- Provide students with a foundation in entrepreneurship, economics, and business relationships.
- Assist the students to become independent learners and problem solvers who possess lifelong learning attitudes. (pp. 31-32)

Technology Education Curriculum Designs

Linked with the purposes of technology education are the five main curriculum designs in technology education. These designs are described by Hansen (1995), Wicklein (1997), and Zuga (1989, 1993) as academic rationalism, technical curriculum, intellectual processes, social adaptation or reconstruction, and personal relevance.

The academic rationalism curriculum design tends to focus on a body of knowledge which is grouped into disciplines, subject matter, or broad fields of study. In technology education, the academic rationalism design is reflected in the way in which curriculum proposals focus on technology as the basis of content and also focus on taxonomies of technological concepts, as discussed by DeVore (1964). This design, as used by technology education, is utilized for the purpose of generating constructs that cut across traditional skills and processes.

The technical curriculum design is based on the analysis of process or performance, using a job and task analysis or the identification and sequencing of a highly-structured behavioral outcome approach (Zuga, 1989). This design is very popular in vocational education and industrial education curricula (Allen, 1919; Fryklund, 1956 & 1970; Lux, 1979; Selvidge, 1923; Selvidge & Fryklund, 1946).

The intellectual processes design makes the development of either cognitive processes such as critical thinking and problem solving or human processes and traits such as creativity and self-confidence the focus of the curriculum, rather than a structured discipline or a sequence of tasks. The primary goal of this design is to increase the student's learning ability through the utilization of problem solving activities in order to transfer problem solving abilities to all areas of the curriculum and life. The emphasis in this design begins with problem solving processes and then focuses on the content and context of the learning situation (Wicklein, 1997).

The personal relevance curriculum design centers on the student with a focus on the individual's needs and interests. The primary goal of this design is to put the student in control of the curriculum instead of allowing subject matter specialists to dictate the curriculum for the student. One example of this type of curriculum in technology education is the Maryland Plan (Maley, 1972). This plan focused on creating a way for students to regain control over the curriculum in industrial arts courses by allowing the students to choose topics of investigation within specified areas such as production and research and development. Another example of the personal relevance curriculum design in the industrial arts/technology education field is the use of self-selected projects in the curriculum (Zuga, 1989).

The social curriculum design focuses on the application of knowledge in realistic or real world situations. This design includes two distinct and opposing views: the adaptation side to social curriculum, and the reconstruction side. The social adaptation side of the design comes from the work of Bobbitt (1918),which focuses on preparing students to fill specific occupational roles in society. The technology education curriculum follows Bobbitt in that it prepares students to understand technology, and leads the students to fill roles as workers on assembly lines or in that it trains students to understand and follow technical directions in project work (Zuga, 1989).

The social reconstruction end of the design spectrum focuses on the way in which the future of society can be changed as a result of the educational activities of current students (Zuga, 1992). The technology education curriculum tends to follow the social reconstruction design in that it tries to incorporate the works of Dewey (1916) and Counts (1932) as well as the works of Apple (1979, 1990), Anyon (1980), and Pinar (1981). Technology education curricula follow the social reconstruction design by having students consider alternative sources of fuel for heating and transportation, for example. Technology education is also incorporating a reconstruction in society through the integration of mathematics, science, and technology in schools, assisting students to learn the relationships between disciplines and the relevance of these relationships in real life situations (LaPorte & Sanders, 1995).

Three Theories of Technology Education

Although the previous five designs are considered to be the primary curriculum designs in the technology education field, these curriculum designs can be simplified into three categories offered by Kliebard (1985), which are relevant to this discussion (Zuga, 1993). These are the social efficiency theory, the human development theory, and the social meliorism theory.

The social efficiency theory consists of two primary thrusts, namely the academic thrust and the vocational thrust. Although the academic rationalism and vocationalism thrusts tend to be split as a result of the ongoing influence of Greek philosophy, they can be united through the concept that "the goal of education and curriculum is to reproduce, efficiently, the existing culture" (Zuga, 1993, p. 10). The technology education academic rationale and technical curriculum designs are included in this theory (Zuga, 1993).

The selection of content material to be taught in the curriculum is simplified when using the social efficiency paradigm. One needs only to survey the past and the present to find that the traditional technology education as well as vocational education curricula reflect the knowledge base of industry, the occupations, or a combination of the two, as in Allen, Hambrecht, and Welch's (1945) *Trade and Job Analysis* (Fryklund, 1956, 1970; Selvidge, 1923). As Zuga (1993) states, "Much of the technology education curriculum theory and design discussions fall into this category" (p. 11).

As for the human development theory, it has been a part of curriculum circles since the late eighteenth century. Some major work in this movement include Dewey's (1916) *Democracy and Education*, Rousseau's (1979) *Emile*, and Herbart's (1914) *Herbart's ABC of sense perception and minor pedagogical works.*

The human development theory is based on the creation of a curriculum from the ways in which children normally develop (Kliebard, 1985). The focus of this curriculum paradigm is on higher-order thinking skills and problem solving. It is believed that "learning to solve problems and investigating topics and problems of personal interest are the keys to a successful education" (Zuga, 1993, p. 12). This paradigm rejects the social efficiency theory of filling empty heads and molding raw material. The technology education intellectual processes and personal relevance curriculum designs are included in this theory (Zuga, 1993).

The primary task of curriculum developers in this paradigm is to identify stimulating activities by having teachers create problems or make situations problematic in order to help students grow both mentally and physically. It was the human development theory that helped to develop the industrial arts field during the early part of the twentieth century. Unfortunately, vocational education ideologies influenced the industrial arts curriculum in the United States to leave the human development theory and transfer to the social efficiency theory (Lux, 1972, 1979). As a result, the field of technology education is currently embedded in the social efficiency theory.

The social meliorism curriculum theory focuses on the changing of the existing society (Kliebard, 1985). The social meliorism theory implies that "society needs to be changed and students should plan and implement ways in which to change it" (Zuga, 1993, p. 13). The concept of social meliorism began several decades ago with the social reconstruction philosophies of John Dewey (Bode, 1933; Counts, 1932; Dewey & Childs, 1933), and is active today with the work of curriculum theorists such as Apple (1979, 1993, 1995) and Pinar (1981).

The social meliorists view students as the future of society, and schools as a part of society. Some of their beliefs include the idea that students should begin immediately working on the current and future problems of society, and that through focusing on real problems, students can learn and develop into responsible adults who will be able to reconstruct society. The technology education social adaptation and reconstruction curriculum designs fit into this theory (Zuga, 1993).

Some examples of social meliorism theoretical activity in the technology education field include the works of LaPorte and Sanders (1995), Pytlik (1981), and Wright (1988). The predominant curriculum theories used and recommended by technology educators are shown in Table 1.

Table 1: Predominant Curriculum Theories (Zuga, 1993, p. 15)

Theory	Design	Sub-design	Authors and Dates of Recommendations
Social Efficiency	Academic		DeVore, 1980, 1964 McCrory, 1980 Maley, 1982 Yost, 1988 Zuga, 1988b
	Technical	Task Analysis	Selvidge, 1923 Bollinger & Weaver, 1955 Fryklund, 1956, 1970
		Systems Analysis	Towers, Lux, & Ray, 1966 Witherspoon, 1976 Ritz, 1980 Schwerkolt & Spontelli, 1987 Wescott, 1988 Jones, 1988 Bjorklund, 1988 Snyder & Hales, 1981 Savage & Sterry, 1990
		Performance Objectives	Wilber, 1948 Almost all authors have focused on objectives
Human Development	Intellectual Processes		Sarapin & Starkweather, 1981 Maley, 1982 Moss, 1987 Hatch, 1988
	Personal		Maley, 1973 Mentioned by: Sarapin & Starkweather, 1981 Maley, 1982 Moss, 1987
Social Meliorism	Social		Pytik, 1981 Wright, 1988

Lack of Consensus in Technology Education

Over the past 20 years, the technology education field has been evolving out of an industrial arts background (Lux, 1981). During this evolution, the implementation of technology education curriculum in technology education programs has varied greatly. At one end of the spectrum, programs have completely thrown out the old industrial arts influences of the past and adapted state-of-the-art laboratories and technologies (Neden, 1990). At the other end of the spectrum, programs have merely changed their name without changing any of the curriculum or facilities, focusing on a hybrid of industrial arts curriculum laced with technology education ideas (Oaks, 1989). Because of this wide variety of programs that exist in the United States, national standards for technology education are being developed (International Technology Education Association, 1996).

During the 1980s, Dugger, Bame, and Pinder (1985) attempted to develop national technology education standards for the field. Although the standards provided a systematic process to assess the major elements of a comprehensive technology education program, the field did not embrace them.

Similar to these and other efforts to establish standards in fields of study such as mathematics, science, and social studies, contemporary technology education professionals along with the International Technology Education Association (ITEA) are attempting to establish a current set of standards for the field. It is the hope of these educators and the ITEA that the establishment of standards in the field will help them to obtain the support from education administrators in order to ensure the stability and future of technology education as a subject matter in elementary, middle, secondary, and post secondary education (International Technology Education Association, 1996). These standards will also include a definition of technology education, a rationale for the study of technology education, and most likely a change in the technology education curriculum structure (International Technology Education Association, 1998).

Although national standards are forthcoming, the technology education programs in Michigan remain diverse in relationship to one another. Because of this continued inconsistency among technology education programs, a study is necessary to learn more about the diversity of the programs, where they are located, and the curriculum model that each program embraces.

Design and Method

Statement of Research Hypotheses

For the purpose of this study, the following hypotheses are stated as conjectural or plausibly directional as results of the data obtained from the questionnaire. A multidimensional chi-square and Analysis of Variance (ANOVA) will be used to assist in the data analysis.

Hypothesis Number 1 (null): There is no significant difference in the implementation of technology education curriculum models between schools within the state of Michigan, when observing the percentages and standard deviations. The null hypothesis can be diagramed in this way: H_0: $T_{S1} - T_{S2} = 0$ where T = technology education curriculum model, S1 = any secondary school in Michigan, and S2 = any secondary school in Michigan, other than the one selected for S1.

Hypothesis Number 2 (alternative): There is a significant difference in the implementation of technology education curriculum models between schools within the state of Michigan, when observing the percentages and standard deviations. The alternative hypothesis can be diagramed in this way: H_a: $T_{S1} - T_{S2} > 0$ where T = technology education curriculum model, S1 = any secondary school in Michigan, and S2 = any secondary school in Michigan, other than the one selected for S1.

Study Rationale and Theoretical Framework

The primary reason to support this study is that there has been very little research performed regarding the curriculum models that exist among technology education programs in Michigan. It is hoped that through this study, knowledge can be contributed to the research regarding the implementation of technology education in the state of Michigan.

Design

The research design method chosen for this project is quantitative in nature. The best design for this project is a survey research design. This design will allow us to obtain information regarding the technology education programs in Michigan.

Population. For the purpose of this study, a listing of all the technology education teachers in the state of Michigan will be entered into a database. These teachers are certified to teach technology education K-12. Presently, the total number of certified technology education teachers in the state of Michigan is 865.

Database. Careful consideration will be observed to prevent teachers from duplicating the survey. Teachers will be instructed regarding the survey procedures.

Sampling. All 865 certified technology education teachers in the state of Michigan are eligible to take part in the study. Since the demographics in Michigan are quite varied, a stratified random sample technique will be used to select the sample. Because the population of eligible teachers is less than 1,000, 30 percent of each demographic population of teachers will be selected to participate in the survey. Each teacher will receive a copy of the instrument along with instructions for completing and returning the instrument. The survey will be mailed during the second week in May 2000, with non-response mailings being mailed the first week of June 2000, and the last week of June 2000.

Instrument. The instrument was adapted from a study performed by Engstrom (2000). The survey will be used to gather data from the technology education teachers. The major emphasis of the instrument will be to obtain information from the teachers regarding their current curriculum content (see appendix).

Procedures. Before being used, the survey will be approved by faculty of the Technology Education program at Eastern Michigan University, by the Business and Technology Education Department Head at Eastern Michigan University, and by the human subjects review committee at Eastern Michigan University. Following approval from the human subjects review committee, the survey will be mailed to 10 percent (87 teachers) of the population for a pilot survey. If some errors in the instrument are found, they will be corrected. After the instrument has been determined to work properly (returning at least 80% reliability among the respondents) the survey will then be mailed to the participating technology education teachers.

Following the return of the surveys, a correction for nonresponse will be performed. The teachers who did not complete the survey will be sent a second copy of the survey. This procedure will be repeated again for those teachers who did not respond to the second mailing. If less than 60% of the teachers respond after the second non-response mailing, a ten-percent sample of the non-response population will be sent a copy of the survey, and the results will be compared to the other respondents for consistency.

Proposed Analysis and Discussion

Analysis of Data

The information gathered from the survey will be converted into numerical data via the Likert scale. Therefore, a multidimensional chi-square and analyses of variance, or ANOVAs will be performed using SPSS software to compare teacher responses to the questions on the questionnaire.

Statistical Analysis. A multidimensional chi-square will be used to compare frequency counts between key questions on the questionnaire. ANOVAs will be performed on the teachers' responses to the questionnaire to test the hypotheses. The alpha level will be set at .05 for this study.

Delimitations. This study will not cover detailed information within each program. Only certified technology education teachers in the state of Michigan will be selected to participate in the study. Also, the study is not meant to influence teachers to change their technology education program curricula to follow a specific curriculum. Confidentiality will be ensured through a coding system.

Conclusions

The review of literature suggests that technology education curriculum models are being implemented in technology education programs in Michigan. However, the type of model that each school follows is not known.

This study will survey certified technology education teachers in Michigan to learn about the technology education programs they teach, and the curriculum model they follow. With the completion of national standards for technology education (International Technology Education Association, 1996) and the need for state funding of technology education programs, information is needed regarding the curriculum model that each technology education program endorses.

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Appendix

Questionnaire

Technology Education

THIS QUESTIONNAIRE TAKES ONLY A FEW MINUTES TO COMPLETE AND MAIL!!!

This questionnaire is being used to gather information about the various technology education programs, and learn the types of curriculum models that exist in Michigan. Please complete this questionnaire and return it in the enclosed postage-paid envelope by (DATE). Your honest and professional opinion is highly valued. Be assured that your responses will be held in strict confidence. Thank you in advance for your prompt return of this survey.

Activity Content Rating Matrix

Please read each of the following activity components below. Completely fill in ONE of the circled numbers, according to the description below, that you feel best describes the importance of that component in the activities in your program.

4 - Very important in the activities in our program

3 - Somewhat important in the activities in our program

2 - Not very important in the activities in our program

1 - Irrelevant to the activities in our program

In an activity in our program, students should:

	Component	Scale
1	Acquire some degree of dexterity when working with tools	4 3 2 1
2	Allow others to critique their solution	4 3 2 1
3	Appreciate good design	4 3 2 1
4	Assess the impacts and consequences of technology	4 3 2 1
5	Build a project that is based on student interest	4 3 2 1
6	Consider environmental issues related to technology	4 3 2 1
7	Consider future trends in technology	4 3 2 1
8	Consider various solutions	4 3 2 1
9	Create a portfolio that documents their work	4 3 2 1
10	Create a solution to the problem	4 3 2 1
11	Create something that has intrinsic value	4 3 2 1
12	Design a solution to a problem	4 3 2 1
13	Develop "hand-eye" coordination	4 3 2 1
14	Develop a broadened appreciation of industry	4 3 2 1
15	Develop an appreciation for good craftsmanship	4 3 2 1
16	Develop an interest in an occupational area	4 3 2 1
17	Establish values on the impact of technology on society	4 3 2 1
18	Examine potential trade-offs of the solution	4 3 2 1
19	Examine their work habits and progress	4 3 2 1
20	Explore a vocational interest	4 3 2 1
21	Express himself or herself through creative work	4 3 2 1
22	Follow a troubleshooting procedure if the solution does not work	4 3 2 1
23	Have a variety of experiences with tools representing many industries and crafts	4 3 2 1
24	Identify common hand tools	4 3 2 1
25	Identify potential impacts of solution while planning it	4 3 2 1
26	Increase an understanding of the impacts of industry on society	4 3 2 1
27	Indicate if the final result matches the desired result	4 3 2 1
28	Integrate information from other academic studies	4 3 2 1

29	Maintain intelligent consumer choices about products of industry	4	3	2	1
30	Make plans for a home workshop	4	3	2	1
31	Make sketches and drawings of potential solutions	4	3	2	1
32	Make something that is useful around the home	4	3	2	1
33	Learn and practice board drafting skills	4	3	2	1
34	Learn and practice Computer-Aided Design skills	4	3	2	1
35	Squaring a block of wood	4	3	2	1
36	Using a wood plane to plane wood surfaces	4	3	2	1
37	Making wood projects from pre-developed jigs and fixtures	4	3	2	1
38	Learning about welding and metallurgy	4	3	2	1
39	Plan the product or system development	4	3	2	1
40	Plan the steps for the construction of a product	4	3	2	1
41	Provide the opportunity to improve the solution	4	3	2	1
42	Utilize a design or problem-solving model	4	3	2	1
43	Utilize an invention process	4	3	2	1
44	Build projects that develop dexterity	4	3	2	1
45	Build projects that teach materials and processes	4	3	2	1
46	Teach life skills	4	3	2	1
47	Utilize an "input, process, output, feedback" model	4	3	2	1
48	Understand the subject according to the national standards of technology education as promoted by ITEA	4	3	2	1
49	Utilize environments, artifacts, and systems	4	3	2	1
50	Learn about physical, communication, or bio-related technology	4	3	2	1

Check the appropriate demographic information below:

Position . . . . ( ) elementary school teacher ( ) middle school teacher

( ) high school teacher ( ) supervisory/administration

Years of teaching experience . . . .

( ) 0-3 ( ) 4-6 ( ) 7-10 ( ) 11-15

( ) 16-20 ( ) 21-25 ( ) 26-30 ( ) more than 30

Years experience in technology education

( ) less than 1 ( ) 1-5 ( ) 6-10 ( ) more than 10

Please check all of the following which describe your program's curriculum:

( ) Industrial arts ( ) Industrial Technology ( ) Tech-Prep

( ) School-To-Work ( ) Technology Education ( ) Vocational

( ) Pre-engineering ( ) Other:

Does your program have one or more of the following? (Check all that apply)

( ) Woodworking lab ( ) Metals lab ( ) CAD lab ( ) Graphic communications lab

( ) Manufacturing lab ( ) Electrical/Electronics lab ( ) Modules

( ) Construction lab ( ) Automotive lab ( ) Other:

Which approach best describes your program?

( ) Applied/Practical Science ( ) Constructive Methodology

( ) Career Emphasis ( ) Design/Problem Solving

( ) Engineering Systems ( ) Math/Science/Technology Integration

( ) Modular Approach ( ) Student-Centered Approach

( ) Tech Prep

Thank you for completing this questionnaire.

Please return to Dr. Phillip L. Cardon in the enclosed postage-paid envelope.

Inquiry-based Teaching in Urban Schools

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Introduction

Teaching science via inquiry has been advocated by science educators for decades and recently, National Science Education Standards (NCES) recommended it as a fundamental aspect of teaching at every level (DeBoer, G. E. & Bybee, R. W., 1995; Lawson, 1995; National Research Council, 1996; Schwab, 1962; Uno, 1990). Such an importance of inquiry has led researchers to study the its role in instruction, student activities, curriculum materials, and teaching practice (Flick, 1997; Henson, 1986; Hogan & Berkowitz, 2000, Keys & Kennedy,1999; Tafoya, Sunal, & Knecht, 1980; Welch, Klopfer, Aikenhead, & Robinson 1981; Pizzini, Shepardson, & Abell, 1991). Teaching via inquiry is considered important because it helps students experience authentic scientific practice and thus learn scientific ways of thinking. This means that irrespective of the social-class, race, gender, or culture all students are required to think and perform according to certain norms – those of middle-class western society. This also means that students coming from a poor family background have to learn to function in an environment that requires cultural capital different from what engenders from their social circles (Apple, 1992; Carlson, 1992; O'Loughlin, 1992; McLaren, 1989). This requirement can pose several challenges; Phelan, Davidson, and Cao (1991) point out the various transitional problems that students face in their study of social groupings of school-age children. The challenges of crossing the borders between various groups intensify in the science courses because they represent masculine, Euro-centric, and elitist views (Aikenhead,1997; Harding, 1991; Stanley, & Brickhouse, 1994) and thus present additional challenges for those who do not come from these groups.

Interestingly, the practice of inquiry in urban schools with high poverty has rarely been a focus of study. Atwater (2000) and Howes (2000) indicate that students' social class and race are rarely included in science education studies. While their critiques are aimed at studies related to gender issues, they are relevant to many others in science education. I believe there will be little disagreement about the observation that reports of effective teaching involve either no description of students' socio-economic status or include those who come from middle and upper middle class background. Consequently, science instruction in schools serving students from low socio-economic background represents an area that needs to be researched and this study focuses on that area by exploring the inquiry-based teaching of three teachers who teach in high-poverty urban schools.

Context of the Study

In this paper I present some of the findings of a larger study. All the schools involved in the study were high poverty urban schools. The two cases presented here are the typical situations found in the study.

Participant teachers

John[1], and Denise teach in two junior high schools in a large Midwestern city. John is a 30-year old Caucasian male who has been teaching science for 4 years and Denise is a 41 year old Caucasian female who has been teaching for eight years. Both John and Denise teach seventh grade in their respective schools. John has a strong background in science; he has taken over 30 semester hours of science courses, some of which were required for chemistry and biology majors in the undergraduate programs at the university he attended. He spends a lot of time preparing for teaching inquiry lessons. He is comfortable with his knowledge of the subject matter, yet, he always takes time to refresh his knowledge through professional development programs. Denise had taken 21 semester hours of science during her undergraduate degree program in elementary education, but only two of these courses were at the 200 level and one was a 400 level survey course in environmental science. While she is not too confident about her content knowledge, she continually tries to improve her knowledge by attending workshops. She does not write any lessons on her own, but relies solely on activities from textbooks and other resources. If she can not find any activity, she avoids teaching that topic. John and Denise have attended various professional development programs that focused on inquiry in different forms. They both have gathered a large collection of hands-on activities from these workshops and have experienced little or no exposure to open-ended inquiry.

John's students like him and show no hesitation to approach him whenever they have questions. Denise, on the other hand, appears to be distant and students did not appear to be very close to her. She never shows any disrespect to students, but there is not much personal conversation between her and the students. Once again, the out-of-class

[1] Pseudonyms are used throughout the paper

interactions the teachers have are almost always with the high–level class, even though there was no observable difference in their interactions with different sections. Students work in cooperative groups in all the classrooms observed. The sizes of groups vary between three to five members and depend on the number of students present on a particular day.

Schools

Both schools that provide the background of this study are high poverty schools according to the definition of US Department of Education (Lippman, Burns, & McArthur, 1996), since more than 40 percent of the students are on free or reduced price lunch. In addition to coming from low socio-economic status (SES), many students live in difficult family situations. The schools are under a lot of pressure from the respective districts because of the poor performances of students on the state-mandated tests. Teachers are required to follow the district curricula and prepare students for the mandatory tests. None of the schools has an official tracking system but the reality is that students in each section of a grade level happen to be fairly similar in terms of academic achievement. For every grade level there is a section for advanced students. I will refer to the three major divisions of each grade level as high-, middle-, and low-level sections. Absenteeism, off-task socialization during lessons, and avoidance of assignments are problems common to the low-level sections in both schools.

Data Collection

I visited each teacher's classroom for two months, on an average, four times a week. I did not visit the classrooms on the days the students had a test or an event that disrupted the usual teaching schedule. For example, during preparation for the Black History Celebration in Denise's school, a large number of her students went for their practice for the program, and I did not visit the classrooms on these or similar occasions. I observed one high-level and one low-level classroom in each school.

Each observed lesson was audio-taped; teachers wore a lapel microphone and the receiving unit was placed along with the tape recorder at the back of the class. In addition to this, I took fieldnotes during the lessons to add details that could not be taped and I added my reflections after I returned from the schools. On most days, I had brief discussion with the teachers regarding the lessons at the end of the school day. This was possible because I happened to observe the afternoon classes. In addition, copies of lessons, student work, and samples of assessment measures were collected from each teacher and all of these served as datasources.

The teachers were interviewed twice – once at the beginning and once at the end of the study. The principal of each school was interviewed once. All the interviews were audio-taped, and transcribed, and the transcripts added to the pool of data. The study focused mainly on teachers' actions and while originally there was no plan for interviewing the students, focus group discussions with three or four students from each of the low-level classes were conducted at three or four weeks into the study. This decision stemmed from the observed differences in the participation in the two kinds of classrooms. Because of the lack of interest in the students in low-level classrooms, I decided to have focus group discussions with them. These sessions were not as formal as interviews and they were conducted to form some ideas about students' thoughts related to their science classes. To keep these sessions from being intimidating, they were not taped, instead, detailed notes were taken during and after the sessions.

Data analysis

The lessons, transcripts, and fieldnotes were combined to construct analytic narrative vignettes for each day's lesson (Erickson, 1986). The process of analysis and theory building began with the iterative process of identifying the emerging categories from each data source. The coding of the data in terms of some initial categories continued with the development of additional categories through induction (Strauss, 1987). The initial categories were then retained, modified or rejected through repeated comparison. All the categories were used in coding every dataset. The coded datasets were then examined to develop concepts that helped in understanding data from various sources. Concepts that illustrated a pattern were subsumed into themes that represent the research findings. Other concepts were then used to confirm or disconfirm the themes. All the themes were then triangulated against relevant datasources then discrepant case analyses were done to build the narratives representing the findings from this study.

Findings

The findings as well as the discussion section is based on the interactions and vignettes from the low-level classrooms simply of because more than half the students in these classrooms either refrained from participation or engaged in socialization during the lessons. Although researchers generally report studies of success, perhaps we can learn also from situations that lack it. Guided by this thought, I am presenting the cases from the low-level classrooms where the teachers felt at a loss about involving students in active participation.

I present the teaching of each teacher in separate sections. In each section, the data from their lessons will be presented to illustrate the nature of their lessons and teacher-student interactions, and their rationales for the instructional strategies. Then I present the findings that are common to all the contexts in a separate section.

John's Class

Lessons In his class, most days, students literally "do" something – they have reviews and work on paper-pencil exercises at the end of each unit. The lessons have very specific step-by-step instructions for doing the activities that are sometimes followed by questions or general instructions for making observations and drawing conclusions. The activities are related to the central topic of the unit but they do not build on the previous ones. That is, the students can do them in a different order because they do not have to use their knowledge from the previous lesson as long as they know some basic concepts. The example of his lesson given in Figure 1 is from his unit on physical and chemical changes.

Students work with materials in thee separate tubs marked #1, #2, and #3. When a group has completed the work with the materials in one tub they pass it on to a neighboring group. The tubs rotate among groups in a round robin fashion. Each activity illustrates some properties of physical and chemical changes but the concept underlying the experiment in Tub#1 is not necessary to understand that in #2 or #3 as long as students know the characteristics of these changes.

Teacher-student interaction: John's class While students do the activities, John circulates among the groups, answers their questions, attempts to keep them focused when necessary or guides them toward making desired observations and conclusions. As will be apparent from the following segments of his interactions with students, his questions are unplanned and sporadic; they can be totally dependent on the situation and concerned with monitoring student participation rather than concept development. For example, the following conversation ensued with a group of students who were working with Tub #1:

> John: Do you have any problems?
> John: Are you writing down your observations? (Checks one student's paper). You need to give more details, you know one or two words is not enough. Josh, why aren't you writing anything?
> S1: *Nope*[1]
> S2: *He (pointing to a member of the group) does everything. I don't get a chance to do anything.*

---

[1] Student responses are italicized to make it easier to identify them.

At this point, John goes over the rules for groupwork and settles the matter then moves on to the neighboring group[1]. (Transcript and Fieldnote: October 29)

Even when his interaction focuses on conceptual matter they are unplanned and therefore, some groups receive help on one topic and not on others. In the transcript quoted above, his conversation is focused on settling disagreements and does not go into checking if the observations are relevant. This is important because with another group, he had the opportunity to modify their observations, which he did not do with the previous group. In this group the students observed a lot of bubbles after stirring and inferred a gas was coming out.

> John: What did you observe?
> S1: *Lots of bubbles. That means a gas is coming out.*
> John: You got the bubbles because you were stirring real hard.
> S2: *Yea. She was going real fast! (Laughs)*
> Students started erasing their responses and writing down new ones.
> (Transcript: October 29)
>
> Three out of five groups inferred that the bubbles they saw after stirring either in the activities with Tub #1 or #3 indicated the formation of a gas. However, John was not with these groups during these activities so these ideas remained unchanged. (Fieldnote: October 29)

John's Rationale He teaches via inquiry because since his undergraduate methods course – where he first experienced teaching this way – he enjoyed this approach and can not imagine teaching science in any other way. He is aware of that the students do not always observe what they need to, so he likes to do a summary of what they should have learned toward the end of each lesson. Typically, John collects students' papers a few times during a unit, corrects them, and then returns them to the students. These corrections point out to students what they should have observed and inferred and John believes that although he is unable to guide all groups during the activities, they get the opportunity to learn the concepts when they receive the corrected papers. He also reviews the concepts students have learned or should have learned at the end of each unit and then they have quizzes or tests.

---

[1] Description of events are added from fieldnotes

Figure 1: Example of John's Lesson

Changes: Physical or chemical?

Name: ______________________ Bell #: ________

You will do several activities today. The instruction for each activity is given below. Make Sure the number on the tub matches the activity number. Discuss with your group before you write down the observation and conclusion. **Wear you safety goggles.**

Tub #1

Be sure to use the right spoons. They are marked **alum** and **ammonia**.

1. Take a baby food jar from the tub.
2. Fill the jar one half-full with water.
3. Add 1/2 teaspoon of alum to the water and stir.
4. Stir in 2 teaspoons of ammonia.
5. Allow the solution to stand for 5 minutes.

Write down your observation in detail and then decide whether you observed a physical change or a chemical change.

Observation:

Conclusion:

Tub #2

1. Fill a jar one half-full with limewater.
2. Use the straw to exhale into the limewater.
3. Continue exhale into the liquid until a distinctive color is observed.

Write down your observation in detail and then decide whether you observed a physical change or a chemical change.

Observation:

Conclusion:

Tub #3

1. Take a clean cup and spoon.
2. Get one cup of water.
3. Put one spoon of cool-aid in the water and stir.
4. Taste the liquid.

Write down your observation in detail and then decide whether you observed a physical change or a chemical change.

Observation:

Conclusion:

Denise's class

Lessons Like John, Denise teaches by engaging students in doing something. Students follow the specific steps given to them and answer the accompanying questions. They have a laboratory notebook in which to write their report. Denise plans her teaching around activities rather than designing them to fit the curriculum. If she does not have an activity on a topic then she moves to next activity rather than next relevant concept.

An example of her lessons on Properties of Light is given in Figure 3. This activity follows a demonstration that light travels in straightline paths. Students are told that they would investigate how light reflects from mirrors. It becomes obvious during the activity, that almost half the students are confused about following the instruction for drawing the lines, placing the pins, and measuring the angles.

Teacher-student interaction: Denise's class Denise, like the other two teachers, continuously monitors student work, moves from group to group, and asks questions to check their progress as well as to provide help. Her questioning is more similar to John's than that of Laura's because the nature and place of her interaction with the groups is sporadic and unplanned. The following segment from the transcript of the lesson presented in Figure 3, shows the pattern of Denise's questions.

Denise: What did you do today?
S1: *I did some angles and stuff?*
S2: *Light.*
S3: *Angle of reflection.*
Denise: What did you find?
S4: *Reflecting off of stuff.*
Denise: What does that mean?
S3: *Same angle.*
Denise: What is same? Are your angles the same? (Checks their answer to the corresponding question in the lesson) Forty one and Fifty nine! They should be the same. Try it again.

This activity followed the demonstration on how light travels and on formation of shadows. Denise also introduced the idea that reflection helps us see objects and that mirrors reflect light. However, there is no explicit attempt to connect this to the activity, nor is there any attempt to check if students have the skills necessary to do the measurement required in the process. The fieldnote for that day shows the general climate of the classroom.

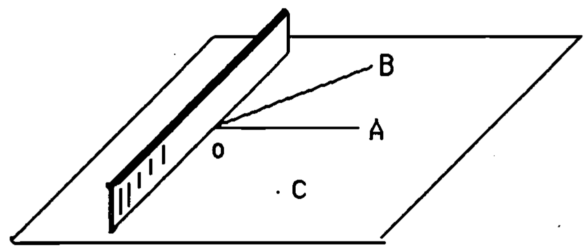
Students had a reading assignment but apparently, other than two or three, they have not read the material and do not know that they are verifying the law of reflection, nor do they seem to understand reflection. They are confused and are having difficulty following the directions given in the handout. Most of them do not know how to measure angles and are also having trouble placing the pins in appropriate positions. They do not know that they have to look at the pins from the level of the paper. Except for one group that got equal angles, all others are repeating the activity to get the correct answer. They obviously do not like to repeat the activity and are still confused about how to do it right. Some of them are going to the other groups to see how they are doing it. There is a lot of social talk going on. (Fieldnote: November, 19)

Denise's rationale She believes that students at this age need to learn by doing not by listening to teachers. If she finds activities with which she is comfortable, then she teaches that topic with more emphasis than others for which she has to rely only on lecture and diagrams. In her own words, "You can't talk to these students for too long, then you will be talking to yourself" (Interview #2), so she tries to keep them engaged, if necessary by watching video-discs and answering questions related to the episodes watched.

Figure 2: Example of Denise's lesson

REFLECTION

OBJECTIVE: Demonstrate the behavior of a reflected light ray.



MATERIALS: sheet of white paper (21 cm x 28 cm), metric ruler, protractor, cardboard (30 cm x 30 cm), 2 straight pins, small mirror, playdough

PROCEDURE:

A. Draw a line across the middle of a sheet of paper. Mark the midpoint as point O.

B. Place the vertex of a protractor on point O. Mark point A at 90^{o} . Draw line segment AO by connecting point A and point O. Extend the line segment 15 cm from point O.

C. Using the protractor, mark point B at 30^{o} to the right of the line segment AO, as shown. Draw a line segment BO. Extend line segment BO 15 cm from point O. This line will represent an incident light ray.
What does angle BOA represent?

D. Place the paper on a piece of cardboard. Inset a straight pin on line BO. About 10 cm from point O.

E. Support the mirror with playdough. Stand the mirror so that the back of the mirror is lined up with the line across the paper. Position the center of the mirror on line AO.

F. Stand to the left of line AO and locate the image of the pin in the mirror. Adjust your position until the image of the pin and the image of line BO are lined up in front of you. Place a second pin directly in front of these images about 10 cm from point O. Mark this as point C.

G. Remove both pins and the mirror. Draw the line segment CO.
What does angle COA represent?

H. Using the protractor, measure angle COA.

RESULTS AND CONCLUSIONS

1. How do angles COA and BOA compare?

2. Compare the angle of incidence of a light ray to its angle of reflection.

Patterns common to all the classrooms

Student participation in these classes varied between 30 to 70 percent, being lower on the days when lessons required more thinking and writing and higher on the days the "hands-on" aspect occupied the most of the time. John and Denise believe the problem of participation is a function of student interest. John has not reflected seriously about it, but he thinks that there will always be some students who are interested in science and others who are not. His job is to try to get students excited but it might not work on every one of them. Denise feels that the low-level students are just not interested in school, many of them will drop out soon, their families do not care about education, so teachers can not do much. She does not understand these students – they are very different from her own children and others in her social circle. In short, they all feel that they have no way of connecting to these students.

In spite of the differences in the nature of lessons and of interactions, the assessment measures were remarkably similar in all the schools. They are tests and quizzes composed of multiple-choice, true-false, and short-answer items that examine how well students have acquired the desired content. Furthermore, there are always reviews prior to the tests.

The other similarity exists in students' views – they like to do experiments but not to write about it and they particularly dislike it when they are wrong and have to change their answers. They dislike homework and reading assignments and rarely have any inducement from home regarding their schoolwork. In most cases, parents or guardians are not educated enough to help them with their homework. A few students desire to go to college; they know that they will have to study hard and get good grades in school to be able to fulfil their desire. Others, however, hope to finish high school but think that they might not; however, they are not sure why think that way. One student said that because none of the members of his family has finished high school it is unlikely that he would.

Discussion

I would like to underscore at the outset that this interpretive study does not aim to establish any causal link between the findings and the characteristics of the participants and the settings. The discussion is focused on exploring plausible explanations that might help us understand the data and provide direction for future research. Two themes emerged from the data that were common to the all the contexts, explain the observations, and have scopes in being applicable to other situations.

Many faces of inquiry

The teachers in this study have different interpretations of inquiry which represent what they learned at professional development programs. Their instructional approaches vary from potpourri of recipe-type activities to carefully designed lessons to teach science. How much and what kind of professional development teachers had seems to have a strong connection to their instructional approaches. The teachers had little or no experience with open-inquiry – an approach similar to what NCES and many other science educators advocate. John uses activities he has collected from various sources; he has modified some of these to fit his teaching style, but his interactions with students are geared toward answering their questions, keeping them on task, and summarizing the lessons. Denise, on the other hand, uses disconnected activities and pays little attention to continuity and prior concepts of students. Keeping students occupied in doing something seems to drive her teaching.

Interestingly, none of the lessons resemble scientific inquiry that "refers to the diverse ways scientists study the natural world and propose explanations derived from their work" (NRC 1996, p. 23), and students in these classrooms do not frame a question or design a study to figure out the answer. It should be noted here that Denise has limited content background, and did not attend any that taught her anything other than recipe-like lessons taught in traditional laboratory sessions. Therefore, it is unlikely that she will design lessons that resemble the way scientists work, that is open-inquiry. Furthermore, teaching practice is a function of teacher's content knowledge and pedagogical experience so it not likely that Denise would use even structured inquiry since she has never been exposed to it. John, on the other hand, has a strong content background and has learned structured inquiry (Tafoya, Sunal, & Knecht, 1980). In this form of inquiry the student

> is presented with a problem but does not know the result beforehand. Procedures are outlined. Selection of activities and materials is structured to enable the student to discover relationships and to generalize from data collected (Ibid, p.46).

This implies that the content knowledge as well as the extent and nature of professional development are important factors in how teachers modify their teaching but these might not be enough to reach students from diverse backgrounds. Teachers in urban schools have an additional challenge of connecting to students, even when there do not come from similar cultural and social settings.

Covert resistance to participation in lessons

Covert resistance from students is a problem among the low-level students irrespective of the approaches their teachers adopt. A majority of these students also happen to come from the poorer neighborhoods and have difficult family backgrounds.

None of the teachers was able to interest these students in learning science. It seems the strategies that work for high- and middle-level sections, where most of the students also happen to be from middle-class families, do not work in low-level sections where a majority of students come from poor families. Students in the latter show little interest in science, many do not participate in the thinking part and do not want to write down any observations or respond to questions. This covert resistance could be brushed aside by science education researchers as a social problem and thus not relevant to the field, since the latter group of students is from a low socio-economic background. However, such a stance implies an indifference to the needs of urban schools, and would help perpetuate inequity in urban schools. It is a responsibility of science educators to help classroom teachers – "we have an obligation as researchers to aid practitioners by preparing and studying tools that they will find valuable" Sadler, 1998, p. 268). While Sadler's comment refers to diagnostic and assessment tools it is as relevant to teaching practices.

If we are to find ways to help urban school teachers in teaching science in a meaningful way we need to explain the resistance observed in this study and juxtapose it to the work of others who provide suggestions. For example, Hodson (1999) suggests, on the basis of Phelan et. al's (1991) work, that if the worlds through which students transit are highly discordant then the process can be hazardous and they might resist it altogether. His theory incorporates Bordieu's idea (1977; 1998) and posits that student's habitus and cultural capital can facilitate or hinder the process of transition because these are functions of social class and economic status. Findings from these teachers classrooms substantiate this view since the students from poor families seem to be unable to get involved in science no matter what form the pedagogy takes, implying a mismatch between their disposition and ways of "doing" science.

This notion of mismatch lead to the idea that stretching some of the processes of science can accommodate those students who bring a cultural capital that are normally not valued by typical school culture. Barton has been successful in getting homeless children interested in doing science and recommend educators to stretch the definition of scientific practice to include informal ways of observing, inferring, and so forth. Her work is impressive and inspiring, however, stretching the definition of science (Barton, 1998) is not possible when teachers are bound by district curriculum and accountable for student performance on state mandated tests. Granted, students can be interested in doing science when they are allowed to pursue topics of their interest and perhaps, school science can be introduced subsequently. But unless this is shown to have been successful in urban schools with students from poverty, teachers are unlikely to embrace this approach.

Another aspect appears to be a key factor in teaching students who live in difficult environment is a sense of personal relationship and trust the teacher and students, as described in the studies described by Barton (1998) as well as Duckworth (1997). This notion needs to be further examined in classroom contexts. But can we expect teachers who interact with, on an average, 130 students a day to have a personal relationship with each one of them and be able to motivate them? While the answer at the outset seems to be in the negative, John has a good rapport with his high and medium achievers who also happened to be from middle-class families. This means, I would contend, that when the habitus and cultural capital of students and teachers have commonalities, it is easier for them to develop trust and rapport.

These students do not like to "think" about notions that are not directly related to them or are tangible. They were engaged in data collection and answering questions directly related to the data or the process of data collection but did not see the relevance of taking the concepts to an abstract level. This is not to imply that these students are incapable of abstract thinking, rather to highlight the disjoint between what they do in school and what they do outside. One can contend that school knowledge might have little connection to what middle-class students do outside the school, yet they are participating in learning. A plausible explanation could be that they are more used to the school game because they have parents with college education, they themselves are more likely to attend college, and they know how to participate in the school culture (Bordieu, 1977, 1998). They like to engage in concrete activities and write brief answers but extensive writing or discussion of possible focus questions for open-inquiry is not something on which they spend time. At these times, they would divert to social talk, this tendency was more prominent in ninth than seventh grade. School knowledge and everyday knowledge have little in common for students from poverty and the gap between the two need attention from the research community. Researchers have to provide teachers with tools that they can use in their teaching so that their job of introducing seemingly abstract ideas to students with various abilities and diverse backgrounds become something feasible. The ways to make school knowledge relevant to students coming from poverty and a habitus different from the one framing school science needs to be done via research focused on this issue.

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Regular Sessions

Discovering Pi with Geometry Software While Accommodating Different Levels of Technological Literacy in a Student Population

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Pi is one of the most important constants with which high school students work. The students know that the constant is useful for doing something or other with computing the area of circles in terms of square units and that it has something or other to do with the measure of the circumference of circles, but they will often mistakenly use the incorrect formulae $A=2\pi r$ or $C=\pi r^2$. If students see π only when doing one computation or the other, it should not be surprising that they misapply the formulae.

Many middle school and some elementary and high school math teachers use the lesson where students measure the circumferences and diameters of common objects, such as tin cans. A great extension to this activity is to then indirectly measure the diameters of basketballs, volleyballs, and (in Maryland) lacrosse balls. Students may want to know the diameter or radius of these objects, but the diameter of a lacrosse ball is difficult to measure without ruining the integrity of the object. If they have developed the formula $C=\pi D$, they can measure the circumference of the ball and then compute the diameter of the ball by knowing that the diameter is whatever number must be multiplied by pi to obtain the directly measurable circumference of the ball. This number can be found by pre-algebra students by trial and error, and by students with some algebra by dividing the circumference by pi.

The attached activity uses geometry technology to reinforce the definition of the constant 6.28…, or 2π, as the ratio of the measures of circumference to radius of any circle. In order for the exploration to not feel like unexplainable magic, it would be most appropriate for the exploration to follow the physical exploration described above. The activity part of the exploration is broken into three columns. The first column gives general directions that can be followed with any technology, including compass and straight edge. The middle column gives incredibly specific, step by step instructions for the student to follow, along with checkboxes so that students can keep track of where they are in the exploration. These checkboxes were originally an accommodation for specific special education students, but seem to be appreciated by all students. The right column provides a space for the student to draw what they see on the screen. The division between the left and middle columns was inspired by following technology explorations created by Jeff Smith of The Ohio State University.

Most canned geometry explorations follow either the mode of the left column (general steps of construction) or the middle column (which buttons to push). It would be nice if the left column were sufficient for all students. Unfortunately, many students are frightened and confused by technology and have difficulty asking themselves questions in order to figure out how to accomplish tasks. The middle column gives these students something to hold on to so that they can complete the assignment. It is important to stress to these students that they should first read the general construction instructions in the left column, and to guess what they should do before following the checkbox instructions.

Many technology explorations include only the "middle column", the detailed, software-specific instructions. This is even more inappropriate than to have the general instructions without having the step-by-step procedures, because with these it is very possible for students to learn procedures without engaging in any high- or even middle-level thinking. The point of high school education is to prepare students' minds to learn and grow, not to be able to follow a list of instructions (as important a skill as this may be). The focus of each lesson should be the educational objective, the desired outcome, not the particular day's activity. When an instructional-technology exploration has specific, step-by-step instructions *without context*, the lesson is sabotaged.

A colleague noted that most schools seem to be tied to one model of calculator and one brand of word processor. The result of this is that students sometimes leave with the mistaken impression that they only know how to use that particular piece of machinery. Indeed, most *teachers* only engage in training with the TI-83, and then freak out when a student pulls a Casio out of her holster. He suggested that a course be created in which students perform the same activity on multiple platforms, and compare and contrast the way that each platform treats the problem. For instance, they could construct a linear regression using a TI-83, a TI-92, whichever Casio, whichever Sharp, Microsoft Excel, and Lotus 1-2-3. Then as a final project, students can be given a problem and told to choose which piece of technology they should use to solve this problem. The grading for this project would be based not only on how well the student solved the problem but also on how well she or he defends his or her choice of technology. Similarly, students could be given specific assignments on a half-dozen word processors. When a student has a computer science course in which he or she only learns MS Word or Claris Clarisworks, sometimes the student leaves with the mistaken impression that the other piece of software is an unknowable, alien thing. A student who engages in comparing pieces of software to each other gains confidence in her or his ability to "figure out" new pieces of software, which has impact on the student's ability to find work upon entering "the real world" (D. Lowell, personal communication, April 12, 2000).

Keeping all of that in mind, I apologize for including a document with TI-89 Cabri-specific instructions. With *very* little modification this worksheet can be used with TI-92 Cabri and with pc-based Cabri, and with slightly more modification it can be used with Geometer's Sketchpad or even manual compass/straight-edge materials. Additional versions of this activity may be available upon request from the author.

The point of this activity is for students to confidently and authentically know what π represents; it is *not* for them to "learn Cabri." "Knowing Cabri" is a worthwhile subgoal, but "knowing geometry" is what will (hopefully) serve the student best in the long run. π is not just a sequence of digits, and it is not $\frac{22}{7}$ (although these come close). If students can authentically understand that π is the ratio *circumference:diameter*, then they are able to remember and correctly apply the formula $C=\pi D$ or $C=2\pi r$ and they will stop telling us that a circle with radius 3 cm has a circumference of 9π centimeters.

Objective: We will define ___ by using geometry software to explore the relationship between circumference, radius, and diameter.

Steps for construction of $\frac{\textit{Circumference}}{\textit{Radius}}$	**What buttons to push when using Cabri for the TI-89**	**Your sketch of what the screen looks like**
Open the geometry software and activate data collection mode (you activate data collection mode now so that your sketch doesn't get messed up when you use the spreadsheet later).	□ Press <On> □ Press <Apps> □ Select 1:FlashApps □ Select Cabri Geometry □ Select "New…" □ Name the sketch "circXXX" where you replace XXX with your initials, by typing "circXXX" in the Variable box □ Open the f8:Tools menu □ Select B:Data View	
Construct a circle.	□ Open the f3:Shapes menu □ Select 1:Circle □ "Click" or press <enter> to construct the center of the circle □ Move the cursor about halfway to an edge of the screen. □ Press <enter> to finish the construction	
Contruct a radius of the circle.	□ Open the f2:Points/Lines menu □ Select 5:Segment □ Right now, the pencil cursor is still on the circle. The words "On this circle" should be right above the cursor. (This is not an action). □ Click to plot the first endpoint of the radius. □ Move the cursor to the center of the circle. The words "This point" should appear above the cursor. □ Click to plot the second endpoint of the radius.	
Measure the circumference of the circle.	□ Open the f6:Measurements menu. □ Select 1:Distance & Length □ Move the cursor to the circle. The words "The circumference of this circle" should appear above the cursor. □ Click. A number should appear.	
Measure the radius of the circle.	□ You are still in "Distance & Length" mode. □ Move the cursor to the drawn	

	radius of the circle. The words "Length of this segment" should appear above the cursor. ❑ Click. A much smaller number should appear.	
Compute the ratio *Circumference:Diameter* for this particular circle.	❑ Open the f6:measurements menu. ❑ Select 6:Calculate. A text cursor should appear on the bottom of the screen. ❑ Press the down arrow twice. The measurement of the circumference of the circle should be highlighted. ❑ Press <enter>. The letter "a" should appear above the measurement of the circumference of the circle and the text at the bottom of the screen should read "a". ❑ Press the "divided by " key. The text at the bottom of the screen should read "a/" ❑ Press the down arrow once. The measurement of the radius of the circle should be highlighted. ❑ Hit <enter>. The letter "b" appears above the measurement of the radius. ❑ Press enter. The bottom of the screen should read "R:x.xx", where x.xx is a number. The number should be somewhere between five and seven.	
Record the circumference, radius, and the ratio between them for this particular circle.	❑ Open the f6:Measurements menu ❑ Select 7:Collect data ❑ Select 2:Define entry from the submenu ❑ Move the cursor over the measurement of the circumference of the circle. The words "this number" should appear. ❑ Click. Ants should start marching around the measurement. ❑ Move the cursor over the measurement of the radius of the circle. The words "this number" should appear. ❑ Click. Ants should start marching around the measurement. Ants are now marching around two different numbers. ❑ Move the cursor over the ratio between the two numbers (6.something, in the lower-left hand corner of the screen). All of	

	the numbers should now have ants marching around them. ❑ Open the f6:Measurements menu. ❑ Select 7:Collect data ❑ Select 1:Store data. The words "Data placed in variable sysdata" should appear in the bottom of the screen (if it doesn't, use "Apps:6" to go into data mode, and then the sequence "f1" "8" to clear out the data variable. If you then start storing data again, everything should work nicely.)	
Change the circle and record the new data. Do this several times.	❑ Change the measurements of the circle by dragging the rim of the circle ❑ Open the f6:Measurements menu ❑ Select 7:Collect data ❑ Select 1:Store data ❑ A shortcut to "Store Data" is to hit "diamond-comma".	
Examine your data. Make observations.	❑ If you can't see all three columns, you will want to get rid of "split screen mode". You can do this most efficiently by doing the following: ❑ Open the f8:Tools menu ❑ Select C:Clear Data View ❑ Hit the <Apps> key ❑ Select 6:Data/Matrix Editor ❑ Select 1:Current ❑ Answer the questions on the attached page.	

Label the columns below. There should be "Radius", "Circumference", and "Ratio"

Look over your data. Make at least three observations about it. Observations can be about one column, or they can be about the relationships between the columns. You should include at least one observation about the ratio.

The number π is defined to be the ratio of a circle's circumference to its diameter. Algebraically, this is represented as "π=C/D". Substitute "2r" for "D". Write the equation that you obtain in the space below.

Multiply both sides by two and simplify. What equation do you obtain?

What is the connection between this equation and the data that you collected?

Go back to the objective. Fill in the blank appropriately.

What is the circumference of a circle with radius one cm.?

Radius one-half cm.?

Fifty cm.?

What have you learned from this exploration that you did not know before?

Visual Perception of Small Living Organisms by Nonmajor Biology Students at The Ohio State University

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This pilot study aims to evaluate novice biologists' ability to perceive small living specimens in artificial ecosystems. It also uses observations of informant behavior and structured interviews to identify attitudes, educational factors, and past experiences that might influence or correlate with the ability to see these specimens. Some specific correlations that will need to be further examined are suggested and possible explanations for observed patterns are explored. The study is part of ongoing research into the role of visual literacy in biology education; that is, the development of students' ability to perceive and interpret biologically useful information in the laboratory and in the real world. This skill is desirable not only in life-science professionals but also in average citizens because it is unlikely that nonscience majors will value biodiversity if they are incapable of physically seeing the majority of living species.

The investigation springs from casual observations of certain learning processes in undergraduates, made while I was teaching life-science classes at The Ohio State University and during undergraduate-assisted marine field expeditions. Intrigued by my observations, I resolved to retrospectively examine my own learning process in the fields of cell biology and marine taxonomy. Both areas have one important theme in common: for the novice they involve a large number of encounters with images that are at first visually unfamiliar. In cell biology the first exploration of living things using a microscope exposes the novice observer to shapes, structures, textures, and lighting conditions that they do not normally experience in daily life. Similarly for a novice naturalist, some organisms appear to be made up of body parts that one utterly dissimilar to those we might see in familiar vertebrate animals. This is especially true of small invertebrates and organisms in marine or aquatic environments where background textures and lighting conditions are often alien to our terrestrial experience.

When performing demonstrations and discussing lab content with students, I noticed that in both the introductory animal taxonomy and the histology classes, there seemed to be a barrier to learning that was not present in other classes. Specifically, students claimed to be unable to see specimens or structures that I was trying to show them, or they were unable to match a picture of a specimen with its real-world counterpart. Students would draw air bubbles instead of cells, shrimp instead of crabs or algae instead of animals. Students stated that they sometimes felt extremely frustrated because, from their perspective, it sometimes seemed as if they were being asked to observe specimens that simply did not exist. Some complained that the microscope or slides must be faulty because they could not see anything that looked like the line-graphic diagrams in their books. In contrast, experienced instructors usually had no trouble finding specimens, even those they had never seen before, in a matter of seconds.

These observations reveal that students have problems with what I will call *visual literacy*, *visual induction*, and *visual deduction*. When students look at a specimen, novices tend to see it as a two-dimensional isolated whole rather than perceiving it as a three-dimensional collection of parts that they can look for in other specimens. They find it difficult to interpret what they see as either a specific example from which they can infer the appearance of a general set (*visual induction*), or a new example of something that belongs to a set that they have already seen (*visual deduction*). These skills are critical if students are to develop a mental picture of what a group of organisms looks like in general and if they are to recognize new representatives that may not look exactly like anything they have seen before. Similarly, students also have problems developing a realistic idea of just how similar two living things must look in order to be considered the same. The hierarchic nature of taxonomic classification and evolutionary relationships further necessitate the need for biology students to be able to sort, scale, and categorize three-dimensional visual information so that they can look for meaningful themes or patterns within related groups of organisms. I call the general ability to seek out, recognize, interpret, categorize, and make inferences from visual information *visual literacy*.

During my own marine field work, I noticed that animal groups I had recently studied began to appear, as if by magic, at familiar field sites or under my microscope, in much the same way that a reader becomes hypersensitive to the appearance of a word just learned. This indicates that observers in visually complex environments may fail to perceive crucial information if they do not have adequate prior exposure to it.

In this study, informants are asked to observe living things in two small, artificial habitats. The first system consists of a 1-liter jar filled with water and containing about thirteen macroscopic species arranged in a simple food web. This small, essentially self-sufficient ecosystem has been established for several years and appears quite natural, featuring a tangled community of plants and a stable diversity of small animals. The second habitat is a 10-gallon aquarium filled with empty egg crates and housing stable populations of giant Madagascan cockroaches, a species of mite and a small species of beetle. Informants were also asked to observe a third container filled with pure water as a control to make sure they were not "seeing" any nonexistent species.

Informants were asked to observe the containers and point out all the living things they could see. They were not asked to identify them, since this experiment was intended as an analysis of visual perception only, not a test of taxonomic knowledge. However, when accurate identifications were offered, they were noted as a sign of the informant's level of overall background knowledge. Informants were asked to describe what they saw and any observational strategies that they employed. All sessions were videotaped for later analysis. After the observational phase of the study was complete, informants were interviewed in order to assess their past educational experiences and attitudes towards living things.

Initial findings indicate that novice biologists do not perceive small living organisms in artificial ecosystems as easily as experienced biologists. In novice biologists, this ability seems to strongly correlate with the extent and type of outdoor activities undertaken and with past educational experiences specifically designed to enhance students' ability to observe living things. Informant indications of empathy for, or positive feelings about living things and the environment also correlate somewhat with visual ability. Detailed and technically accurate knowledge of the mechanics of ecosystems does not seem to correlate with observational ability; indeed, students with misconceptions about ecological mechanics do not necessarily seem to be at a disadvantage when it comes to their ability to see living things under the conditions of this study.

Since this study suggests that novice biologists have difficulty visually perceiving small living things, instructors should not assume that students see the same thing that they do during fieldwork or observational exercises. Furthermore, it may be desirable to expose students to fieldwork and other exercises specifically designed to develop the ability to see living things in their natural environment, since these kinds of activities seem to produce a measurable effect.

Answering the Creationists: The Importance of Religiously-Neutral Science Education

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The Institute for Creation Research (ICR), located in El Cajon, CA, is celebrating its thirtieth anniversary in September, 2000. Well financed through private donations, the center is engaged in both national and international outreach, arguing for the introduction of "scientific creationism" into public science classrooms. Much of this activity is widespread but it goes unnoticed by most educators and professional scientists. Anti-evolutionists have moved from national courtrooms to focus their efforts on local bodies such as school boards of single school districts. Recent successful manipulation of science standards in Kansas by anti-evolutionists drew intense national attention from the media, professional organizations, and teachers only *after* the damage had been done. Increased awareness and greater local and national involvement by scientists, teachers, and parents will be necessary to avoid any more successful attacks against public science education.

The Problem

The fundamentalists among anti-evolutionists, the Young-Earth Creationists (YECs), base their scientific views on a literal interpretation of the book of Genesis in the Bible. In addition to their well-publicized attacks on the scientific community, YECs spend much of their time reaching out to fellow Christians with hopes of convincing them about the vital importance of believing in a literal six-day creation. In this situation, science takes a backseat behind theological and ethical arguments. YECs successfully create a false dichotomy between science and religion by arguing that evolutionary theory is inherently atheistic. Furthermore, they point to the supposedly inherent ethical implications of evolutionary theory and their incompatibility with biblical teachings. For evidence, anti-evolutionists successfully point to antitheistic statements made in the popular science literature. Science writers often mix philosophical reflections with scientific conclusions or principles, making it difficult for the general reader to distinguish between science and personal interpretation. Furthermore, this confusion enters the public science classroom through well-read, and well-meaning, science educators who involuntarily overstep the boundaries of science by misinterpreting such personal reflections and conclusions as science. To avoid providing fertile ground for creationist attacks, educators must be careful to stay within the boundaries of science and keep religious interpretations separate from scientific interpretations. Science can and must be taught in a religiously-neutral fashion.

Overstepping the Boundaries of Science

Both creationists and evolutionists have addressed the problem of scientists voluntarily or involuntarily overstepping their boundaries. Here, I will briefly focus on two common examples I frequently encounter as a student in the science classroom. The intent here is not to criticize the personal ethical and religious convictions of any individual, especially where I provide specific examples from the literature in my presentation. Many times, philosophical world views held by these individuals reflect my own views as well. My goal is only to point out inappropriate applications of these personal views.

Fallacy #1: Speculating upon the nature and behavior of the supernatural

This argument is based on the assumption that if God exists, then certain physical aspects or natural phenomena should exhibit certain characteristics. On the surface, this has the appearance of hypothesis-formation and testing, and therefore appears to be a valid scientific endeavor. Evidence used to support this argument is usually presented as descriptions of physical attributes of various organisms that supposedly would not be as they are, had they been designed by a supernatural entity. Examples I have encountered in my science classes include: (a) the inefficiency of the bone structure in a horse's leg (when broken death is usually imminent); (b) the apparent uselessness of the human appendix; and (c) the presence of nipples in men. I have also been presented with statements that the presence of two kidneys in humans (one more than necessary for life) and the history of mass extinctions are "scientific evidence" that a designer does not exist.

However, the "If God, then..." argument fails because it makes *a priori* assumptions about the nature of the supernatural. For example, if a designer were at work, the horse's leg bones would be constructed differently, humans would have only one kidney, and organisms would not go extinct. However, a supernatural entity can choose to create anything it wishes, no matter how bizarre, inefficient, or useless it may seem to *us*. What a supernatural designer would or would not do is beyond what science can address. It should be stressed, however, that all of the above phenomena are adequately explained by evolutionary theory. These phenomena provide scientific evidence for evolutionary theory but say nothing about the existence or involvement of a supernatural entity.

Fallacy #2: Moral and ethical judgements portrayed as scientific conclusions

Apart from claiming that evolutionary theory is used to spread an atheistic world view, YECs believe the concept of evolution undermines all basis for humanity's morals and values. YECs blame evolution for a series of "societal evils" ranging from genocide, lawlessness, slavery, and liberalism, to rock music. YECs fail to specify that ethical implications of any theory are not inherent conclusions but are the result of individual, subjective, personal interpretations.

A similar fallacy is committed when educators stress the importance of environmental and conservation policies using arguments of "equal worth" between humans and animals. Scientific evidence is presented to suggest that humans are not more special (in a moral sense) than animals. The presented evidence includes shared evolutionary ancestries, similar genetic codes, and behavioral similarities. The late appearance of humans in the history of life on Earth has often been presented to me as evidence that humans are relatively insignificant. YECs seize upon this and similar ethical interpretations to argue effectively against the science used in evolutionary theory. Educators should stress in classrooms that ethical interpretations are completely separate from scientific interpretations. Where ethics and science are mixed, such as in conservation ethics, educators need to clarify the differences between scientific conclusions and ethical implications. Science can and should be taught in an ethically neutral manner.

Conclusions

The claim that YECs make concerning the inherently atheistic and immoral nature of evolutionary theory is false. Science cannot make any statement about the existence or non-existence of the supernatural. Unfortunately, evolutionary theory, and science as a whole, has often been misrepresented as providing conclusive evidence for the non-existence of the supernatural or conclusive support for a particular ethical system. YECs use these misrepresentations to underline a false dichotomy between religion and science, and successfully recruit new members to their cause. It is important for educators to understand and honor the limitations of scientific endeavor and to distinguish between philosophical interpretations and scientific statements. Teaching religiously-neutral science results in "creationism – free" schools and science that is free of philosophical atheism and ethical statements disguised as science facts.

Suggested readings for further information

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Designing Instructional Tools Using the Tenets of Constructivism

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Developing innovative materials that inspire teachers to use them and students to learn from them is not an easy task. In order to better understand the struggle we had in developing a prototype of an instructional design (*AlgeLearn*) from the constructivist perspective, we will examine our planning and decision making process. First will define constructivism as we see it now. We will then discuss literature that examines the use of this theory in instructional design. Finally, we will give a brief overview of the *AlgeLearn* product. Early in the process of trying to design the instructional product to meet our belief that students need the opportunity to construct their own knowledge while experiencing mathematics, it was clear that incorporating that experience would be difficult. Before even trying to design instructional activities from a constructivist perspective, it was of utmost importance that we determine our own definition of constructivism based on theory and practice. In addition, we hoped that the product would be marketable. Neither of these tasks was straightforward and many times the two seemed to contradict one another.

Strommen (http://www.ilt.columbia.edu/ilt/papers/construct.html) explains, "[a] brief overview of constructivist ideas reveals their utility...Constructivism emphasizes the careful study of the processes by which children create and develop ideas." Yet constructivism has many definitions. The various theories seem to agree on the notion that the best teaching practices are those that allow students to formulate their own understandings of mathematics. The differences lie in the way in which different theories view knowledge, how students construct understanding, and the role of the teacher in the process of understanding. In formulating our own definition we use elements of both radical constructivism and social constructivism. This combination is similar to initial examination of the emergent perspective. Further, we feel that the theory of situated learning is essential in defining constructivism.

According to radical constructivists such as Piaget and von Glasersfeld, children construct their own personal understanding through activity. The teacher has the responsibility of finding activities that enable the student to develop understanding (Sierpinska, 1998). Social constructivist theory stresses the importance of social interaction for knowledge construction. Students are brought into the culture of mathematics through interactions with a more experienced other. For Bruner (1986), enculturation occurs as a result of a series of negotiations of meaning between people in a social environment. Vygotsky (1978) wrote of the zone of proximal development. This zone was the stage at which the student was ready to develop a deeper understanding of mathematics with the help of an expert (van Oers, 1996). This understanding was the result of cooperation and interaction between the students and the mathematics expert. Our view combines this notion of individual knowledge construction with the importance of social knowledge construction.

Activity alone, even the best activity, will not always be sufficient for understanding. However all knowledge construction does not occur as the result of negotiations with an expert; students at times are able to make unguided discoveries within their work. The emergent perspective, which combines these two elements, would better describe our stance. Voigt defines two types of negotiation of meaning (Cobb, Jaworski, & Presmeg, 1996). *Implicit negotiation* refers to times when students make discoveries that do not match the expected outcomes and may even surprise the teacher and student (p. 4). *Explicit negotiation* occurs during activities and interactions that were designed specifically to elicit the construction of that knowledge (p. 4). It is through a combination of activity and interaction that both types of negotiation can occur. The teacher is responsible, as in radical constructivist theory, for finding an activity that helps students develop mathematical understanding. Through interaction, however, the teacher is then able to capitalize on opportunities to help students gain a deeper understanding as new knowledge emerges from an activity.

Activity holds a prominent role in our view of constructivism. However, the type of activity is extremely important. Activity should engage the students and provide an appropriate setting for knowledge construction and discovery. Choosing or developing activities is in our opinion the most difficult aspect of teaching from a constructivist perspective. One way to help motivate student interest is to use authentic activities. Activities should relate the mathematics learned in the school with the mathematics used outside the classroom (Cobb & Bowers, 1999). Classroom mathematics should be real world mathematics. This can be done by introducing topics in context.

The literature also provides some suggestions on how to go about building environments that support the basic tenets of constructivist theory. Spiro (www.ilt.columbia.edu/ilt/papers/Spiro.html) describes a "constructivist stance which stresses the flexible reassembly of preexisting knowledge to adaptively fit the needs of a new situation." He recommends flexibility in various areas including: multidimensionality and nonlinearity; allowance of the same items of knowledge to be represented, presented, and learned in a variety of different ways and for a variety of different purposes; and provision of optional background information, supplementary guidance, expert commentaries, concrete examples, and cross-references. Like the theory of situated learning, Black and McClintock (www.ilt.columbia.edu/ilt/papers/ICON.html) emphasize that authenticity and rich context be incorporated in the design of materials so that knowledge-building occurs within the context of meaningful activities. Based upon such ideas, Savery and Duffy (1995) suggest that designers consider: anchoring all learning activities to a larger task problem; supporting the learner in developing ownership for the overall problem or task; designing an authentic task; designing the task and the learning environment to reflect the complexity of the environment in which they should be able to function at the end of learning; giving the learner ownership of the process used to develop a solution; designing the learning environment to support and challenge the learner's thinking; encouraging the testing of ideas against alternative views and alternative contexts; and providing opportunity for and supporting reflection on both the content learned and the learning process.

In developing the prototype for *AlgeLearn* we desired to use technology as Strommen " (www.ilt.columbia.edu/ilt/papers/construct.html) suggested: as a "powerful tool for children's learning by doing." However the practicalities of this in our endeavor were not always clear cut. Using the Internet as a platform for exploration and growth, *AlgeLearn* was designed to allow teachers and students the flexibility to explore mathematics in a meaningful way. The students can be actively engaged in projects that allow them to use real-world data to explore mathematical concepts. In addition, they not only work with a small group, but also post their work so that the entire class can share in their ideas and give assistance. The teacher is able to monitor student progress and capitalize on discoveries by posing questions or pointing the students to a related mathematical concept. This activity can then help bring the students into the current mathematical culture. The activities found at the *AlgeLearn* site are situated in real-world context engaging students in mathematical and authentic situations. In addition to allowing the students the flexibility to explore the situation using various tools, the problems are posed so that the students and teachers can develop their own questions to explore.

It is difficult to develop a product that is constructivist, and still marketable. Providing opportunities within the product for student and teacher choice is not enough to define it as constructivist in nature. At the same time, a product with no structure is not marketable. *AlgeLearn* provides for student choice, but goes further. The open-ended nature of questions allows the student to first examine the situation and begin to make discoveries. The teacher can then begin to focus exploration to help students increase their understanding of particular mathematical areas. A teacher's handbook or companion website will be essential for the success of such a product. In this handbook suggestions for various ways to use problems would be a necessary feature. The prototype problem deals with buying a home: Students are asked to collect data on homes and then begin to explore patterns. This problem might lead to explorations with graphs, comparisons of attributes, formulations of conjectures, or investigations in the mathematics of finance. Flexibility for both students and teachers is paramount to the design.

Even though there are several suggestions for the development of instruction design to support the tenets of constructivist theory, there is recognition in the literature that this is not yet enough. We agree with Jonassen and Rohrer-Murphy (1999) in their assessment that the "problem with constructivism for instructional design [is] that, while detailed conceptions and examples of the kinds of constructivist learning environments exist, less practical advice is available on how to construct them" (p. 61). The *AlgeLearn* prototype has promise, but needs further refinement. It is our hope to continue to explore ways to use technology and to develop designs that better model the various theories of mathematical learning.

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Using a Rubric to Evaluate an Integrated Science Unit

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One goal of the recent science reform movement is to integrate the science disciplines (National Science Teachers Association [NSTA] & American Association for the Advancement of Science [AAAS], 1989; National Associated Press [NAP], 1996). According to the National Science Foundation (NAP, 1996) this will help increase understanding of concepts. Additionally, integration will promote overall scientific literacy by educating students in all disciplines instead of reserving the more traditionally difficult courses for the elite of society. This portion of the reform includes thematic or integrated science.

Thematic units are not a new concept in education. Dewey (1938) suggested that students should learn concepts in a natural, holistic way as they would learn them in real life. For example, if one wants a student to learn how to measure, actually put the student in a situation where he/she would have to know how to measure and let the student figure it out. The natural curiosity of a human being is a powerful motivator if tapped in the correct manner.

With the publication of *Science for All Americans* (Rutherford & Ahlgran, 1989) the American scientific community has warmed up to the idea that science can be taught to everyone. Since the publication of Rutherford and Ahlgren's book, there has been a call to restructure the science curriculum (1989). *Science for All Americans* discussed goals for making science meaningful and understandable for all people. The goals are about helping the citizens of this country become scientifically literate. The publicity about the need for scientifically literate citizens stems from many of the recent societal problems we are facing. "Because of the growing impact of science and technology on societal and individual affairs, people from many sectors of society have expressed that science education be reappraised" (Hassard, 1992, p. 12). Some examples of these societal issues are landfill space; nuclear waste dumping, and even mandatory recycling. To deal with these and other societal problems, Hurd, author of *New Directions in Science Education* (1988), suggests that "the science curriculum of the future be based on interrelationships between human beings, natural phenomena, advancements in science and technology, and the quality of life" (p. 3). For citizens of this country to be educated enough to make the decisions about environmental and other scientific disciplines, citizens need to be able to understand the complex factual situations and how to apply those facts to make sound decisions. To make these decisions, citizens must have a deeper understanding of concepts and how they work (Hassard, 1992).

The *National Science Education Standards* (NAP, 1996) stress the integrated development of science and concepts. Showing patterns and connections between concepts will help students become more science literate (NAP, 1996). The goal of the *Standards* is that with patterns and connections between concepts students will have a clearer and more thorough picture of how things work. Three to four years of integrated science was recommended by the NSTA's Scope and Sequence and Coordination effort in 1992. The integrated science courses include concepts that are common throughout science and form the basis for a new method of teaching. These two sources have led to the development of thematic units in order to meet the new standards and benchmark being set up for science educators to follow. However, many different interpretations of the standards and the implementation of thematic units currently exist. Based on this problem, a rubric was developed to enable educators to review and evaluate published science thematic units to determine if the units contain appropriate content and pedagogy to effectively meet the *Standards*. The rubric provided will be used to facilitate the understanding of important components and strategies needed in the appropriate use and development of thematic units.

Components of a Thematic Unit

A goal of thematic units is to help students create a deeper understanding of larger concepts or topics. Textbooks today are filled with fact after fact. "Facts can be memorized fairly easily (and forgotten readily), but complex processes can be mastered and concepts developed only gradually, by actively engaging in the process and by actively transacting with the external world and with other people" (Weaver et al, 1993, p. 32). Content can be a source of meaning and explanation for students, or it can be basic facts to be memorized and forgotten after the test. According to the *National Science Education Standards* (NAP, 1996), "less is more." It is time to do more with less information. "Teachers must focus on and select only what is most important to learn. What is then learned will be of a general nature and will be relevant and useful. Fundamental ideas, when learned, have greater applicability to other subjects areas and to life than material learned in isolation" (White, 1995, p. 161). Thematic units give the teacher the flexibility to take the time to delve deeply into one topic and help students gain a deeper understanding of that one topic. This can be done by spending more time on one concept and building students' schema about that topic so that they are able to understand and explain that understanding to the teacher or to someone else. The teacher must find the real world importance for all students and use it to help facilitate learning. “Students that have the opportunity to see their learning in a context of real world significance are often inspired to want to know more” (Pappas, et al., 1990, pp. 4-5).

Meaningful content requires that activities must be from everyday life and prior experience. More importantly, meaningful content must be from the world around our students (Kovalik, 1994). Students need to have a base frame of reference for a concept in order to relate ideas and find relationships that connect the concept to other ideas. We must have some concrete reference on which to base our ideas in our memory to be successful at learning.

Anther important element of meaningful content is the use of a variety of experiences that are genuine, challenging, and interesting to both the students and the teacher. Children need to be involved in a variety of experiences and styles of learning or they will lose the ability to develop new patterns in that manner after a while. Without meaningful experience, in many different settings, children will not develop important pattern-seeking abilities.

As part of the thematic unit, authenticity is the ability to experience real life situations, to have ownership of activities, and to provide activities that are based on students' needs and interests. Often when students feel they have some say in what activities they will work on, those activities have more meaning. When the activity is the students' idea, it is more meaningful, interesting, exciting, and therefore authentic to the individual. One of the key components of thematic units is the flexibility for choice on the part of students and teachers. Student choice gives the entire class the opportunity to feel a part of the activities and learning experiences.

Children learn through collaboration with others within a community of learners (Cordeiro, 1992, Pappas et al, 1990). They feel supported by peers and the teacher. Children bring their own knowledge to the problem to help create a solution. A community is an environment where any idea can be considered. In a community classroom the teacher “observes carefully, and listens closely, trying to understand how it is her students are constructing knowledge” (Pappas et al., 1990, p. 79). Effective facilitators design different activities that promote group learning as well as individual learning. Community also serves as a way to provide different leaning experiences for the students.

A key element to using and developing thematic units successfully is making sure that materials, activities, and experiments are age-appropriate (Cordeiro, 1992). This does not imply the restriction of materials to a specific age group. It does mean to make sure that there are reading materials and activities available to students above and/or below the grade being taught. By supporting each student at his/her particular level of development, teachers are helping students feel that they are capable of succeeding and meeting the teachers' expectations.

Objectives are statements of what the student are to learn. The thematic unit provides two types of objectives for all students' learning. The first is a general objective, which gives the overall purpose of the activities or lessons. These learning objectives are the core of thematic units; however, they tend to be broad and open ended. The second type is the behavioral objective, which states exactly what the student and teacher will be doing during the lesson. These objectives are important because they ensure that teachers and students have a guide or focus to follow.

The evaluation portion of a thematic unit is flexible, but extremely important. If an educator is going to teach using a new method, then he/she also needs to test or evaluate in a new manner. Students should be evaluated based on what they have accomplished in the project. Forms of alternative assessment can be used so that students and parents as well as teachers are aware of progress made. Some types of assessment that work well with thematic units are performance-based assessment, portfolios, or project-oriented assessment.

Thematic units are becoming more and more popular on today's textbook market. Knowing what the key components of a thematic unit should be can help educators make sound decisions when purchasing these textbooks. The rubric provided during the presentation can be one tool to help educators look more critically at thematic units and make solid choices for their students and districts.

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Instructional Effects of Multiple Analogies on Conceptual Understanding and Learning Motivation in Science Education

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Analogies are widely used in science instruction as well as everyday communications because they are creative and powerful tools for assimilating new information and fitting it into people's existing knowledge base. Several instructional models, for example, the General Model of Analogy Teaching (Zeitoun, 1984), Bridging Analogies (Clement, 1987), and Teaching With Analogies (TWA) (Glynn, Britton, Sermrud-Clikeman, Muth, 1989), were developed in science education. However, many studies have shown that analogies may also deeply mislead students' learning processes (Glynn, Duit, & Thiele, 1996). Spiro, Feltovich, Coulson, and Anderson (1989) suggested multiple analogies in order to prevent missing information or misusing analogy in science education.

According to schema theory, learning by analogy is a process of encoding and elaborating new knowledge based on previous schema (Rumelhart & Norman, 1981). The attributes of existing schema are transferred through structural mapping of new unfamiliar schema and existing familiar ones. In the case of using multiple analogies, therefore, effective learning can take place because there are more opportunities to test, dismiss, and modify partial schema (Gick & Holyoak, 1983). Furthermore, according to the component process theory of analogical reasoning, analogical problem solving passes through specific processes which consist of essential components like encoding, inferring, mapping, and applying (Sternberg, 1977).

In order to use analogy more systematically, an instructional model was designed on the basis of schema theory and component process theory in analogical reasoning. The model using Multiple Analogies based on Component Process theory (MACP) has six phases: introducing multiple analogs, extracting common attributes of analogs, introducing target context, mapping similarities between analogs and target, drawing the target concept, and applying the target concept to another context. The purpose of this study is to examine the instructional effects of this model on students' conceptual understanding and learning motivation.

Methods

Subjects

A total of 109 eighth-grade students participated in this study. They came from three classes of a public middle school in Seoul, Korea. These classes were taught by a female teacher who had been teaching for 10 years and were randomly assigned to MACP, TWA, and control groups. Based on the ANOVA result (MS=29.40, F=.15, p=.86) of previous term achievement score, the hypothesis of homogeneity among the three groups could be confirmed. The number of subjects in each group is shown in Table 1.

Table 1. Numbers of subjects

Group	Male	Female	Total
Control	17	19	36
TWA	17	19	36
MACP	18	19	37
Total	52	57	109

Procedures

The Group Assessment of Logical Thinking and Learning Motivation Test were conducted as pretests one period before the instruction. A science teacher instructed three groups for ten periods regarding chemical changes and reactions with different teaching methods. The MACP group was taught by multiple analogies through the six-step process of analogical reasoning proposed by Sternberg (Table 2). The TWA group was instructed using the Teaching With Analogies model designed by Glynn et al. (1989). Analogies were not used in instruction for the control group. The Science Conception Test and Learning Motivation Test were administered to prove instructional effects of the proposed model.

Table 2. The comparison of two instructional models with component process[a]

Component process	MACP model	TWA model
(1) encode	(1) introduce multiple analogs	
		(2) cue the analogous situation
(2) infer	(2) extract common attributes of the analogs	
		(3) identify the relevant features of the analog
(3) encode	(3) introduce the target context	(1) introduce the target
(4) map	(4) map similarities between the analogs and the target	(4) map the similarities
(5) apply	(5) draw the target concept	(5) draw conclusion about the target concepts
		(6) identify the analogy breaks down
	(6) apply the target concept to another context	

[a] Numbers in parentheses indicate procedural orders.

Data analysis

In science conception tests, the students' performance in each of the 10 tasks was ranked at three levels (from 0 to 2) along a progression of conceptual understanding: (0) false or no response; (1) correct multiple choice but incomplete description; (2) scientific description. Two researchers scored the same students' response respectively and then discussed their variations. The interscorer agreement was .94. A total score of conceptual understanding was calculated for each student.

Results and Discussion

Instructional effect on conceptual understanding

An analysis of covariance showed significant differences among the three groups on the conception test score, MS= 67.15, F= 3.65, p= .030. The means and standard deviations for the groups are shown in Table 3. The MACP group significantly surpassed the control group, t= 2.38, p< .05. The other groups did not differ significantly on the conception test.

The tendency for the two groups with analogies to score higher than the control group supports suggestions (Duit, 1991) on the efficiency of analogies. In particular, the fact that the mean of the MACP group was significantly higher than that of the control group shows that the instructional model designed in this study was effective in improving students' understanding of scientific concepts.

Table 3. Means and standard deviations of the conception test score (Full score=20)

Group	*M*	*SD*	*Adj. M*
Control	9.78	5.00	9.30
TWA	10.82	5.43	11.09
MACP	11.78	4.98	11.99

Instructional effect on learning motivation

An analysis of covariance showed insignificant differences among the three groups on the Learning Motivation Test score, MS= 679.96, F= 2.2, p= .114. The means and standard deviations for the groups are shown in Table 4.

Even though analogies were known to be helpful in improving students' learning motivation (Keller, 1983), the differences among the three groups were not significant. It seems that the visual media used in this study rather than the analogies influenced the students' motivation.

Table 4. Means and standard deviations of the learning motivation test score (Full score=150)

Group	pre-test M(SD)	post-test M(SD)	Adj. M
Control	88.72(21.89)	109.75(16.28)	108.51
TWA	84.97(22.63)	103.00(22.85)	103.84
MACP	85.76(19.64)	99.46(23.39)	99.86

Conclusions

Science instruction with multiple analogies based on the process of analogical reasoning was effective in improving students' conceptual understanding. Science teachers are to be careful in guiding the students to infer the relations between familiar analogs, to map the related attributes, and to look for the target concept. On the other hand, the fact that there was no significant improvement in students' motivation was contrary to our expectations. A follow-up study is therefore necessary. In order to examine the instructional effects of the proposed model more exactly, a long-term study is necessary depending on the characteristics of learners, target concepts, and analogs. An in-depth study on the process of conceptual understanding in using analogies is needed as well.

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A Comparative Study of US and Korean Science Curriculum Reforms

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The Curriculum Reform Movement in Korea

In Korea, the National Ministry of Education specifies one set of curriculum guidelines that details the topics of study and the number of instructional hours required in every level of schooling. Along with a single official core curriculum for the entire nation, it also approves textbooks published by several commercial publishers. Textbooks resemble each other in content because they must be based closely on the national guidelines.

The science curriculum has been revised at the national level seven times, in 1955, 1963, 1974, 1981, 1988, 1992, and 1997. Since the third national curriculum, the science curriculum has been strongly influenced by the National Science Foundation funded alphabet curricula. However, upon meeting the criticism of highly "discipline-centered" inquiry or discovery approach to teaching and learning, there was an attempt to complement this theoretical, discipline-centered curriculum, which stresses the structure of the disciplines. As a compromise, the fifth national science curriculum revision (implemented in 1989) incorporated Science-Technology-Society (STS) curriculum components. Consequently, by adding social issues to the existing science syllabus, which was already overstuffed, the amount of learning goals and contents was increased. Regardless of the endorsement of the STS orientation in the fifth national curriculum revision, the backbone of the science curriculum has remained discipline-centered rather than student-centered throughout the three subsequent curriculum revisions.

With the influence of the US science curriculum reform movement toward scientific literacy, Korea went though the sixth science curriculum revision in 1995 (implemented in 1996 at the high school level). The features of the sixth national science curriculum in Korea can be summarized as follows.

First, with the influence of *Scope, Sequence and Coordination* (NSTA, 1992), the sixth science curriculum revision entails teaching across the four science disciplines, rather than drawing stark boundaries between the disciplines. That is, as a required course in the tenth grade, the sixth curriculum newly established a "common science" course that has an interdisciplinary characteristic, providing integrated approaches to science teaching. Second, by dividing (Earth) science I (the literary course, for nonscience major students) and (Earth) science II (the science course, for science major students), the science courses are geared to educate scientifically literate people, especially for the nonscience major students. Third, by incorporating the historical, ethical, technical, and social dimensions of science (the STS orientation), it presents science as a more liberal enterprise than was the case in the professional and technical curricula developed since the third national curriculum. Fourth, considering the past science curriculum in Korea was overstuffed and some topics were taught over and over again in needless detail, the content is reduced by ruling out topics mainly of technical interest (the "less is more" principle). Finally, the focus of learning science shifts to students by reinforcing students' activity such as discussion, experiments, and observations.

To keep up with a rapidly changing world, Korea went through the seventh curriculum revision in 1997. The main feature of the latest curriculum reform can be summarized as follows.

First, the new curriculum places great emphasis on the sequencing of courses across school levels (elementary, middle and high school), which aims to reduce previously existing "leaps" in terms of content difficulty. Second, the content is reduced by ruling out technical topics. Third, with a variety of optional courses, students can deepen and widen their science study according to their learning abilities and needs. On the other hand, it also offers "the national common basic science (for grades 3 to 10)" for all students. Fourth, there is a heavy emphasis on inquiry learning, which is to enhance students' problem-solving skills in their everyday life situations.

These features reflect and resemble the recommendations of the US reform movement. On the other hand, it is important to note that throughout the history of curriculum revision in Korea, there have been continuing pendulum swings between a theoretical, discipline-centered curriculum and a liberal, humanistic, and student-centered curriculum, which pays more attention to students in terms of their interest and psychological preparedness. In conclusion, the sixth and the seventh national science curriculum revisions reflect rather a student-centered movement by reducing technical and sophisticated topics, taking constructivist learning theory into consideration, and adding more STS related topics. Students (especially nonscience majors) can therefore find personal and social relevance in science learning. The US and Korean science curriculum reforms throughout history are summarized in Table 1.

Table 1

Comparison between the US and Korean curriculum reforms

Features	U.S.	Korea	Features
Inquiry ↓	**Up to the 1950s** [1917 ~ 1957]: - Emphasis on practical, vocational, social and humanitarian aspects of science - 'progressive (child-centered) education' - life adjustment function of education	**Syllabus** [1945 ~ 1954] **1st Curriculum** [1955 ~ 1963] & **2nd Curriculum** [1963 ~ 1974] - 'progressive (child-centered) education' - life adjustment function of education	
STS ↓	**1950s National Science Foundation Curricula.** - Inquiry (or discovery) learning	**3rd Curriculum** [1974 ~ 1981] & **4th Curriculum** [1982 ~ 1988]: - inquiry learning (science teaching as inquiry process) - emphasis on the structure of the discipline **5th Curriculum** [1988 ~ 1992]: - adopting STS theme as one of the learning goals	Inquiry ↓
Scientific Literacy ↓	**1970s and 1980s Science-Technology-Society (STS) curricula.** - the STS interpretation of scientific literacy		STS ↓
↓ ↓ ↓	**1980s Science Literacy crisis:**	**6th Curriculum** [1992 ~ 1997]: - Scientific Literacy - offer a 'common science' course for the 10th grades **7th Curriculum** [1998 ~] - 'the national common basic science' - a elective-centered curriculum in the high school	Science Literacy ↓ ↓ ↓ ↓

Possible Future Direction of Curriculum Reform

Based on this review of the major paths to change in science teaching and learning and the history of science curricular reforms in Korea and the US, future reform directions can be predicted.

First, before initiating any more reforms, we need to define the ideal characteristics of a scientifically well-educated person. What kind of future citizens do we (science educators) want to produce via the school science curriculum? Depending on the desirable images and status of our future citizens, we need to redefine the goals of science education. Second, in Korea, regardless of great effort to reduce the content covered in the science curriculum, there is still too much to learn on the consumers' side and too much to teach on the teachers' side to keep up with the rapidly increasing knowledge base. Therefore, we need to shift the primary goal of science education from "knowledge (scientific concepts) acquisition and understanding" to other directions. First of all, we need to define what aspects of science we desire our future citizens to know. Depending on the possible demands on future citizens, the goals of science education could be varied. Possible alternative goals of science education can be to learn how to find (locate) necessary information and facts, how to think scientifically as well as logically, and how to process information. Third, there is an urgent need to provide the necessary student motivation for an effective science education reform effort. Beyond overcoming students' antiscience attitudes, we need to find ways to motivate and increase students' interest in science learning. The changes in Korean curriculum goals throughout curriculum reforms are shown in Table 2.

Table 2

Changes in science curriculum objectives across the Korean curriculum reforms

Curri-culum	Features	Objectives					
		knowledge		attitude	(life coping) ability		
1[st]	Students-centered						
2[nd]							
		Concepts	Inquiry	Interest	Problem-solving	STS	
3[rd]	Discipline-centered						Tentativeness of scientific knowledge
4[th]							
5[th]							Experimental skills
6[th]							
7[th]							

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An analysis of the teaching and learning theories of the new national science curriculum in Korea

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After the Korean educational law firstly legislated and promulgated in 1949, there have been seven revisions of the national curriculum in Korea. Each national curriculum was influenced by contemporary teaching and learning theories, the needs of society, and international trends. For example, the fifth national science curriculum from 1987 to 1992 reflected the STS (Science-Technology-Society) movement (Cremin, 1964; Ministry of Education (MOE), 1997c). The sixth national science curriculum (1992-1997) had a human-centered approach with an emphasis on social, technological, and social aspects in science education. The sixth curriculum also offered new integrated science subject, "Common Science" in order to reduce the amount of subject matter (MOE, 1997b, 1997c, 1998a). However, several obstacles such as large class size and the high pressure of the national college entrance examination, face science education. Class size has been the single most important factor hindering effective instruction and blocks strategies to deal with students' intellectual differences. Therefore, science teachers could not teach their students according to the level of student achievement. In addition, the teachers are heavily dependent on lecturing by textbook regardless of the characteristics of science contents and objectives.

The new seventh national science curriculum was developed to correct the weaknesses of the former curriculum and to meet the needs of students, teachers, and society (Kim, 1997; Kwon, 1997; MOE, 1999). The fundamental frameworks of the new curriculum will be explained.

Direction of the Seventh New National Science Curriculum

General Framework

The fundamental ideas of the science curriculum are the development of a student-centered curriculum and in-depth and supplementary differentiation. According to these ideas, the seventh national curriculum was designed within the general framework as follows (Kim, 1997; MOE, 1999, p. 6):

(a) To design the curriculum to help students acquire basic abilities which will enable them to lead the trends of social change;

(b) To introduce a system of a national common basic curriculum together with an elective-centered curriculum;

(c) To optimize the volume and level of the content of learning and to introduce a differentiated curriculum so as to provide students with in-depth education;

(d) To diversify the content of the curriculum and methods of instruction in order to match each student's ability, aptitude and career choice;

(e) To broaden the autonomy of individual schools in organizing and implementing their own curriculum;

(f) To reinforce the quality control of education by establishing a curriculum evaluation system.

Amongst those frameworks, (c) and (e) had been already introduced in the former national curriculum, but they have not had an effective impact on science classrooms. Therefore, the seventh national science curriculum has paid full attention to the improvement of three important factors in science education: the science teacher, the student, and the science content (See Figure 1).

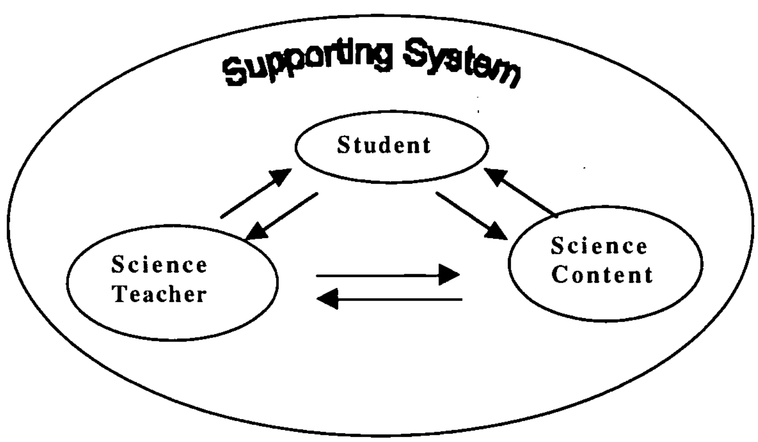

Figure 1. Structure of Science Education (Kwon, et al, 1998)

First of all, this new science curriculum offers two different science courses: *In-depth* course for high achievers and *Supplementary* course for low achievers. Students are divided by their ability after they complete core science courses. In this new science curriculum, the compulsory course *Science*, the general elective course *Life and Science*, the intensive elective subjects *Physics I, II, Chemistry I, II, Biology I, II*, and *Earth Science I, II* developed as a part of the new science curriculum. Each school offers elective courses considering the demands of its students (Kwon, 1997; MOE, 1997a).

Second, the amount of science content was reduced in order to minimize students' learning load. The science content was limited to important concepts and essentials (Choi, 1997). For example, *Science* as a compulsory course is taught from grade 3 to 10. This subject is designed to establish a sequential continuum from grade to grade and school level to school level. The students are divided into three levels: Lower level (grades 3 to 5), Middle level (grades 6 to 7), and Upper level (grades 8 to 10). These divisions are designed to remove discrepancies between levels, and to maintain the close connection between grades. As grades increase, the major focus of science content is changed as follows: phenomena-based content (for grade 3-5), phenomena and concept-centered content (for grade 6-7), and concept-centered content (for grade 8-10). Inquiry-based learning is emphasized in all grade levels (Choi, 1997; MOE, 1998b, 1999).

Third, the curriculum provides much flexibility for the teacher and the school. This means that science teachers can extend the instructional hour, depending on the characteristics of instructional topics (e.g., block scheduling). In addition, the school makes its own curriculum organization and implementation plans based on its situation and in accordance with the national science curriculum. The school is also able to adjust weekly and monthly instructional plans within the total number of instructional hours for the year. As mentioned above, the new science curriculum has attempted to overcome the defects of the sixth curriculum. Another noteworthy characteristic in the national science curriculum is its intent to apply important contemporary teaching and learning theories to science content. The fundamental theories will be summarized in the following section.

The primary teaching and learning theories in the new science curriculum

A significant number of science teaching and learning theories have been used in schools. Since the 1990s, the popular theory of science education in Korea is based on onstructivism. Recently, conceptual change has attracted researchers' attention. Moreover, a need for students' conceptual change has affected the national science curriculum. On the other hand, there is also a need to steadily improve students' inquiry ability.

The early science curricula struggled to resolve these two needs, but failed to present a teaching and learning theory (or method) that might help science teachers. The new science curriculum recommends cognitive conflict as an educational theory that can meet these two needs. As a teaching strategy, cognitive conflict includes the main steps of major teaching and learning models of science education (See Table 1). Many studies have proposed cognitive conflict as a necessary precondition for a student to change from his/her preconception to a scientific conception (Posner et al., 1982; Hewson & Hewson, 1984; Kwon, 1989; Niaz, 1995). In addition, the first step in inquiry is to doubt something, and cognitive conflict is the best way to begin inquiry (MOE, 1997a).

Table 1. The major teaching and learning models of science education and their stages (Kim, 1995)

Teaching and Learning Models	Cognitive Conflict (Kwon, 1989)	Generative Learning (Osborne & Wittrock, 1983, 1985)	Learning Cycle (Karplus, 1980; Lawson, 1986)	Hypothesis-Testing (Kauchak & Eggen, 1980)	Discovery Teaching (Kauchak & Eggen, 1980)
Stages	Reveal preconceptions	Focus Challenge	Probe	Set hypothesis Make plan	
	Present anomaly (**arousing conflict 1**)			Collect data	Observe
	Introduce new conception		Introduce new terminology	Test hypothesis, Conclusion	Discover the rules, regulate
	Apply new conception (**conflict 2**)	Apply new conception	Apply new conception	Apply new conception & seek for new problem	Apply new conception
	Compete two conceptions (**conflict 3**) Apply new conception				

Figure 2 shows the Cognitive Conflicts Model. This model supposes three kinds of cognitive conflicts. Piagetian cognitive disequilibrium or cognitive conflict is a kind of mental imbalance between one's cognitive structure and the environment. In other words, it is imbalance between internal structure and external input. However, cognitive conflict could appear without external input. One might examine his/her own cognition without contacting his/her environment. In this case, a cognitive structure is regarded as a metacognitive object. Therefore, Hashweh (1986) suggested a different kind of cognitive conflict, so called *metacognitive* conflict which is a conflict between cognitive schemata. This metacognitive conflict could be essential to reach a unified internal structure.

In addition to these two kinds of cognitive conflicts, Kwon (1989) suggested the third kind of cognitive conflict. It may be clarified by using the following diagram.

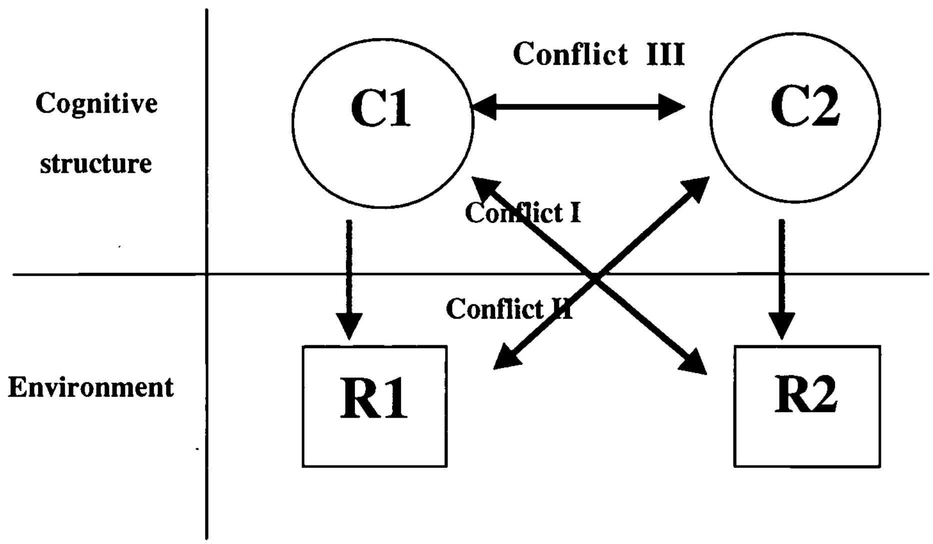

Figure 2. Cognitive Conflict Model (Kwon, 1989)

This diagram is a modified version of Hashweh's original diagram (Hashweh, 1986). The upper part represents cognitive structure and lower part represents environment. For science instruction, a cognitive structure can be replaced by scientific conceptions. C1 represents students' preconception or misconception. In a classroom situation it would be mostly a misconception. C2 represents a scientific conception to be learned. R1 represents environment which could be well explained by C1, while R2 is any environment explained only by C2. R1 and R2 do not represent only one single external phenomenon. They represent all kinds of observations and stimuli from one's environment.

In this diagram, cognitive conflict by Piaget is conflict between C1 and R2 (Type I), while cognitive conflict by Hashweh is a conflict between C1 and C2 (Type III). However, in the diagram one may easily recognize another kind of cognitive conflict between C2 and R1. Kwon proposed this as another kind of cognitive conflict (Type II). One may argue that this is just the Type I cognitive conflict. It may be correct, but for instructional purposes, to categorize this as a different conflict would be meaningful. Since Type I and Type II are all the cognitive conflicts between a cognitive structure and environment, the two cognitive conflicts could be categorized as the same kind. Under such a real situation as a teacher designs a new instruction; however, the two types of cognitive conflicts will function very differently in the preparation of instructional materials and in time allocation of activities. Therefore, to categorize the Type II as an independent type of cognitive conflict is meaningful.

Using the three kinds of cognitive conflict strategies, one might design many varieties of instructional sequences depending upon the characteristics of the concept to be taught and the instructional situation. The following elements of cognitive processes are expected in the various teaching environments. Kwon proposed three different types of conceptual changes: (1) concept expanding type change (C1<C2), (2) commutative type change (C1 $\leftrightarrow$C2), and (3) revolutionary type change (C1$\rightarrow$C2)

Concept expanding type change (C1$\leftrightarrow$C2)

This type of conceptual change is possible when the new concept (C2) is more general that the old concept (C1). This category of conceptual change is usually expanding variables. In case of an equilibrium of a body, the vector summation of all the forces acting on a body should be zero (C1). However, this condition of equilibrium is not complete; another condition, the summation of torque, should also be zero. The second conception includes two variables, force and torque, while the first conception includes only one variable, force.

In this kind of conceptual change, conflict I (conflict between C1 and R2) would be essential; however, conflict III (conflict between C2 and R1) would be very weak if it is not totally absent.

Commutative type change (C1$\rightarrow$C2)

An expanding type of conceptual change will occur when C2 is more general and inclusive than the concept C1. However, in the case of commutative type change, the two conceptions are at almost the same level of inclusiveness and hierarchy. Coulomb's law and Gaussian law in electrostatics are examples. Even though Gauss' law is more formal and convenient in solving some electrostatic problems, the two reflect conceptually the same depth of meaning. Another example is two different expressions for Newton's second law of motion. One is F=ma, and the other is F=dp/dt. Even though the latter is more general, it is not important when we take into consideration only constant mass problems, which are generally used at the secondary level.

In this case, the terminology "conceptual change" would not be appropriate since the old conception (C1) is still necessary even after learning C2. The two conceptions are not contradictory but complementary. To learn C2, in the commutative type of change, conflict I, II, III may exist, but the strength of the conflict may not be strong.

Revolutionary type change (C1→C2)

This category of conceptual change would be the most important in implementing cognitive conflict strategy. In teaching science, this kind of change should be at the core of instruction. In revolutionary conceptual change, all three kinds of cognitive conflicts will play an important role in a teaching sequence.

Conclusion

As mentioned above, there have been seven revisions of the national curriculum in Korea. Each science curriculum includes valuable objectives. Since the fourth national science curriculum, the major focuses on science education have been inquiry-based learning, conceptual change, and science literacy. However, it was hard to achieve these major components in science curriculum because of several obstacles. As we explained, the amount of science content was excessive for students. The science content also lacked a sequential continuum between grades. In addition, the basic educational theories supporting the former science curricula did not reflect the situation of the school and classroom. Most science teachers have realized that a more effective and practical curriculum to integrate diverse teaching and learning methods is strongly needed.

The new science curriculum is mainly based on the Cognitive Conflict Model as a major teaching and learning theory because cognitive conflict strategy in the model can offer one of the best ways to encourage students to doubt and begin inquiry. We agree that there is no perfect teaching and learning theory that can explain all kinds of conditions in the classroom situation. We hope that this new theory-based science curriculum will overcome several obstacles of science education and contribute to Korean science education for the new millennium.

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What do the new *Standards* look like in action? Some practical examples from Algebra II

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In the classroom, several groups were working with blocks while, over on the other side of the room, more groups were bouncing a racquetball on the floor. A few groups could be seen with their heads bent over a piece of paper, watching one student draw lines. The students were talking to each other, but not about the upcoming dance. Phrases such as " why do you suppose it did that," "hum, I thought it would go this way" and "what was that formula from last year" could be heard from all around the room. What was going on here? This was a high school classroom, after all. Why were the students playing with blocks, bouncing balls, and talking to each other? Had this unit gone totally awry?

On the contrary, these students and their teacher were actively involved in a unit of study based on the *Standards* (National Council of Teachers of Mathematics [NCTM], 2000). In this classroom, the students were actively engaged, discussing their data, seeking equations to model their data, and writing about their results. Each group had been assigned three laboratory activities, which included data collection, data analysis, prediction of future events, and a presentation of the results. This unit had become, as the *Standards* (NCTM, 2000) directs, the springboard for the students to experience mathematics in a way that would allow them to construct their own learning and to see connections.

Three activities were used in the unit. While all three activities involved looking for a pattern, each activity required different skills. The first activity, "Diagonals of a Polygon," was a pencil and paper activity where students had to draw the diagonals of polygons, starting with a 3-sided polygon, then a 4-sided polygon, an so on. Each group recorded the number of sides of the polygon and the number of diagonals from all vertices. The group then had to find a pattern to relate the number of sides to the number of diagonals. Working in groups, the students could select any method of finding the equation. Since this lab did not require the use of technology, this was an opportunity to encourage the use of a pencil and paper method to find an equation to model the data. The manual dexterity required to accurately draw and count the diagonals for a figure with many sides led to insightful discussions about the usefulness of mathematical equations.

In the second activity, "The Double Staircase," the students used cubes to build a set of stairs to find a connection between the number of stairs and the number of cubes needed to build the stairs. Again, the groups were asked to record their information and to show the process they used to find an equation to model the data. The students were encouraged to test their equation by using it to determine the number of cubes needed to build a set of stairs not already listed in the table. The groups then actually built that set of stairs and counted the number of blocks, proving or disproving their equation. Each group was required to present a write-up explaining the process used to find the equation.

The third activity used the Calculator Based Laboratory (CBL) to research the connection between time and the height of the ball during a bounce. This activity used the "Ball Bounce" program from Real-World Math with the CBL System (Brueningsen, Boser, Antinone, and Brueningsen, 1994). After collecting the data, the groups then selected one of the bounces and found an equation to model that bounce. The students were asked to explore how the equation would change for the different bounces. Since the students were using the graphing calculator to collect data, this was an appropriate place to use the regression feature of the calculator to find an equation to fit the data. The messy data that was collected in this activity opened the door for conversations about appropriate technology use.

All three of the activities generated data modeled by quadratic equations, allowing the students the opportunity to see the same kind of data from three very different sources. While students may typically see quadratic equations in connection to parabolas, they often do not see examples set in the real world that address different learning styles. These three activities helped the students make connections between algebra and geometry, demonstrated the behaviors mathematicians use, and provided examples to demonstrate appropriate and inappropriate calculator use.

The first activity provided a connection to geometry and presented a forum for the students to use some of the knowledge and terminology from that class. While this may not be a "real work world" example, this activity shows the students the way mathematicians have to think when they are looking for patterns.

The cube activity offered a chance for the students to work with a three dimensional situation. Visualizing in three dimensions is a necessary skill in many areas, including higher-level mathematics, and one with which many students need more practice. This activity could easily be rewritten and situated in an architectural context, providing a true "real-world" application.

The third activity provided the students the opportunity to use technological tools and to become comfortable with collecting information in this manner. As stressed in the

Standards 2000, students must learn to work with technology and learn how to use it appropriately. Many teachers fear technology because of the potential for misuse. If students are never taught when and how technology can be best used, and how to avoid misuse, a valuable tool will be missing from the educational experience.

Teaching mathematics during this era, while sometimes challenging, can be invigorating and stimulating. Establishing a classroom that is a mathematical community will be invigorating and stimulating for teachers and the students. As students are forced to discuss and discover the connections between quadratic equations and the world, the students will find themselves involved in constructing and reconstructing their conceptual understanding. During this process, the teacher will become part of important, enthralling conversations with the students about mathematics. Who could question the value of this environment?

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Conceptions-based radioactivity curriculum

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Our research has focused on understanding students' current beliefs about radioactivity. We have conducted a review of current literature, performed and analyzed over thirty interviews, and administered a questionnaire twice as a pre- and posttest. Our research has shown that many students do not possess a canonical understanding of radioactivity and radioactive processes. Our goal is to develop a curriculum that would help the students achieve a correct view of radioactivity. Research by Thacker (1994) and McDermott (1991) show that traditional lecture forms of instruction do not develop an understanding of physics concepts different from the initial common sense conceptions. Lijinse (1990) and BoyleS and Stanisstreet (1994) also report how mass media negatively affects students' ideas about radioactivity in Europe. Our efforts have provided us with an insight into what students at The Ohio State University believe about radioactivity. We have used this knowledge to create inquiry-based materials that attempt to elicit student beliefs about radioactivity, confront incorrect beliefs, and offer guidance to resolving these beliefs to fit what is currently accepted in the scientific community.

Some Student Conceptions

Other studies, as well as our own work, have provided information that many people in the field of science education may find useful. Millar (1994) has shown that students have difficulty differentiating between radiation, radioactivity, and radioactive material. This issue was shown to cause problems in students' ability to understand the difference between contamination (accumulation of radioactive atoms) and irradiation (exposure to radioactive particles). Prather (2000) has expanded work in this area and reports that students incorrectly believe that objects exposed to radioactive particles become radioactive. Prather has also done considerable work that focuses on student ideas about half-life. (We will discuss these findings at the end of the presentation, as our curriculum focuses on developing an accurate understanding of lifetime.) In our own research, we have elicited various beliefs about what affects radioactivity. For instance, many of our subjects believe that temperature affects the radioactivity of a sample—that the hotter it is, the more radioactive, even though temperature does not affect radioactivity. Other subjects believed that the location of an atom relative to the surface of a material would determine if it was more or less radioactive. These and other findings are being used to develop new curricular materials.

Curriculum

Our piece of a curriculum is part of a larger whole that is currently under development. We present our current inquiry-based curriculum related to lifetime. We will be creating similarly designed curricula to address other issues, such as sources of radioactivity, irradiation/contamination, and radioactive decay particles. Our materials are designed to be used in a full-term physics course for preservice teachers. The students in this course would perform various inquiry-style sections while working in a group of three to five students. There would be no formal lecture in this course. The materials are designed to cause the students to make predictions about a scientific concept related to radioactivity. The students will then follow through the workbook, either verifying or disproving their prediction. As the learning section continues, the students will perform various activities designed to guide their beliefs toward a more scientifically accepted view about the topic. At different stages in the section, the group is required to be "checked off" by the instructor before moving to the next section. This checking off process allows for real-time assessment as well as enrichment (through Socratic Dialogue) for students who may still be having difficulties.

Interactive Presentation of the Curriculum

At the conference, I will provide a learning section that focuses on the lifetime of radioactive atoms. This section will use colored wooden blocks to simulate radioactive atoms. The participants will be asked to work in groups of three to four people. I intend for groups to follow the learning section as if they were students. This will require rolling the dice, recording predictions and results, and analyzing the data. I seek feedback from the participants related to the activity; therefore, I will leave ample time for comments toward the end of the session. Participants who wish voluntarily to submit their learning sections that they used during the presentation will be provided with an unmarked copy for their own use.

Pedagogy of the Half-life Learning Section

The pedagogy used to develop this activity will be discussed following the peer evaluation of the learning section.

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Poster Presentations

Science Education in Korea: New Curriculum and Challenges

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After World War II, the Korean educational system was dramatically changed. Since 1949 the Korean national curricula have been reformed seven times in 5-10 year cycles in response to the changing needs of society. A new seventh science curriculum also was strongly influenced by educational issues and international trends for the 21st century. The curriculum gradually comes into effect for all grades from March 2000 through March 2004. This paper introduces the new national curriculum in Korea and in particular the major reforms and challenges in science education. We will first explain the problems of the sixth national science curriculum.

THE SEVENTH NATIONAL SCIENCE CURRICULUM

Background

The sixth national science curriculum was designed to develop "scientific literacy" for all students, and to promote their awareness of the influences of science on the development of technology. The basic characteristic of this curriculum was to have a human-centered approach (Ministry of Education [MOE], 1997b, 1998a). Based on this basic idea, *Common Science* was offered as a compulsory subject for all high school students in order to improve students' scientific inquiry abilities and connect their scientific knowledge with technology and society. However, there were discrepancies between the idea of the national science curriculum and the textbook for *Common Science*. For example, *Common Science* included four science disciplines (physics, chemistry, biology, and earth science) but not in a fully integrated approach. There were very poor content connections with technology and society. In other words, the traditional boundaries within science disciplines were not softened and connected in this course.

As Choi and Nam (1995) studied, many science teachers addressed several practical problems of the sixth national science curriculum. One of the major problems is that the science content was too large to teach in available instructional time. Another problem is large class sizes. Even though the science teachers realize their students' different abilities and intellectual levels, they cannot teach meaningfully. For example, there are usually more than 40 students in a classroom. It is hard to apply their educational ideas to science class because of large class sizes.

Characteristics

The new seventh revised science curriculum was developed to correct the weaknesses of the former curriculum and to meet the needs of students and society. The science contents are limited to the essentials in order to minimize students' learning loads (MOE, 1999). As Kim (1996) stated, the sixth revised science curriculum focused on students' inquiry and interest about natural phenomena. The new curriculum also emphasizes inquiry learning in all grade levels.

This new science curriculum also was strongly influenced by contemporary education theories and issues for the new century. According to these needs, the goals of science in the seventh revision are to help students to (a) understand scientific knowledge and apply it to their real life through inquiry-based learning; (b) foster scientific inquiry-based abilities in order to apply them to real life; (c) foster scientific attitudes to solve real life problems based on scientific interests and curiosities; and (d) understand the influence of science on the development of technology and society (MOE, 1997a). The curriculum goals reflect an increased emphasis on scientific knowledge and inquiry-based abilities as a component of scientific literacy.

The science curriculum focuses on a student-centered approach and *Symhwa bochung hyeong kyoyuk kwachong* (literally, "in-depth and supplementary differentiated curriculum") (MOE, 1997a, 1998b). The science curriculum is designed to provide more opportunities to learn science content, depending on students' achievement. According to their achievement ability, each school offers different types of science courses: in-depth courses for higher achievers and supplementary courses for lower achievers.

In fact, there are discrepancies within the former 6-3-3 ladder type school system (6 years for elementary; 3 years for middle, and 3 years for high school). In this 6-3-3 pattern, each school level implements its own curriculum. The science contents have no sequential continuum between school levels. However, this new curriculum is designed to establish a sequential continuum from school to school and to reduce gaps between the three school levels (MOE, 1997c). In this new science curriculum, students are subdivided into the following three levels: lower level (grade 3-5), middle level (grade 6-7), and upper level (grade 8-10). These divisions are designed to remove the level-discrepancies and to maintain the close connection between grades.

In addition, as students move grade to grade the major focus of science content is changed from phenomena and activities-based content to conception-centered content. The curriculum is divided into a knowledge section and an inquiry section. The former section is composed of four main themes: motion and energy, matter, life, and earth. This section is organized to make close connections between grades. The latter section consists of three areas: basic inquiry, integrated inquiry, and inquiry-based learning activity. This section emphasizes the gradual development of inquiry-based abilities (MOE, 1998b).

There is one compulsory science course, *Science*, for grades 3 –10. In contrast, the general subjects for grades 11 and 12 are subdivided into general and intensive elective courses. For example, there is *Life and Science* as a general elective course, while the intensive elective courses for science include *Physics I, II*, *Chemistry I, II*, *Biology I, II*, and *Earth Science I, II*.

Discussion

The new Korean national science curriculum will fundamentally change the structure of the Korean educational system. Even though the curriculum is designed to meet the needs of students, school, society, and educational trends, some obstacles and dissatisfactions will become clear in the near future. Large class size and the extreme pressure of the national college entrance examination have become obstacles in Korean science education. In addition, the lack of fundamental curriculum research, of new science curriculum preservice and inservice programs, and of instructional materials and facilities for hands-on activities have caused some discrepancies between the curriculum and practice in schools.

The new science curriculum includes remarkable components for education reform: changing the 6-3-3 school system to a 10-2 pattern (grades 1-10 and 11-12), reducing the amount of science content, changing the style of the national college entrance examination, providing curriculum flexibility for teachers and schools, and reorganizing science content for sequential connections between school levels and grades. It is hoped that this educational reform will solve current science education problems and contribute to the development of Korean science education for the 21st century.

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