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Learning Activities That Combine Science Magic Activities with the 5E Instructional Model to Influence Secondary-School Students' Attitudes to Science

Jang-Long Lin, Meng-Fei Cheng,Ying-Chi Chang, Hsiao-Wen Li,
Jih-Yuan Chang & Deng-Min Lin
National Changhua University, TAIWAN

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The purpose of this study was to investigate how learning materials based on Science Magic activities affect student attitudes to science. A quasi-experimental design was conducted to explore the combination of Science Magic with the 5E Instructional Model to develop learning materials for teaching a science unit about friction. The participants were recruited from among the students of a middle school in central Taiwan. Based on our results, we conclude that our combined teaching method involving Science Magic activities and the 5E Instructional Model is effective for developing learning materials for teaching, and that this method improves students' attitudes toward science.

Keywords: Attitudes toward science, 5E instructional model, scientific inquiry, Science Magic

INTRODUCTION

Attitudes concerning science have been highlighted in science education for several decades (Duschl, Schweingruber, & Shouse, 2007; Gauld & Hukins, 1980; Osborne, Simon, & Collins, 2003; Osborne & Dillon, 2008). Science teachers make efforts to arouse interest and engagement among their students in science learning (Lin, Lawrenz, Lin, & Hong, 2013; Ramsden, 1998). In other words, in their learning process, students are not only expected to acquire scientific concepts and skills, but also develop positive attitudes to science. However, studies have shown that students' attitudes to science often turn progressively negative across grades, especially during secondary school (Barmby, Kind, & Jones, 2008; Potvin & Hasni, 2014; Simpson & Oliver, 1990; George, 2000). Therefore, it is essential to investigate how to improve secondary-school students' attitudes to science.

Correspondence to: Jang-Long Lin,
National Changhua University of Education,
Changua City/TAIWAN
E-mail: phljl@cc.ncue.edu.tw
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Attitudes to Science

According to Gardner (1975), attitudes to science can be subcategorized into *attitudes toward science* and *scientific attitudes*. The former refers to emotional responses or feelings about any aspects of science learning, such as liking or disliking the topic of science, and enjoying or not enjoying science learning. The latter constitutes the willingness to incorporate scientific knowledge and skills into one's own scientific thinking and methods (Gardner, 1975; Gauld, 1982; Haladyna & Shaughnessy, 1982; Osborne, Simon, & Collins, 2003).

Attitudes towards science and scientific attitudes have been recognized to play important roles in science learning. In Taiwan, the Ministry of Education (2003) proclaimed that the development of more positive student attitudes towards science and scientific ideas was one of the major goals of the science curriculum

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State of the literature

- The attitudes of students concerning science often turn progressively negative across grades, especially during secondary school.
- Science Magic was designed based on scientific principles and knowledge; however, current science education lacks instructional approaches to integrate its activities into science learning.
- The 5E Instructional Model has been suggested as an effective and essential strategy for inquiry-based science instruction.

Contribution of this paper to the literature

- This study proposes a way to teach the scientific concepts underlying Science Magic.
- Our research group developed an original instructional approach that integrates Science Magic activities and the 5E Instructional Model, which provides students with an opportunity to practice authentic scientific inquiry and improve their attitudes to science.
- We used quantitative approaches to examine improvement in student attitudes to science, and qualitative approaches to explore how use of the proposed combined instructional approach improved science instruction in the classroom.

according to the *Grade 1-9 Curriculum Guidelines for Taiwan*. As specified by the guidelines, attitudes to science comprise four items: enjoying inquiry, taking pleasure in discovery, being careful and precise, and being objective in pursuing the final truth (Table 1).

Johnson, Wardlow, and Franklin (1997) proposed that hands-on activities would help students effectively develop positive attitudes toward science. Serin and Mohammadzadeh (2008) noted that it is important to help students improve their attitudes toward learning science by giving them enough time to pursue individual activities and to learn the subject thoroughly during class activities. Regarding scientific attitudes, Gauld and Hukins (1980) indicated that the scientific attitudes of students could be influenced by the teaching strategy used. Accordingly, if learning activities are well designed to efficiently draw the attention of and foster engagement among students, and if teachers provide students with sufficient time to manipulate the materials in the activities, students will be more likely to develop positive attitudes to science. In this study, we used Science Magic, a program of interesting hands-on activities to teach a unit about friction, and then investigated the impact of this program on student attitudes to science.

Science Magic

In recent years, magic performance, particularly the use of magic tricks in the Science Magic program, has been perceived as being not only a form of entertainment, but also an activity-based science-education tool (Hsu, Wang, & Hsu, 2012; Lin et al., 2014). Distinct from traditional magic tricks, Science Magic activities have been designed based on scientific principles and knowledge. Hence, in addition to arousing the attention and interest of students, elements of this program could help students develop relevant science knowledge and skills through the observation and manipulation that occurs during Science Magic activities. As a result, we decided to include a series of learning activities in this study that were designed based on Science Magic.

Certain issues remained unresolved at first, namely, how to apply Science Magic concepts and practices to develop learning activities, and which instructional strategies should be adopted to enhance the impact of such learning activities. Among numerous instructional strategies, many researchers have indicated that inquiry-based strategies are effective and essential for science teaching and learning (Arnold, Kremer, & Mayer, 2014; McBride, Bhatti, Hannan, & Feinberg, 2004; Michaels, Shouse, & Schweingruber, 2008; Yakar & Baykara, 2014). Therefore, we decided to combine an inquiry-based strategy with Science Magic activities to design learning activities to help to improve student attitudes to science. In our study, we used the 5E Instructional Model, which was proposed by Bybee and Landes (1988), believing it to be one of the most effective strategies for teaching scientific inquiry.

5E Instructional Model

The 5E Instructional Model involves a systematic strategy. The five phases encompassing instruction using this model are Engagement, Exploration, Explanation, Elaboration, and Evaluation. Each phase offers salient characteristics to help the teacher to develop learning activities and to guide students as they learn science (Bybee & Landes, 1988; Bybee et al., 2006). The purpose of each phase is as follows.

Engagement: This phase motivates students using learning activities to make connections between prior knowledge and newly introduced concepts. In this phase, the teacher should demonstrate certain activities or pose questions to hold the attention of students and elicit their interest.

Exploration: This phase provides hands-on experiences for students to discuss science concepts and skills at a later time. It is necessary to afford students adequate time to explore the ideas or situations that they faced during the Engagement phase.

A. B.

Figure 1. The use of a spring to measure static and kinetic frictional force by pulling a woodblock across a tabletop.

***Explanation*:** The aim of this phase is to help students create and develop scientific concepts and skills. Therefore, teachers ask students to explain the concepts or skills that they observed or learned through previous activities. The teacher should then draw a conclusion and introduce formal science concepts to students.

Elaboration: This phase provides an opportunity for students to apply the scientific concepts they learned in a new context. Through this phase, students may gain better comprehension of the information they learned.

Evaluation: This phase allows students to evaluate their understanding and teachers to assess educational outcomes. Evaluation should be carried out as a part of each phase of the learning activities.

This study adopted a series of Science Magic activities to help students develop concepts through the Engagement, Exploration, and Explanation phases; later, we provided students with another Science Magic component as an opportunity to apply the concepts they learned. However, if a concept proved to be more difficult for students than anticipated, additional Science Magic activities were used to assist students in better developing concepts during the Engagement, Exploration, and Explanation phases prior to applying those problematic concepts.

RESEARCH METHOD

Research Procedures

The study employed a quasi-experimental design to explore the impact of integrating elements of Science Magic into inquiry-based instruction. Before the instruction, the experimental and comparison groups completed pre-tests using the Science Attitude Scale. After instruction, both groups also completed post-tests. The quantitative data was analyzed with ANCOVA (analysis of covariance) using SPSS 17.0 for Windows. By comparing the difference between both groups' mean scores for post-tests, the impact of the teaching materials used in this study on student attitudes toward science was determined. Additionally, data from student interviews and the qualitative analysis of classroom observations revealed how these teaching materials impacted student attitudes to science.

Participants and Learning Materials

The participants in this study included two eighth-grade classes at a central Taiwanese junior high school; an experimental and comparison group was formed. The experimental group consisted of 37 students (19 boys and 18 girls), and the comparison group consisted of 31 students (15 boys and 16 girls). Both groups were taught lessons of a similar duration by two different teachers. The teaching materials for both groups were designed according to the five phases of the 5E Instructional Model. The major difference between the two groups entailed the methods each instructor used to assist students in practicing qualitative reasoning concerning the lesson topic, friction.

The learning material employed by the comparison group included a current science textbook used by Taiwanese junior high schools. Per this material, the teacher cited several common life experiences to guide students to perform qualitative reasoning, thereby connecting their pre-existing knowledge with new concepts about friction. Afterward, students proceeded with quantitative reasoning about friction concepts by performing the activity depicted in Figure 1, which involves pulling a woodblock across a tabletop. In the activity, students used the balance of a spring to measure the magnitude of static, maximum static, and kinetic frictional force. Furthermore, by putting different weights on the woodblock and pulling it again, students explored the mathematical relationship between normal and maximum static frictional force.

In the experimental group, the employed teaching materials were similar to those used by the comparison group, although the activities for qualitative reasoning were substituted with appropriately designed Science Magic activities, such as the Striving Ring, Obedient Ball, Unseparated Books, Powerful Little Towels, and Powerful Paper Ring. Afterward, students in the experimental group also enhanced their quantitative

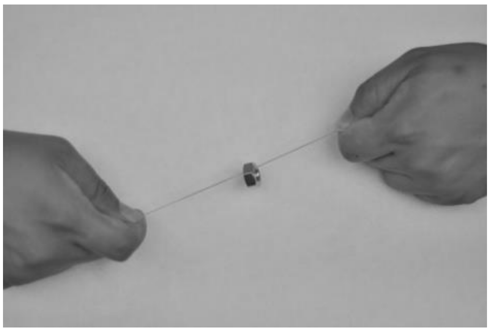

Figure 2. The Striving Ring.

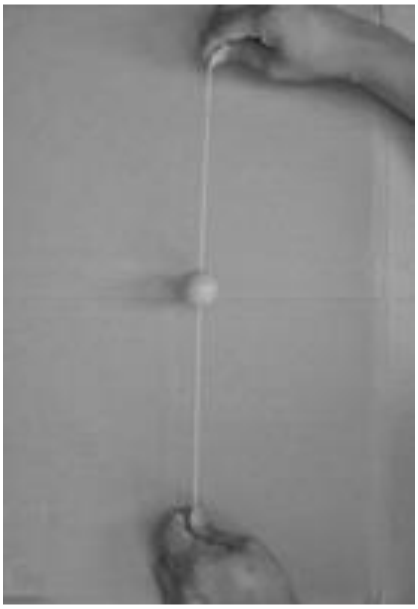

Figure 3. The Obedient Ball

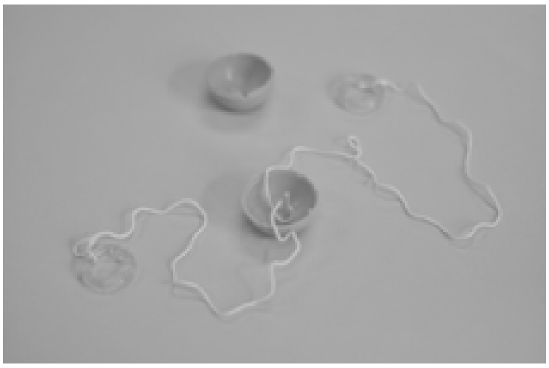

Figure 4. Obedient Ball materials.

reasoning skills regarding friction concepts by performing the woodblock activity.

The Five Science Magic Activities

The Striving Ring activity was designed to encourage students to engage in learning activities, and to help them develop an understanding of the characteristics of static friction through the first three 5E phases: Engagement, Exploration, and Explanation. Next, students applied the concepts learned from the Striving Ring activity to practice and explain another Science Magic activity in the Elaboration phase: the Obedient Ball. The purpose of having the students participate in the Unseparated Book and Powerful Little Towels activities afterward was to assist them in understanding the relationship between maximum static frictional and normal force through the phases of Engagement, Exploration, and Explanation. At the end, the Powerful Paper Ring activities provided students an opportunity to apply the concepts learned in the Unseparated Books and Powerful Little Towel activities. These activities are described as follows:

Striving Ring (Engagement, Exploration, and Explanation)

This activity uses the frictional force between a ring and rubber band to make a ring stay on the rubber band. By skillfully restoring the rubber band's force, the student moves the ring upward in resistance to gravity (Figure 2).

Three phases comprise this activity:

Engagement: The phenomenon of the ring moving upward on the string results in conceptual conflict in students' minds, and should arouse interest and curiosity. Hence, students usually want to try the activity to understand why the phenomenon occurs.

Exploration: Students are given sufficient time to manipulate the Science Magic equipment and explore why the ring stops on the string or moves upward. The teacher poses questions to guide students rather than directly explaining concepts and providing answers, subsequently encouraging them to work together and observe carefully.

Explanation: Students are encouraged to discuss their ideas and observations with others, and also explain the phenomenon in their own words. Additionally, they are asked to provide feedback concerning why the ring stops and why it moves upward. After conducting discussions and providing explanations, the teacher clarifies relevant concepts for students and supplies them with the correct concepts and definitions.

Obedient Ball (Elaboration)

The Obedient Ball and its components are shown in Figures 3 and 4. As shown in Figure 5, a long piece of cotton thread is wound around a reel inside the ball, which extends outside the ball's shell. By pulling the thread tightly or loosely, one can control whether the ball stays on the cotton thread or falls down. The ball is called "obedient" because it seemingly follows the user's commands.

Elaboration: The Obedient Ball is an activity in which students can make use of newly learned definitions and concepts. In this phase, students elaborate on their understanding of the characteristics of static friction. The activity guides them to consider what other forces affect friction, and to consider the relationship between frictional and normal force.

Unseparated Books (Engagement, Exploration, Explanation)

In this activity, a student first interlaces two books page by page. Then, the teacher asks two students to separate the books (Figure 5). Through this, students learn that it is nearly impossible to separate the books by merely pulling on their spines, but they are easily separable by simultaneously blowing and pulling on them.

Engagement: Most students are eager to try this activity upon discovering that it is difficult to separate the books.

Exploration: At this phase, the teacher should offer students adequate time to perform the activity and explore how to separate the books.

Explanation: Students provide feedback concerning why the books cannot be separated and how they might easily do so. After discussing their thoughts with others, the teacher clarifies student understanding and provides them with correct information.

Powerful Little Towel (Engagement, Exploration, Explanation)

This activity involves folding two towels together (Figure 6) and then holding and pressing the fold using one's fingers. Next, the teacher asks two students to separate the towels. The holding and pressing action of the fingers increases the normal force of the joint, and consequently enhances the maximum static frictional force between both towels. Students perform three phases similar to those outlined in the Unseparated Books activity.

Powerful paper ring (Elaboration)

In this activity students are instructed to use a piece of paper to support the weight of a heavy object; the paper should be folded into a tubular shape, and no paste should be used (Figure 7). Students discover that when normal force increases, so does maximum static frictional force.

The Evaluation phase in this study was implemented in two ways. First, the instructor introduced a common life experience at the lesson's end, after students' applied newly learned concepts during the Elaboration phase. At that point, instructors evaluated whether students achieved the instructional objectives. Second, the instructor evaluated whether students achieved the goals

Figure 5. Unseparated Books activity

Figure 6. Powerful Little Towel activity.

Figure 7. Powerful Paper Ring activity.

that they were expected to during the study's first four phases. These goals included being motivated by the activities during the Engagement phase, actively exploring concepts through the activities during the Exploration phase, discussing and formulating the scientific principles underlying the activities in the Explanation phase, and deciphering activities in the Elaboration phase.

Data Collection and Data Analysis

As mentioned earlier, data sources included pre and post-tests to determine Science Attitude Scale scores, in addition to classroom videos, student surveys, and individual interviews that were conducted at the study's end.

Table 1. Science Attitudes Scale Sub-Component Content Descriptions and the Number of Items in Each

Science Attitude	Content	No. of items
Enjoy inquiry	To enjoy inquiry and discovery	3
	To enjoy practicing scientific ideas and demonstrating them through activities or experiments	5
Take pleasure in discovery	To believe that careful observation and inquiry will lead to new discoveries	2
	To develop confidence in and interest toward inquiry	3
	To possess a positive attitude toward science and to believe in the positive value of science learning	6
Be careful and precise	To make the best choices according to one's comprehension and knowledge	5
	To know that information obtained by careful and precise inquiry is reliable	5
	To believe that there are causes for changes in phenomena and that the outcomes are based on the causes	2
Be objective and pursue the final truth	To know that reliable knowledge is acquired through careful observation and thought	4
	To pursue the truth by objectively collecting evidence and examining disputed information	6

Science Attitude Scale

The Science Attitude Scale adopted by this study was designed by Lin (2009) according to the Taiwanese Grade 1-9 Curriculum Guidelines (2009). The Science Attitudes measured by the scale included: enjoying inquiry, taking pleasure in discovery, being careful and precise, and being objective in pursuing the final truth. The test's scoring is based on a 5-point Likert scale. The Cronbach α of the total scale and sub-scales are .868, .789, .804, .767, and .763, respectively; all are higher than .760. The content and number of items comprising the sub-scales of this scale are described in Table 1. The data obtained from this scale was analyzed using covariance analysis.

Individual student interviews: To further explore the impact of Science Magic-based learning activities on student attitudes to science, we selected all students from the experimental group who reported experiencing a drastic attitudinal change toward science for additional interviews.

Classroom videos: Throughout the instruction, lessons given to a selected group from the experimental class were recorded to gain a better understanding of students' detailed reactions and behaviors.

Student surveys: After the teacher administered lessons according to the curriculum developed for this study, students were requested to provide feedback regarding the learning materials and instruction they received. Besides giving us an opportunity to obtain data related to students' opinions, this survey allowed students to evaluate what and how they learned based on the instruction.

FINDINGS

Quantitative Data Analysis

The attitudes to science expressed by the experimental group showed marked improvement after the instruction. The mean score of the experimental group in the pre-test was 157.73, whereas that of the comparison groups was 151.52. In the post-test, the experimental group's mean score was 167.54, which was higher than the 151.32 mean score of the comparison group. The ANCOVA analysis results indicate that the means of the post-test scores are statistically significantly different between the two groups ($F=24.119$, $p=.000$). We also separately analyzed the scores according to the sub-scales of the Science Attitude Scale. The results show that the experimental group scored higher on the post-test than the comparison group did for each sub-scale. Through ANCOVA, the results reveal that the experimental group also performed significantly better than the comparison group for each sub-scale: enjoy inquiry ($F=7.883$, $p=.007$), take pleasure in discovery ($F=43.052$, $p=.000$), be careful and precise ($F=6.433$, $p=.014$), and be objective and pursue the final truth ($F=6.030$, $p=.017$).

Qualitative Data Analysis

The qualitative data included classroom videos, student surveys, and individual interviews. A summary of the findings is provided below.

Dimension 1: Enjoy inquiry

We discovered that learning materials combining Science Magic activities and the 5E Instructional Model not only enhance student curiosity, enjoyment, and enthusiasm when learning about friction, but also help students gain a deeper understanding of concepts related to friction.

According to our classroom observation of the experimental group, students were amazed by the phenomena they observed through the Science Magic-based learning activities; thus, they were eager to explore and perform the activities to demonstrate these phenomena themselves. The students intently engaged in their lessons and interacted actively with the teacher. For example, in the Striving Ring activity students were surprised at the reason why the ring moved upward; they even initially attributed this phenomenon to supernatural forces:

Teacher (T): Why does the ring move upward?
Student 1 (S1): Move upward?
S2: Ah! [amazed]S3: Ah! [amazed]
S4: Miraculous…I can't explain that!
S5: Supernatural forces!

In the student survey results, individuals in the experimental group reported that they were very interested in the current instruction, and looked forward to performing similar activities in upcoming lessons. They expressed that such instruction is substantial and interesting. Additionally, most students indicated that they were impressed by the instruction, as in the following example:

The instruction is very interesting and impressive. I suggest that magic activities like these be used in ordinary science courses. By doing so, the instruction would become interesting instead of being tedious and could help us to thoroughly learn the principles behind the activities.

In the interviews we conducted to further confirm the effects of Science Magic-based learning materials on student attitudes to science, students indicated that the Science Magic–based learning activities aroused their curiosity efficiently. They also believed that learning through such activities was more concrete, and that the concepts became easier to perceive.

S35: I think that the instruction based on Science Magic [activities] is helpful for me in learning science, because presenting physical concepts through magic tricks can enable us to learn science with more curiosity and desire.

S36: It becomes more interesting in the class [when we perform Science Magic activities] because gaining knowledge by performing magic is more concrete than learning by dictation. Presenting knowledge by dictation is abstract, whereas Science Magic makes it easy to learn.

Dimension 2: Taking pleasure in discovery

The Science Magic-based learning materials are not cookbook-style laboratory experiments, so there are neither established procedures nor variables for experimental manipulation. However, the students in the experimental group showed a strong desire to decipher the Science Magic activities to learn the underlying scientific principles. During the instruction students carefully observed and participated in the activities, proposed possible hypotheses, and then actively discussed deciphering the activities amongst members of their small groups. Consequently, when the students cracked the code they not only gained a sense of achievement, but also developed greater enthusiasm about learning science. By repeating the aforementioned process and performing other Science Magic activities, students can gradually develop confidence and pleasure in discovery, which is a result of inquiry. Because of the interest and confidence they developed during the process of successfully deciphering the activities, students were willing to represent their respective groups and demonstrate the activities and their underlying principles to other groups. Hence, these students genuinely experienced the value of scientific principles and science learning by successfully performing Science Magic activities and applying what they learned to solve new problems, including those that commonly occur in daily life.

Our classroom observation during the Striving Ring activity revealed that students showed great enthusiasm in their small groups while proposing numerous possible ways of solving the magic phenomena. Although the students differed in their notions, through careful observation, manipulation, thinking, and discussion they made new discoveries and gained an understanding of the principles underlying the phenomena they observed:

S1: Rotate it?
S1: Try to rotate it.
S2: Do you still think so?
S3: When the ring moved upward, it seems that it rotated.
S2: I don't think so. I think the cause is the pull exhibited by the rubber band.
S2: We can't accomplish this by rotating it, I guess!
S2: Oh—I see! I see! I see!
S3: Rotate it?
S2: No—no—no—I did it! Look!

Classroom observation also revealed that the instruction using Science Magic-based learning materials helped students develop confidence and an interest in inquiry. During the activities, numerous students appeared to actively volunteer as team representatives who were capable of articulating and demonstrating the activities' underlying scientific principles. These scenes revealed that students who attained a correct realization of the underlying scientific principles by deciphering the phenomena were full of confidence, and willing to serve as representatives of their small groups in demonstrating the activities to others.

The subsequent interviews with students also reveal the effect of the Science Magic-based learning materials on the "To Develop Confidence and Interest in and Through Inquiry" aspect. The findings indicate that such instruction can efficiently raise the level of interest and confidence in students regarding science learning.

S34: I usually rely on rote learning of science [content]. But when learning science through Science Magic [activities], learning becomes interesting and impressive.

S36: Maybe it is the Science Magic that makes us concentrate on and be interested in the instruction. And then, I will understand more about what the teacher taught and be more confident of myself.

According to the survey, the students in the experimental group were interested in learning this unit and could perceive the value of the underlying scientific principles. Because the Science Magic activities are designed based on scientific principles, after the instruction, students discovered that every magic event they had observed follows scientific principles; therefore, they recognized the importance of scientific principles in general. Take one student's comment in the survey as an example:

S8: It is interesting to apply simple principles to the design and performance of a surprising Science Magic activity. This translates dull principles into fun experiments. [Through Science Magic activities] I really experience the interesting nature of science.

Moreover, when we asked the students whether this instruction using Science Magic-based learning materials would enhance their curiosity about the common phenomena of our daily lives and how they perceived the learning activities, some placed emphasis on the scientific principles.

S34: In this unit, the teacher used Science Magic [activities] to present physical concepts. So, when we watch other magic shows later, we will know that there must be some scientific principles behind [the tricks] and will want to understand their mechanisms.

Dimension 3: Be careful and precise

These results showed that such instruction can help students recognize that various phenomena in the world have their own underlying principles. This type of instruction also allowed the students to practice how to select and analyze data through the careful observation and verification of information. During the instruction, we observed that the students learned that there must be some reason why the phenomenon displayed by the activity occurred. Furthermore, the students carefully observed phenomena, actively interacted with their peers, reflected on their experiences when filling out the survey, and knew how to organize and summarize the possible factors corresponding to the magic activities. They even knew how to make the best choice according to their knowledge in cases where their new and prior understandings were in conflict. As a result, we conclude that the novel combined type of instruction that we developed can help students recognize that the various phenomena of the world each follow unique scientific principles. Using this strategy also allowed students to practice how to select and analyze data through careful observation and the verification of information.

In our classroom observation during the performance of the Striving Ring activity, we observed that when the teacher made the rubber band slope downward to allow the ring to move downward, students knew that the downward motion of the ring was caused by gravity. However, when the teacher allowed the ring to move upward, students thought that it was magical that the ring could resist gravity and move upward. However, even then, students believed that the phenomenon must be caused by certain factors.

S1: [The teacher's] action is very slight!

S2: How long will I [have to] practice if I want to perform like that?

………………

S1: [The teacher's] action is very slight; [the rubber band] may rotate like this. He must have done something!

Also, we report a similar finding in the Obedient Ball activity. When the teacher pulled the cotton thread tightly, students could not believe that the ball stayed on the thread. Yet, students believed that the phenomenon must be caused by certain factors.

T: Why can I control it by stopping it or making it fall down?

S1: [Referring to the teacher] He must have done something!

……………………

S3: Why?

S1: There must be something inside the ball.

Furthermore, in the survey, students clearly expressed that they know there is always a cause behind the magic. This indicated that, when exploring the learning activities, students carefully and precisely observed the resulting phenomena and then distinguished the differences between their original ideas and the phenomena that they observed later. As a result, they could make the best choice according to their newly acquired knowledge.

S1: In reality, the Science Magic [activities] apply certain scientific principles to hoodwink people. That is, the magician must have done something. As long as we have understood the principles, all can be clear.

S9: The principle of this activity is similar to that of the previous ones: all comes from the frictional force. There *actually are so many things related to the frictional force in our lives.*

Additionally, in the Powerful Paper Ring activity, the students analyzed and confirmed the questions they were facing. They attributed the factors of the trick's success to two aspects. First, the paper ring has to be strong enough to support the weight of the heavy object. Second, the seam of the ring held by the student's fingers also should be strong enough. In short, the activity itself promotes the careful observation of natural phenomena among learners; moreover, students could further explore the variables of the magic activities based on their own knowledge.

S1: So we have to fold the paper.

S3: Knot it!

S1: The key point is that you should fold it into a ring. The seam should be fixed when it is held by the fingers. Then, we can carry a heavy object using the paper ring and the seam will not come open.

S3: You make it very thin, and then tie it.

S1: I don't know…but there should be two points. First, it must be strong enough to support the heavy object. Second, the seam of the ring should be strong enough too because it is pressed by the fingers.

Students' interviews after the instruction confirmed their performance in class. The learners investigated the possible variables of the magic activities more carefully and precisely than they had before the instruction; also, they developed a desire to repeatedly confirm the validity of the variables and attempt the experiment again.

T: What will you do if your results are different from those of others?

S34: Check one by one the steps of the experiment I've just done, try to find out if there is something wrong or whether the measurement is accurate enough, and then redo the experiment.

Dimension 4: Be objective and pursue the final truth

The learning materials designed for use in this study, which combined Science Magic activities and the 5E Instructional Model, successfully used the characteristics of the Science Magic program. Learners, therefore, solved the mystery behind seemingly inconceivable phenomena by applying simple scientific principles to explain their findings (Hsu, Huang, & Yang, 2010). Students were often surprised and intrigued by the phenomena they encountered early in the instruction. Additionally, by independently deciphering the magic tricks students often became more interested in checking the underlying principles and variables of the activities, and developed a more positive attitude toward science learning. Furthermore, they were only willing to accept the validity of the information they just learned after independently confirming the results. This indicates that the students had developed a desire to pursue the final truth.

In the Powerful Paper Ring learning activity, we observed that the students did not initially believe that the thin, un-pasted paper ring could support the weight of a heavy object without breaking or tearing. This possibility may seem mysterious to students. However, through careful observation and diligent thinking, discussion, and practice, students came to grasp the principles behind the magic and discovered that they could perform the magic trick successfully by themselves. From this process the students developed the desire to pursue truth by objectively collecting evidence; they also came to understand that reliable knowledge is acquired through careful observation and thinking.

T: Raise your hand if you think it is "mission impossible."

[Some students raise their hands, but others continue working]

T: You've done it!

The other group members: Wow!

S2: [Borrowing the paper ring from S1, who just used it to successfully perform the trick] So... you connected the two ends of paper ring like this...?

S1: Yes!

S2: I see! So, you pressed the joint when you manipulated it.

S1: Yes! And then... [S1 performs the trick again]

In the interviews, we discovered that the students in the experimental group clearly acknowledged that there may be various existing viewpoints, obtained via their own observations or deductions or provided by other students or the teacher. The students realized that when conflicts exist between viewpoints, they should try to pursue the truth by themselves, either by collecting more information or by repeating the experiment This finding is consistent with that which we obtained during the classroom observation period (i.e., that students can know that certain information is reliable through careful observation and contemplation).

S35: Once I learned this science information, I came to understand what principles were embodied in common phenomena. This will make life more convenient. Also, I learned to cultivate my preference for doing experiments and that I like to explore. Instead of just believing what others say, I will verify the correct answer by myself.

S18: When I learn other subjects later, I can think about the problem by myself first and then discuss it with my classmates. If there are differences between [our] ideas, I will evaluate which is correct by [using] more deliberate thinking. When the teacher presents to us [an idea in] the lecture, I will compare my own idea with that of the teacher. If these two ideas are different, I will think again about what the teacher explained. By doing so, it will help me to *make a more significant impression and get a better grasp of the topic I have learned.*

DISCUSSION

Previous studies indicate that applying the 5E Instructional Model has a positive effect on enhancing students' science learning (Boddy, Watson, & Aubusson, 2003; Bybee et al., 2006; Fazelian & Soraghi, 2010). To further enhance students' science performance, conceptual understanding, and meaningful learning, researchers have integrated different tools in the 5E instructional model, such as mobile learning activities (Liu, Peng, Wu, & Lin, 2009), conceptual cartoons (Birisci & Metin, 2010), and analogies (Orgill & Thomas, 2007).

Similar to these studies, this study also adopted the 5E Model as the instructional strategy to design material and implement teaching. However, it differs from the previous studies in that we proposed a unique and innovative approach to applying Science Magic activities in each phase of 5E Model. In the following section, we discuss why Science Magic activities can be effectively integrated into the 5E Instructional Model to positively affect students' attitudes to science.

Why Science Magic-based Learning Activities resulted in an Observed Positive Effect on Student Attitudes to Science

First, participation in Science Magic activities can arouse the interests of students and encourage them to actively participate in the instruction. Gibson and Chase (2002) indicated that students may be interested in and motivated to study science if their instruction is conducted using an inquiry-based approach. However, how to encourage students to maintain a high level of motivation and interest to participate in inquiry activities is a challenge faced in implementing inquiry learning in classrooms (Edelson, Gordin, & Pea, 1999). According to our findings, Science Magic activities helped teachers to easily achieve this objective. Students in the experimental group expressed that they were very interested in participating in the instruction, and looked forward to other Science Magic activities in upcoming lessons.

Moreover, our findings mirror Swarat, Ortony, and Revelle's (2012) research, which emphasizes the importance of constructing an interesting learning environment to enhance the interest of students in science through classroom activities designed to draw on their various interests. In the light of our findings, we recommend that Science Magic activities constitute one type of activity capable of boosting student interest in science while also playing a role in constructing an interesting learning environment. Being integrated into the 5E Instructional Model, Science Magic activities not only trigger student interest in the early learning stages, but also encourage them to explore the scientific principles underlying Science Magic throughout the learning process. Students may maintain an especially high interest while deciphering the magic activities and identifying the scientific principles embedded within them.

Second, Science Magic activities are practical, easy-to-perform, and hands-on. Previous studies have indicated that practical, hands-on activities have a positive effect on student attitudes to science (Johnson et al., 1997; Serin & Mohammadzadeh, 2008); our findings are in line with the aforementioned research. Also, Barmby et al. (2008) pointed out that students generally feel that the scientific knowledge they acquire in school is impractical, not explained well, and is irrelevant to their lives; hence, students feel turned off by science as it is taught in school. These investigations further highlight the need to improve the science classroom experience among students. Accordingly, our study provides an approach for designing learning activities to resolve this predicament based on the Science Magic program,.

Third, Science Magic activities provide students with opportunities for effective qualitative exploration, reasoning, and understanding. The process of learning science begins with qualitative reasoning and progresses to investigate quantitative relationships, similar to the process that scientists adopt for conceptual understanding or problem-solving (Etkina et al., 2006; Van Heuvelen, 1991). Students in the experimental group implemented qualitative exploration through Science Magic activities, whereas members of the comparison group applied the concepts of friction to everyday life experiences. Although examples from daily life are usually used to motivate students in learning and offer opportunities to implement inquiry (Ergin, Kanli, & Ünsal, 2008), not all students have the same life experience that teacher propose. Therefore, compared with life experience–based examples, we believe that Science Magic activities are more practical and can provide a shared experience that students can discuss together.

Finally, deciphering Science Magic activities improve student self-confidence in learning science. Brickman, Gormally, Armstrong, and Hallar (2009) indicated that students could achieve greater self-confidence through inquiry-based learning, while Swafford, Orr, and Hall (2014) found a positive correlation between the number of hands-on activities that students participated in and increased confidence. Similarly, our findings also show that Science Magic activities can be applied to enhance students' self-confidence and to encourage continued discovery and learning. Students successfully solved the magic activities and were able to independently manipulate the materials. Moreover, they understood the scientific principles embodied in the demonstrated phenomena and developed greater confidence in their ability to learn scientific material. When students acquired new knowledge and developed skills independently, particularly by deciphering the miraculous phenomena they observed during the activities, they would realize that all the Science Magic tricks are based in scientific principles; consequently, they will comprehend the value of scientific phenomena and principles.

Effectiveness of Combining Science Magic Activities and the 5E Instructional Model

Based on the results of current study and prior research concerning the 5E Instructional Model (Bybee & Landes, 1988; Bybee et al., 2006; Bybee, 2009), we explain why Science Magic activities can be effectively integrated into the 5E Instructional Model. First, during the Engagement phase the Science Magic activities motivated students by focusing their attention and perplexing them. As Bybee et al. (2006) stated, "Engagement brings about disequilibrium; exploration initiates the process of equilibration" (p. 9), a requirement the Science Magic activities fulfill. In the Engagement phase, by performing a Science Magic activity, the teacher demonstrates a phenomenon that results in cognitive conflicts and the arousal of student curiosity. This conflict motivates students to try the activity themselves and to attempt to decipher it.

Furthermore, when students decipher Science Magic activities and discover the scientific principles embodied in the observed phenomena, they can then demonstrate the same events and explain their underlying concepts to others. Hence, the teacher can easily help students use scientific terms to give thorough explanations. During this process students clarified concepts and improved their skills, conforming to the primary characteristic of the Explanation phase.

Also, Science Magic activities are appropriate for use in the Elaboration phase, which provides students an opportunity to apply the knowledge and the skills that they developed. It would be best for the teacher to provide a new, challenging activity in this phase, such as those used in this study. Per our observation, when students successfully deciphered an activity they immediately desired to solve a new one. Finally, the Evaluation phase is an important opportunity for students to evaluate the knowledge and skills that they have acquired. When students repeatedly solved and demonstrated the Science Magic activities in front of their peers they simultaneously evaluated their previously acquired knowledge.

Implications for Future Studies

This study proposed a novel approach for combining Science Magic activities using the 5E Instructional Model to develop learning materials. Our earlier research indicated that the experimental group's achievement test score was significantly higher than the comparison group's (Lin et al., under review; Lin, Lai, Li, & Chang, 2012). Based on these results, this study provides empirical evidence that integrating Science Magic with the 5E Instructional Model to develop learning materials is effective, advantageous, and promising. In future studies related to inquiry-based instruction, more research should be devoted to developing Science Magic activities related to other science topics, such as light, energy, and heat, which can then be integrated into inquiry learning to improve students' learning performance and attitudes to science.

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REFERENCES

Arnold, J. C., Kremer, K., & Mayer, J. (2014). Understanding Students' Experiments—What kind of support do they need in inquiry tasks? *International Journal of Science Education*. Advance online publication. doi: 10.1080/09500693.2014.930209

Barmby, P., Kind, P., & Jones, K. (2008). Examining changing attitudes in secondary school science. *International Journal of Science Education, 30*(8), 1075-1093.

Birisci, S., & Metin, M. (2010). Developing an Instructional Material Using a Concept Cartoon Adapted to the 5E Model: A Sample of Teaching Erosion. *Asia-Pacific Forum on Science Learning and Teaching*, 11(1), 1-16.

Boddy, N., Watson, K., & Aubusson, P. (2003). A trial of the five Es: A referent model for constructivist teaching and learning. *Research in Science Education, 33*(1), 27-42.

Brickman, P., Gormally, C., Armstrong, N., & Hallar, B. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. *International Journal for the Scholarship of Teaching and Learning, 3*(2), 1-22.

Bybee, R. W. (2009). The *BSCS 5E instructional model and 21st century skills*. Washington, DC: National Academies Board on Science Education

Bybee, R. W., & Landes, N. M. (1988). The biological sciences curriculum study (BSCS). *Science and Children, 25*(8), 36-37.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes N. (2006). The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications. Colorado Springs: BSCS. *International Journal of Man-Machine Studies, 29*, 407-427.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (Eds.), (2007). *Taking Science to School: Learning and teaching science* *in grades K-8*. Washington, DC: National Academies Press.

Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *Journal of the Learning Sciences, 8*(3-4), 391-450.

Etkina, E., Van Heuvelen, A., White-Brahmia, S., Brookes, D. T., Gentile, M., Murthy, S., Rosengrant, D. & Warren, A. (2006). Scientific abilities and their assessment. *Physical Review Special Topics - Physics Education Research*, *2*(2), 020103.

Ergin, I., Kanli, U., & Ünsal, Y. (2008). An example for the effect of 5e model on the academic success and attitude levels of students': "Inclined projectile motion." *Journal of Turkish Science Education, 5*(3), 47-59.

Fazelian, P., & Soraghi, S. (2010). The effect of 5E instructional design model on learning and retention of sciences for middle class students. *Procedia - Social and Behavioral Sciences, 5*, 140-143.

Gardner, P. L. (1975). Attitudes to science: a review. *Studies In Science Education*, (2), 1-41.

Gauld, C. (1982). The scientific attitude and science education: A critical reappraisal. *Science Education*, *66*(1), 109-121.

Gauld, C. F., & Hukins, A. A. (1980). Scientific Attitudes: a Review. *Studies in Science Education, 7*, 129-161.

George, R. (2000). Measuring change in students' attitude towards science over time: An application of latent variable growth modeling. *Journal of Science Education and Technology, 9*(3), 213-225.

Gibson, H. L. & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education, 86*, 693-705.

Haladyna, T., & Shaughnessy, J. (1982). Attitude toward science: a quantitative synthesis. *Science Education*, *66*(4), 547-563.

Hsu, L. R., Wang, C. M., & Hsu W. L. (2012). The development and dissemination of Science Magic. *Science Education Monthly, 346*(March), 2-11.

Hsu, L. R., Huang, C. Y., & Yang, T. T. (2010). Implication and design of science magic. *Science Education of National Pingtung University of Science and Technology*, *31*, 16–27.

Johnson, D. M., Wardlow, G. W., & Franklin, T. D. (1997). Hands-on activities versus worksheets in reinforcing physical science principles: Effects on student achievement and attitude. *Journal of Agricultural Education*, *38*(3), 9-17.

Lin, C. C. (2009). *A Study of the Growth of Attitudes About Science Among Eighth Graders.* Unpublished Master's thesis, National Chiayi University, Chiayi City, Taiwan.

Lin, H. S., Lawrenz, F., Lin, S. F., & Hong, Z. R. (2013). Relationships among affective factors and preferred engagement in science-related activities. *Public Understanding of Science*, *22*(8), 941-954.

Lin, J. L., Cheng, M. F., Chang, J. Y., Chang, Y. C., Li, H. W., Lin, D. M., Huang, H. L., & Lai, P. C. (under review). The effects of combining inquiry-based instruction with science magic on the learning outcomes of a friction unit.

Lin, J. L., Cheng, M. F., Chang, J. Y., Huang, H. L., Chang, Y. C., Li, H. W., & Lin, D. M. (2014). Science magic for inquiry-based instruction. *The Physics Teacher, 52*, 268-269.

Lin, J. L., Lai, P. C., Li, H. W., & Chang, Y. C. (2012). *Research on the Effect of Combining Inquiry Learning Cycles with Science Magic on Learning Outcomes in Friction for Eighth Graders.* Paper presented at the 1st International Conference on Current Issues in Education (ICCIE), Yogyakarata, Indonesia.

Liu, T. C., Peng, H., Wu, W. H.,& Lin, M. S. (2009). The Effects of Mobile Natural-Science Learning Based on the 5E Learning Cycle: A Case Study. *Educational Technology & Society, 12*(4), 344–358.

McBride, J., Bhatti, M., Hannan, M. A., & Feinberg M. (2004). Using an inquiry approach to teach science to secondary school science teachers. *Physics Education, 39*(5), 1-6.

Michaels, S., Shouse, A. W., & Schweingruber, H. A. (2008). *Ready, Set, SCIENCE!: Putting research to work in K-8 science classrooms.* Washington, D.C.: National Academies Press.Ministry of Education of Taiwan (MET) (2003). Grade 1-9 Curriculum Guidelines- Science and Technology. Taipei, Taiwan.

Orgill, M. K., & Thomas, M. (2007). Analogies and the 5E Model. *Science Teacher, 74*(1), 40-45.

Osborne, J. F., & Dillon, J. (2008). *Science Education in Europe: Critical reflections.* A Report to the Nuffield Foundation: London, England.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049-1079.

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research. *Studies in Science Education, 50*(1), 85-129.

Ramsden, J. M. (1998). Mission impossible?: Can anything be done about attitudes to science? *International Journal of Science Education*, *20*(2), 125-137.

Serin, O., Mohammadzadeh, B. (2008). The relationship between primary school students' attitudes towards science and their science achievement (sampling: Izmir). *Journal of Educational Sciences*, *2*(6), 68-75.

Simpson, R. D., & Oliver, J. S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education, 74*(1), 1-18.

Swafford, C, Orr, M., Hall, D. (2014) Building Confidence Through Hands-on Activities. Proceedings of the 2014 ASEE Gulf-Southwest Conference.

Swarat, S., Ortony, A., & Revelle, W. (2012). Activity matters: understanding student interest in school science. *Journal of Research in Science Teaching*, *49*(4), 515-537.

Van Heuvelen, A. (1991). Learning to think like a physicist: A review of research-based instructional strategies. *American Journal of Physics, 59*(10), 891-897.

Yakar, Z., & Baykara, H. (2014). Inquiry-Based Laboratory Practices in a Science Teacher Training Program. *Eurasia Journal of Mathematics, Science & Technology Education, 10*(2), 173-183

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