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Design and Implementation of Integrated Instruction of Mathematics and Science in Korea

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Students can learn subjects more meaningfully through integrated education, as it helps them to link school education with their real lives. There is a strong need to develop an alternative integration method to promote effective implementation of integrated education at a classroom level. The purpose of this study was to develop a model for instructional design for the integration of mathematics and science, and to design and implement instructions using the developed model. The implications of applying the model to lower grade students in Korea were also discussed.

Keywords: case of Korea, integrated education, mathematics and science education, symmetry

INTRODUCTION

Integrated Education

In the knowledge-based society of the 21st century we need to reduce individual differences of students and nurture learners' core competency through school education in order to prepare for a future society in which jobs require more advanced levels of knowledge and application skills (Trilling & Fadel, 2009). Since there is a growing interest in what kind of competency the creative human talent of the future society must be armed with, working innovation into the curriculum, teaching methods and assessment has become the major issue of education policies at home and abroad. Against this backdrop, much interest is being given to the area of integrated education.

Integrated education helps students to apply knowledge they learn at school to their life experiences by linking school education with their individual lives. Pang & Good (2000) reviewed the literature on the integration of science and mathematics and pointed out that mathematics and science should be related to real-life situations for students to learn and be able to apply diverse subject knowledge together as needed. In particular, science plays a role as a contextual framework for the application of mathematics to help learners construct knowledge about the world in which we live, while scientists utilize mathematics to verify discoveries about the nature (Foster, 1999). In the area of mathematics education, research has been carried out on "Realistic Mathematics Education [RME]" in the Netherlands, which is children's mathematization of a subject matter in the context of the real world, and the National Council of Teachers of Mathematics [NCTM] have suggested connection standards (NCTM, 1989, 2000). In the area of science education, the U.S. government announced that as part of the NCLB policy, the integration of 4 subjects, such as science, technology, engineering and mathematics, whose academic research objects and methodologies are recognized to be highly related to one another, can help learners acquire a deep understanding about each subject (Breiner et al., 2012). All in all, the value of the integration of mathematics and science with other academic fields or with everyday life has been highly appreciated. The integration of mathematics and science can help students by "doing" mathematics and science, through which they can form new perspectives to look deeper into the world in which they live (Davison, Miler

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State of the literature

- The integration of mathematics and science can help students to apply knowledge they learn at school to the world in which they live, gives a chance "to do" mathematics and science, and allows students to deepen their understanding of the concepts.
- There have been many studies on models of integrated education, but there is a gap between the theoretical models and the implementation of integrated education at the classroom level.
- In integrated education, students should learn through concrete hands-on experiences, experiments and practical works, the lessons should be based on a conceptual theme in which the mathematical or scientific thinking could take place, and the lessons should be a “natural integration” in the real world so that students could create a cognitive structure by themselves.

Contribution of this paper to the literature

- This paper reviews the models and issues in integrated instruction.
- This study introduces a Convergent Concept Understanding Model consisting of exploring a phenomenon, understanding a concept, and applying a concept.
- This study presents a case-study on the basis of the aforementioned model at an elementary school in Korea, wherein an integrated lesson about symmetry, a concept commonly dealt with in both mathematics and science lessons, was presented.

& Metheny, 1995). Given this, there is continued interest in the multidisciplinary aspects of mathematics and science.

In addition, multidisciplinary education compares a concept in one subject with a similar concept in another subject, which helps students to learn better than when studying them as separate concepts, and gives them a chance to look at the concept from multiple perspectives to provide an understanding in a broader sense. Also, it can provide more motivation to students by offering experiences which are more relevant and less fragmented to their learning contents (Jacobs, 1989). However, as multidisciplinary education is implemented with a top-down approach as part of a policy decision, multidiscipline itself becomes the objective (Park, 2012). As a result, integration is being implemented without a clear objective. The present study suggests a model for the instructional design of integration to solve the question of how to design and implement instructions which are faithful to the genuine meaning of integrated education, and proceeds to evaluate students' performance on the instructions which were developed and applied by this model. This study aimed to make suggestions to allow effective integrated education to be carried out.

Review about Models of Integrated Instruction

The integration of mathematics and science is very meaningful in that it can enrich students' learning experiences, deepen their understanding and change their attitudes about these two subjects by identifying and applying a method which can appropriately integrate the two into the teaching and learning process (Berlin & Lee, 2005). The integration of mathematics and science can especially enhance students' understanding about mathematics and science concepts, while also helping them to associate their knowledge of mathematics and science with their everyday lives. If this successfully achieved, students will recognize mathematics or science not as academic pursuits, but as something that can help them better understand the world in which they live. As a result, students' abilities and confidence can be nurtured when they learn mathematics and science (Davison, Miller & Metheny, 1995; Furner & Kumar, 2007; Lonning & DeFranco, 1997).

Lonning & DeFranco (1997) and Huntley (1998) suggested the continuum model for deciding what level of integration might be appropriate for the development of an integrated curriculum in mathematics and science. Lonning & DeFranco (1997) divided the continuum model into several categories depending on appropriate levels for the students in consideration of the correlation between the contents of the integrated mathematics and science curricular or the integrated curriculum, and the goals specified in the curriculum. In contrast, Huntley (1998) provided a continuum model determining how much overlap was present in the contents of mathematics and science from the perspective of the interaction range between the two, and based on what kind of subject the integration should be centered on. In addition, Huntley (1998) argued that the integration of mathematics and science is to assist the interaction of mathematics and science, and to support each other. He placed a greater importance on the synergy resulting from the interaction of two subjects to help students' learning than on the actual contents contained in the mathematics and science curricula. In contrast, the model of Lonning & DeFranco saw mathematics and science as separate subjects. They also argued that activities in the integrated curriculum are meaningful only if they meet the national standards and are appropriate to the level of the students. Huntley placed

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stress on whether students had learned the new contents or not, regardless of their grades (Lee, 2011).

The studies by Lonning & DeFranco (1997) and Huntley (1998) looked at integrated education from the macro perspective of integrated curricular development. In contrast, most individual studies on the integrated lessons of mathematics and science were carried out from a micro perspective (Elliott et al., 2001; Hong, 2009; Munier & Merle; 2009; Shin, 2005), with a focus on which contents should be the core of the integration and how they should be implemented. Those studies have limitations in that instructions were designed and implemented without offering an instructional design model. Lee, Rim & Moon (2010) pointed out the absence of the model of instructional design in the existing research, extracted six fundamental principles by analyzing the related literature on integrated mathematics and science curricula, and suggested a model of instructional design after taking into consideration the results of analysis. The model of instructional design consists of five steps: a) extraction of mathematical concepts, b) formalization, c) abstraction, d) reinforcement of concepts, and e) generalization for progressive mathematization. This model was based on the understanding of already learned scientific concepts, and was developed with the objective of gradually improving the understanding of mathematical concepts.

Taking all the aforementioned facts into consideration, a gap exists between the macro perspective studies on multidisciplinary approach and the micro perspective studies on the implementation of integrated education at the classroom level. This can trigger much concern in that it may reduce the effectiveness and value of implementing integrated education, and suggests that there is a strong need to develop an alternative integration method to overcome this challenge.

Issues in Integrated Instruction

As we are shifting toward a complex and diversified information-based society where knowledge, information and creativity are the main pillars, the main agent of education has changed from teacher-centered to learner-centered, which has in turn transformed the education paradigm. According to the constructivist epistemology, knowledge is continuously reconstructed through individuals' cognitive interactions based on social experiences, so the active role of a learner is very important. Especially, cognitive constructivism claims that learning can be transformed into something meaningful through leaners' cognitive structural changes and their interaction with the existing cognitive structure. It also provides many implications for integrated education in the knowledge-based modern society.

Piaget, who had deep interest in how children perceive and understand the world, claimed that all organisms have the tendency to undergo 'assimilation,' in which they provide a meaning to experiences based on the present, followed by 'accommodation,' in which they modify it to fit the real world situation, in order to become accustomed to the environment. Cognitive development is achieved through the 'equilibration' process of adjustment, through which a balance between assimilation and accommodation is struck. Education based on Piaget's epistemology should be done through the voluntary explorative method of a child, and should provide chances for repetition and practice to ensure the internalization of what students have learned through re-discovery and reconstruction of their knowledge in an active manner. Especially, Piaget stressed that concrete activities are very important because children have a different way of thinking than adults. By providing contexts with which children can discover facts and relations through questions and experiments, they can reach the authentic understanding of a certain concept or theory through "doing". Children will generalize the concepts they acquire through this process and voluntarily apply them to new situations (Ginsburg & Opper, 1988; Piaget, 1964).

In the early 20th century, Moore (1903) emphasized that mathematics at primary schools must adopt a laboratory method to ensure that students' abilities of learning are nurtured through observation, experimentation, reflection and deduction to allow them to relate mathematics to specific things. Through the mathematics education reform movement, the practicality of mathematics and the change of mathematics study into activity-based learning such as experiments and real measurements have been emphasized in mathematics education. Van de Walle (2004) argued that if students learn through understanding and interpretation processes-'explore, represent, explain, conjecture, predict and justify'-which are stressed by references of the mathematics education reform, they can engage in active thinking to understand mathematical concepts inherent in activities. Meichtry (1992) also stressed the importance of providing direct and detailed experiences to students to help them gain a better understanding of abstract science.

Considering all of the above arguments, children understand contents through concrete operational experiences and experiments as well as through laboratory work, and construct knowledge through inquiry to overcome the cognitive disequilibrium: "An inquiry is any process that has the aim of augmenting knowledge, resolving doubt, or solving a problem" ("Inquiry," 2014). The European Commission stated that in order to overcome the current phenomenon of the decreasing interest of students in science and mathematics subjects, we have to shift from the traditional deductive method, which dominated classrooms in the past, to "Inquiry-Based Science Education(IBSE)" to raise their interest in mathematics (Rocard et al., 2007). IBSE has advantages in that it is effective regardless of the different learning abilities of students, and is not mutually exclusive to the traditional deductive method. Actually, if they are well combined, it can engage various different ways of thinking.

To solve problems which may occur in the complex modern society requires critical thinking, problem solving, communication and cooperation. To that end, it is necessary to integrate skills and contents based on core academic subject knowledge (Partnership for 21st century skills, 2012). Among the primary and secondary education level research in South Korea, results of analysis on the core contents of convergence programs indicated that there are many cases where the integration of chapters and concepts on which the converged subject is focused are based on subject content related topics (Ju, Moon & Song, 2012). This is in the same context as the argument of Perkins (1989), who claimed that when selecting the criteria of fertile themes for integrating instruction, the integration should take place based on the core concept of the subject. However, the concept, which should be the core of integrated education, should go beyond the facts to identify a relationship between several concepts, or a pattern among relations, and to expand them to big ideas. He also argued that a concept should consist of contents which can allow for conceptualization (Nikitina, 2006). This is because common sense level topics have the risk of encouraging learners to understand a series of information superficially rather than deeply (Grossman, Wineberg & Beers, 2000). Drake & Burns (2004) said that it is necessary to determine the core knowledge and skills which need to be taught in a subject for integrated instruction, and to select a conceptual theme by exploring the common concepts and functions among subjects. Based on experiences obtained from the implementation of interdisciplinary integrated instruction, Shin (2005) stated a concern that because the theme-oriented approach for multidisciplinary integration incorporates several subjects, it might end up being an artificial integration with focus on the activities. The study carried on to claim that through interdisciplinary integration focused on common concepts or skills, integration based on the unique logical sequences of the academy should take place. In light of these aforementioned logics, the contents should consist of conceptual themes which can be commonly dealt with in the subjects to allow the implementation of integrated education.

Since learning cannot exist by itself outside the context of real life, learning which is unrelated to reality cannot be meaningful. Through integration, students can effectively connect school and society, and can voluntarily create a cognitive structure. Integration serves as the medium between school and society by facilitating realistic learning (Ingram, 1979). According to Zazkis & Liljedahl (2008), we must transform knowledge into something easily memorable and meaningful by putting the knowledge into a context at the time of discovery, or into the context in which it will be used by humans, instead of simply demonstrating the knowledge. The Korea Foundation for the Advancement of Science and Creativity (2012) stated that the ultimate convergence of the STEAM education is "natural integration" in real life, because real world problems are complicated and require multidisciplinary knowledge to come up with solutions rather than the limited knowledge of a certain subject. Recently, Alvarado & Herr (2003) stressed the importance of exploration and conceptual understanding, suggesting object-based inquiry, which can develop the understanding of a concept by utilizing a common object in everyday life as the material. The lesson should start with an explorative question which can raise any curiosity that students may have. Students can build a deep understanding in the process of voluntarily making exploratory questions and then exploring them. Therefore, if the lesson is designed to connect learning through integrated education with realistic contexts and phenomena, the value can be more readily appreciated.

"Learning Cycle Model," a teaching and learning model of science and mathematics based on inquiry and conceptual understanding, would be a potential model for the integration of education. Karplus, who participated in the Science Curriculum Improvement Study [SCIS], suggested a Learning Cycle Model consisting of exploration, invention, and discovery, which were alternatives to assimilation, accommodation and equilibration defined by Piaget's developmental theory. The Learning Cycle Model is a learning model which was introduced to promote the learning of basic concepts and cognitive development in science (Ministry of Education and Science Technology, 2011). The Learning Cycle Model based on student-centered inquiry activities consists of 3 phases: Exploration, Term Introduction and Concept Application (Lawson, 1995; Lawson, Abraham & Renner, 1989). In the first "Exploration" phase, students are allowed to have enough direct experiences and freely explore new situations with minimal guidance from a teacher. In this phase, students will experience cognitive conflicts, which cannot be solved with the accustomed ways of thinking. This is the moment when students fall into cognitive non-equilibrium, and try hard to restore it. Students are encouraged to express and describe what they investigate and discover in their own words. This is connected with a science concept which a teacher introduces in the following phase. The second phase, "Term Introduction," introduces scientific concepts to explain the things that students experienced in the "Exploration" phase. Students should clarify the similarities and differences by relating their own expressions with those of experts. In the final "Concept Application" phase, students understand and explain new situations and phenomena by associating the new concept with examples, which can help them to gain a deep understanding of and generalize the concept by relating it with various example situations. The Learning Cycle Model can contribute to improving students' ability of investigation by inducing them to discover new concepts by themselves through a simple experiment (Karplus, 1977). Many studies at home and abroad have demonstrated the effectiveness of the Learning Cycle Model for encouraging students to understand scientific concepts and enhancing their ability of investigation (Lavoie, 1999; Zollman, 1990), and it has also shown positive effects on the understanding of mathematical concepts and creativity in the mathematics area (Gail, Kim & James, 2003).

Gagne suggested the learning hierarchy, in which intellectual skills are organized from simple to complex. In other words, students must learn a low level of elements to move on to study a higher level, which requires an accumulative learning process. The intellectual skills involved include discrimination learning, concrete concept learning, defined concept learning, rule learning, and problem solving. According to the learning hierarchy, concept learning is the foundation for problem solving lesson. Moore (1994) emphasized the importance of concept learning and suggested the Concept-Understanding Scheme, which consists of concept definitions, concept images and concept usage; a learner should first understand a concept in order to be able to make an example based on that concept, or apply the example. Therefore, learners can build a deep understanding of a concept only if they are given chances to apply it.

MODEL FOR THIS STUDY

Based on what we have learned in the processes of Piaget's Cognitive Development and Lawson's Learning Cycle Model, the following common features could be found by phase. In the first phase, students explore new phenomena and experiences based on the previous knowledge they have accumulated through their experiences. As mentioned previously, integrated education can realize the essential meaning of learning by playing a bridging role between school and society through engagement with authentic contexts. In the second phase, students can formalize the knowledge about a new experience by associating what they explored in the first phase with a new environment or terminology. In the third phase, students can understand the related knowledge more deeply by applying the formalized knowledge of the second phase to different situations and experiences.

Table 1. Phase-specific similarity of Piaget's cognitive development and Lawson's learning cycle model

phase	Piaget's Cognitive process	Lawson's Cycle Model	Similarity
1	Assimilation	Exploration	Explore new experiences based on the knowledge that students already know.
2	Accommodation	Term introduction	Formalization of knowledge by associating what they have explored with a new environment or terminology
3	Equilibration	Concept application	Deeply understand by applying a formalized new knowledge to other situations or experiences.

Table 2. Phase-specific characteristics of integrated concept understanding model

Phase	Characteristics
1.Explore a phenomenon	- To become aware of and explore a new phenomenon based on what students have experienced before - To explore a phenomenon of a realistic context from mathematical or scientific perspectives
2.Understand concept	- To formalize and generalize empirical knowledge by relating the concept which a learner has understood based on phenomena and experiences to mathematical or scientific words
3.Apply concept	- To apply formalized concepts to various situations to explain new situations or other concepts - To solve a new problem situation using the concepts - To understand concepts in depth

Based on the aforementioned discussions, this study would like to suggest an inquiry-based model for the understanding of convergent concepts. Phase 1 can be defined as the phase of "exploring a phenomenon," wherein students become aware of and explore new phenomena based on their experiences. In other words, students explore a phenomenon occurring within an authentic context or experiences which they may encounter in their daily lives from mathematical or scientific perspectives. In order to help students better understand the integrated concepts which are commonly addressed in both mathematics and science lessons, Phase 2 and Phase 3 were presented herein by differentiating the levels of understanding of the concepts. Phase 2 is the concept understanding phase, in which students will formalize and generalize the concept they previously understood based on phenomena and experiences by associating it with mathematical or scientific representations. Phase 3 is the concept application phase, wherein students can gain a more deep understanding of the concept by applying the formalized concept from Phase 2 to various situations or new phenomena to come up with solutions to new problem situations.

The objective of this model was for students to acquire in-depth understanding of a concept. The model starts with the phenomenon exploration phase, goes through the concept understanding phase wherein students are encouraged to express the explored phenomenon using mathematical and scientific concepts, and finally finishes with the concept application phase wherein students can form a broad understanding about the concept. After the concept application phase, students can return to the concept understanding phase in order to acquire a more in-depth understanding of the concept. This model can be expressed in a schematic diagram in Figure 1.

Implementation

This study aimed to present a case-study of the elementary school level integrated education of mathematics and science on the basis of the aforementioned "Convergent Concept Understanding Model."

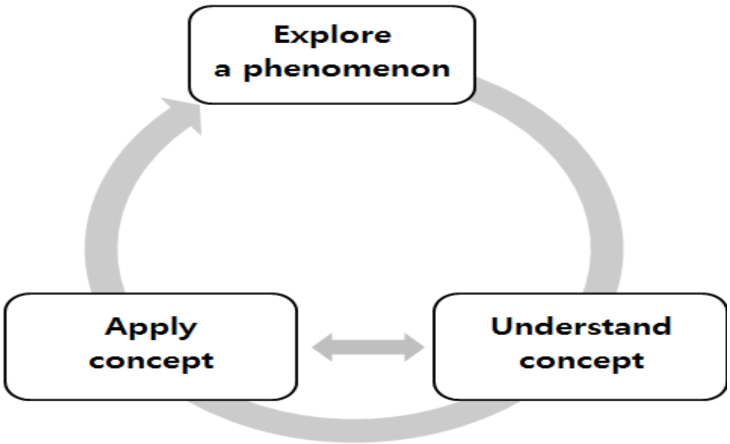

Figure 1. Convergent Concept Understanding Model

Table 3. Goals of Integrated Lesson for Lower Graders ('Room of Halfie and Mirror')

Mathematics aspect		Science aspect	
Understanding of concept and principle	Understand the symmetry of the real image and mirror-reflected image by using the mirror	Understanding of basic concept	Understand the reflective properties of light
Mathematical reasoning	After observing figures of various shapes, do reasoning to find out the common features of symmetrical figures	Interest in phenomenon	Observe different reflected images of the shape depending on the type of mirrors and due to changes in angle.
Problem solving and communication	Create the reflected half of a shape using symmetry and predict the completed shape	Scientific inquiry ability	Predict the variations of a shape depending on different positions of the mirror, and do an inquiry about the properties of the mirror

Participants

A total of 37 elementary school students (20 males and 17 females) from elementary schools located in Seoul Metropolitan City voluntarily took part in the integrated education developed by this study.

Instruction example of lower graders

The lower graders' instruction, which targeted elementary students in the 1st or 2nd grade, included a lesson in which students could explore the principles of a mirror, which they have often encountered in their daily lives, and the principle of line-symmetry inherent in the mirror. This lesson integrated scientific activities, in which students would learn about reflection among the various properties of light, with mathematical activities, in which students could explore the principle of symmetry through the mirror-reflected images. Symmetry is a lower concept of transformation. Transformation-related content is closely associated with various ideas that students learn from elementary school to high school. The reasons why the importance of transformation is continuously emphasized within the curriculum are as follows (Rubenstein & Thompson, 1994). First of all, it is because of an accessibility aspect of transformation. As translation, flipping, rotation and enlargement are all related with motor sensation, students can operate them at various levels and easily recognize any possible changes. Second, there is also a communication aspect, in which the transformation-related terminology provides a simple method with which to explain various phenomena. Third, it gains focus due to a problem-solving aspect. Symmetry, rotation and ratio in size transformation can offer tools to solve various problems. Fourth, a connection aspect is also present. Transformation can facilitate the application of mathematics in various areas including design and construction, and can integrate diverse mathematical ideas such as similarity, congruence, coordinates, synthetic geometry and multivariate data measurements. Among the types of symmetry, line symmetry can especially be easily understood together with the reflective properties of light included in the science content. Since elementary lower graders have become informally aware of the characteristics of the image reflected in the mirror through their daily life experiences and actually use the mirror very often, the line of symmetry was adopted as the conceptual theme of the integrated instruction herein in order to help students understand the concept of symmetry. The goals of the lesson were as follows in Table 3. In addition, the specific lesson plan for each phase of the model is can be seen in Table 4.

The typical performance example of each phase given to the students was as follows. In the phenomenon-exploration phase, the major activities were to explore the characteristics of images reflected in the mirror, to observe what is reflected in the mirror by exposing only half of the body to the full-length mirror, and to observe changing images by rotating a small mirror to different angles either individually or as couples.

In the concept-understanding phase, students would learn how to express what they discovered and observed during the phenomenon-exploration phase with the formalized concept of symmetry, and could understand the concept of mirror-related line symmetry more deeply. This phase consisted of various activities which helped students learn the concepts of line-symmetric figures, figures with reflective symmetry and axis of symmetry.

In the concept-application phase, students were given the opportunity to create their own mirror room based on the principle of mirrors and symmetry, so that they could apply the previously learned concept of symmetry.

Figure 1. Performance examples of activities 2 & 3 in Phase 2.

Table 4. Phase-specific lesson plan of the convergent concept understanding model for lower graders in elementary schools

Phase	Lesson theme	Lesson plan
Explore aphenomenon	Inquire about the symmetry principle suing the mirror	< Mimicking Mirror and 'Halfie'> ▸activity 1: After showing the magic saving box mounted with a mirror, encourage students to make guesses about the principle of the magic ▸activity 2: Find out the types of vocations which make use of mirrors, and guess why they use mirrors ▸activity 3: Mimicking Mirror- By utilizing mirrors of different sizes, explore the characteristics of the shapes of images reflected in the mirror and attract students' interest in symmetry ▸activity 4: By using the secret mirror of the 'figure country,' observe a symmetric shape within a plane figure and explore the characteristics of the symmetric figure
Understand concept	Understand the concept of symmetry (line-symmetric figures and figures in the position of line-symmetry)	<Mirror and Mystery > ▸activity 1: express what was explored in Phase 1 with the mathematical (symmetry) and scientific (reflection) terminology ▸activity 2: "Find Halfie!": Among the given figures, find a symmetric figure and create it with a colored paper ▸activity 3: "I'm a 'symmetry' cook": understand line symmetry and figures with reflective symmetry
Apply concept	Produce the results using the mirror and the symmetry principle	<Halfie and the Room of Mirror> ▸ activity 1: create my own mirror room: create the mirror room based on the symmetry principle using a mirror and I-clay ▸ activity 2: appreciate the mirror room

In the existing curriculum in Korea, the concept of symmetry of mirror-reflected images in the subject of science is currently being taught separately from the concept of symmetry in mathematics. Moreover, although some activities are present in mathematics through which students could learn the characteristics and nature of line-symmetric figures, they are being taught separately from the science curriculum. Therefore, students were not given the opportunity to recognize that the characteristics of images reflected in the mirror are exactly the same as those of the line-symmetry figure. However, through this integrated lesson, students were able to better understand the symmetry concept through hands-on activities and experiments. Especially, the phenomenon-exploration phase and the concept-understanding phase were more sophistically designed so that students could distinguish between the different concepts-line symmetric figures, figures with reflective symmetry and axis of symmetry-and also understand their relations to one another.

Reflections

A survey was conducted on the students who participated in the integrated lesson developed by this study. The survey was a questionnaire which consisted of 8 questions on a 5-point Likert scale to ask the students to express their thoughts about the integrated lesson.

According to the results of the survey, given that the questions "Thanks to the lesson, I find mathematics and science more interesting" and "The content of the lesson helped me learn more about mathematics and science" won 4.5 points, the integrated lesson contributed to enhancing students' interest in mathematics and science and was very helpful to students' learning. By providing students with opportunities to enjoy learning mathematics and science, the integrated lesson is expected to help them develop positive attitudes towards studying the two subjects. Also, considering that the question "The content of the lesson helped me solve problems that I encounter in my daily life" got 4.4 points, students recognized that the problem situation and solving process based on mathematics and science principles in the integrated lesson were relevant to their daily lives. In addition, given that the question "I hope to have more of similar activities during future lessons" garnered 4.8 points and that the question "The content of the lesson was interesting" won 4.6 points, these indicate that students would actively participate in such activities in the future. The individual reflections over their

Table 5. Participants' Response Results.

Statements	Mean
The content of the lesson was interesting.	4.6
The content that I learned in the lesson was something new.	4.4
Thanks to the lesson, I find mathematics and science more interesting.	4.5
The content of the lesson helped me learn more about mathematics and science.	4.5
The content of the lesson helped me solve problems that I encounter in my daily life.	4.4
The level of the lesson was suitable to me.	4.8
I was able to learn the importance of teamwork through the activity to solve a problem together with friends during the lesson.	4.2
I hope to have more of similar activities during future lessons.	4.8

Table 6. Students' Reflections over Their Participation in the Integrated Lesson.

Cognitive aspect	Conceptual understanding	It is amazing that I can learn both mathematics and science principles at the same time during one lesson.
		It is great to learn the principle and concept through various activities and helps me better understand them.
		I found something that I wasn't interested in, for example, gear, very intriguing.
		I could learn more about mathematics and science principles through various interesting activities.
	Connection to real life	Through activities, I came to know that various vocations utilize mathematics and scientific concepts and I became more interested in those related vocations.
Affective aspect	Interest in lesson	I became more interested in mathematics and science.
		I think that the lesson was interesting and enjoyable.
	Attitudes toward learning	Through the group work with new friends from other schools, I could experience cooperation and have a better sense of teamwork.

participation in the integrated lesson can be summarized in Table 6.

After taking into consideration all the results of the survey, this study proved that the integrated education of mathematics and science could contribute to raising students' interest in these subjects, and boost student motivation to participate in learning activities. In addition, the integrated lesson offered students the opportunity to learn mathematics and science in a fun and enjoyable way, nurtured their creative thinking, and enhanced their spirit of teamwork through cooperative learning activities.

DISCUSSION

In the midst of growing needs for integrated education due to social changes, this study suggested a model based on a concept that is commonly dealt with in both mathematics and science lessons. To build the model, we listed the common issues in mathematics and science education and used the list as the basis for model development. First of all, children should learn through concrete hands-on experiences, experiments and practical work. Second, lessons should be based on a conceptual theme involving a common concept and function of the two subjects so that patterns among the relations of various concepts could be identified by students and further expanded to higher levels of the concept, in which mathematical or scientific thinking could take place. Third, we had to ensure "natural integration" in the real world in order to realize a genuine sense of learning through which students could create a cognitive structure by themselves. In regard to these objectives, we produced a three-phase process from Piaget's Cognitive Development and Lawson's Learning Cycle Model. The three phase cyclic model for the understanding of integrated concepts consists of 'Exploring a Phenomenon,' 'Understanding Concept' and 'Applying Concept' phases.

Based on the model suggested herein, we designed and implemented a lesson. For demonstration of the phases suggested by this study, symmetry was adopted as the conceptual theme. The themes selected for instructional design not only have great importance within the curriculum, but also have close relevance to matters that students may encounter in their everyday lives. They were selected because they can encourage students to readily participate in the inquiry process and allow students to see phenomena from a mathematics and science point of view.

Especially, the goal of the phases suggested herein was to understand the mathematical concepts of symmetry-especially line-symmetric figures, figures with reflective symmetry and axis of symmetry-which all involve the reflection properties of mirrors and light. The lesson consisted of various activities ranging from the phenomenon understanding phase to the concept understanding phase, in order to help students understand the concept more deeply. Through repetitive and differentiated activities, students could learn about line-symmetry figures and figures of reflective symmetry, and they had the opportunity to create mirror rooms by applying these concepts. Through the lesson, students were able to know that the image reflected in the mirror, which is usually taught in a science lesson, could be explained by the mathematical concept of line-symmetry. The students could explore the phenomena, which triggered their interest thanks to a high relevance to their surrounding living environment, understand what they explored within the concept or a formalized mathematics and science knowledge, and apply the concept to a new problem situation to build in-depth understanding of the concept. Through this process, they could form an attitude of keen interest in their surrounding environment, and of exploration and inquiry in a more self-directed manner.

This study suggested an integrated lesson model and also planned and implemented a lesson based on a conceptual theme which is commonly dealt with in both mathematics and science lessons. Based on the results, we would like to suggest the following arguments from the perspectives of curriculum development, mathematics education and science education. Drake (2007) placed great importance on the rigor of abiding by the standards when designing an integrated curriculum and on its relevance to students' daily lives to raise their interest. Today's integrated education is designed based on themes which are highly relevant to the living environment of students. However, it fails to do provide more than just a common sense level of integrated instruction, and has become degraded simply to fun-oriented activities. In addition, the phenomenon of integration for integration's sake has occurred in some cases, because integrated education has not been based on interdisciplinary knowledge but on arbitrarily collected subjects which are superficially related to a certain topic.

According to Newell (1994), we can facilitate an interdisciplinary approach if we place the focus on broader themes rather than on specific facts when designing a curriculum for the interdisciplinary course. Integrated education should not stop at simply learning discrete concepts, but the acquired knowledge of one subject must lead to a broader understanding of other related subjects. To this end, a common conceptual theme was adopted in the present study, which was dealt with in both mathematics and science lessons. The theme was something students could experience in their daily lives, and was also worthwhile to learn from both mathematics and science perspectives. Through the lesson, students became able to see and interpret a certain phenomenon, not from a single perspective, but from multiple perspectives. Therefore, when developing an integrated curriculum, we need to exercise more prudence so that students will not stop at simply acquiring knowledge, but can nurture an insight to through which to see the world. To that end, we efforts need to be made to develop and implement small units of curriculum, for example, lesson by lesson or unity-by-unit. After that, based on the accumulated experiences, a yearlong curriculum could be developed.

Ingram (1979) suggested three principles about what kinds of nature should be sought by students' learning process in an integrated subject. One of them was 'learning how to know,' which was to ensure that the learning of students would be a creative and productive experience, also emphasizing discovery by learners. Piaget (1964), Meichtry (1992), and Van de Walle (2004) stressed the importance of understanding the thinking process of children when they were engaged in hands-on experiences and experiments. In school education, students must not show interest only in acquiring discrete knowledge, but need to experience and understand the nature of mathematical and scientific thinking and learn the process and methods of such thinking. People often think of mathematical and scientific knowledge as the complete truth discovered by experts. However, by experiencing the thinking process of completing knowledge, students can understand the essence of mathematics and science and recognize their usefulness. In this study, students who participated into the lesson, which focused on the methodological aspect of exploring mathematics and science, stated in their reflections that they could better understand the mathematical and scientific concept more easily by participating in various experiments and hands-on activities, and that they could recognize the usefulness of mathematics and science because they were very relevant to their daily lives. By experiencing learning by doing, students can nurture their thinking abilities and apply their knowledge to other situations and subjects. Therefore, integrated education along with the subjects of mathematics and science should not focus on the content of knowledge, but pay more attention to process skills or inquiry methods.

The problems facing modern society can be solved only by utilizing the knowledge of various scientific disciplines. By providing an opportunity for students to look at certain problem situations from various aspects of life, they can nurture their critical thinking abilities, and the classroom will be shifted from a teacher-centered to a student-oriented learning environment. In addition, integrated lessons should place the focus on a big idea rather than on discrete knowledge so that students can better understand the correlation of topics from different disciplines (McComas, 2009; Prain & Hand, 1996; Richadrs & Shea, 2006; Yarker & Park, 2012). Integrated education will obviously ensure that what students learn in the classroom will not end up becoming 'knowledge in school,' but serve as the foundation for solving complex and dynamic problems that will be encountered in the future society. The integration of multiple disciplines should not be done merely for integration's sake, but must help students develop their thinking ability. Furthermore, continued efforts should be made to materialize a meaningful integrated education that can serve as the foundation for academic development.

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