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Using and Building Scientific Models to Enhance Elementary-School Teachers' Understanding of Astronomy Phenomena

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ABSTRACT

This study aimed to enhance elementary-school science teachers' understanding of astronomy concepts including season, moon phase and eclipse by using and building scientific models. Twenty-nine elementary-school science teachers from Udon Thani, Thailand participated in this study in 2014. The teaching sequence was designed to address difficult astronomy concepts. Firstly, questions of the astronomy phenomena were asked. After common misconceptions were answered, teachers become dissatisfied with the old conceptions. Then, scientific models were presented and explained. Finally, science teachers built scientific models to explain the astronomy phenomena. The research design of this study was one group pre-test-post-test design. Twenty-five questions from an astronomy test were used to access teachers' understanding of the concepts. The data were analysed using the mean score, percentage, standard deviation and t-test for dependent samples. It was shown that the average percentage of correct answers before and after the teacher training programme were 32% and 58%, respectively. The post-test mean score was significantly higher than the pre-test score. These findings lead to the suggestion that teaching astronomy concepts by building scientific models and using them can be a meaningful learning activity in the science classroom.

Keywords: Elementary-school science teachers, scientific model, astronomy phenomena concepts

INTRODUCTION

Science is generally viewed not only as a body of knowledge, but also as a way of knowing as well as the process of discovering and explaining nature. The study of science branches into two distinct categories: the life sciences and the

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physical sciences. The life sciences include such areas as biology, botany and zoology. The physical sciences include such areas as physics, chemistry and astronomy (Hewitt, 2001). Science education is very important for the development of any nation because it is a part of human daily life. Therefore, science has been a compulsory subject in most countries for a long time (Bennett, Lubben, & Thompson, 2013). Understanding science helps people know how things around them work; everyone needs to have scientific literacy to make decisions and to debate scientific issues (Tasakorn & Pongtabodee, 2005). People who have a strong understanding and ability to understand science tend to hold productive. Learning in science and technology is important for all people in this economically competitive world. However, Osborne and his colleagues (Osborne, Simon, & Collins, 2003) have argued that the continuing decline in the number of students choosing to study science over the past 20 years requires research focusing on students' attitudes towards science. They have raised concerns about the kind of classroom environment and activities that might increase students' interest in studying science in school.

Thailand has undergone many educational reforms and changes. In its national curriculum, general science first appeared in the school curriculum in Buddhist Era 2503 (Thepboriruck, 1976). Policies concerning science and technology development are reflected in the Six National Economic and Social Development Plans (B. E. 2530-2534). Science and technology topics were included in the work-orientated experience, which was one of the five learning experiences taught in the elementary curriculum in B. E. 2521 (Udomsin, Chuaphanich, & Cate, 1990). Due to the rapid changes brought by information and communication technology in the age of globalisation that has made knowledge easily accessible, knowledge is playing an increasingly more powerful role today in developing human resources to obtain the necessary skills and information not only to adapt to changing circumstances but also to spearhead national development (Office of the Education Council [OEC], 2004). The 1997 Constitution and 1999 National Education Act [NEA] of Thailand have provided the framework of guidelines for educational reform in Thailand. The National Education Act of 1999, Section 9, emphasises science and technology, and is based on the principle that all learners are capable of learning and self-development. With respect to the NEA of 1999, science is a compulsory topic in the Thai school curriculum from Grades 1 to 12 and all Thai people have to enrol in compulsory education for nine years, covering six years of primary education and three years of lower secondary education (Yuenyong & Narjaikaew, 2009).

The National Education Act of 1999 emphasises science and technology education and the Institute for the Promotion of Teaching Science and Technology (IPST) plays a major role in establishing standards of teaching/learning science including teaching/learning approaches, materials and promoting in-service teacher training on teaching/learning science. The Basic Education Curriculum of B. E. 2544 (A. D. 2001) promulgated which content areas of the science strand, out of the eight compulsory strands for basic education, were to be emphasised. The science strand has eight content areas: living things and living processes; life and the environment; matters and properties of matters; forces and motion; energy; processes that shape the earth; astronomy and space; and natures of science and technology (Klongsara & Charlee, 2013). The common practice in elementary schools is to allow science, together with several other subjects, to be taught by a generalist teacher. Elementary-school teachers tend to have limited science subject matter knowledge and low confidence in science teaching, so they tend to focus on topics they are more proficient in and therefore more confident to teach such as biology while skimming through or even avoiding topics they are less familiar with and therefore less confident to teach such as physics, earth science and astronomy (Appleton, 2007). With limited science knowledge and less confidence in teaching science, teachers tend to use teaching strategies that are often not appropriate ways of engaging students to learn science.

An astronomy and space national science curriculum standard was added as a new content area for the elementary-school level in Thailand; it was derived from practices developed in the Basic Education Core Curriculum of B. E. 2544 to present time. Therefore, it is a fairly new area for both elementary-school teachers and students. In Thailand, astronomy and space was found among the seven science sub-strands in the Basic Education Core Curriculum of B. E. 2544 (A. D. 2001) and B. E. 2551 (A. D. 2008). Standard Sc. 7.1 provides that elementary-school students should be able to indicate that the sun, the moon and the stars exist in the sky (Grade 1); to search for and discuss the importance of the sun (Grade 2); to observe and explain the rising and setting of the sun, knowledge related to the moon and the change between daytime and night-time and to determine directions (Grade 3); to construct a model to explain characteristics of the solar system (Grade 4); to observe and explain determination of directions, as well as times and seasons related to the visibility of the stars by using star charts (Grade 5); and in Grade 6, to construct a model and explain the cause of the seasons, phases of the moon, a solar eclipse and a lunar eclipse and to apply this knowledge (Office of Basic Education Commission [OBEC], 2011).

Although astronomy is one of the oldest sciences in human history, astronomy education is not the oldest course for elementary-school teachers in many countries to teach. Research has found that students have several misconceptions about astronomy. Aristotle, a Greek philosopher and scientist, is probably recognized as the originator of the scientific study of the stars. However, a variety of concepts about astronomy held by Aristotle as well as several related to physics, particularly the concepts of energy, force and motions, are misconceptions. Many students hold Aristotle's concepts, which diverge considerably from those of modern-day scientists and these misconceptions are resistant to change (Sadler, 1998). Because these ideas are grounded in long-held beliefs and personal experience, the change in perception requires students to connect the new knowledge with their existing knowledge structure. Much research has been done into identifying the misconceptions that students bring to the science classroom (Duit & Treagust, 2003). In addition, many school teachers are also hold misconceptions about astronomy. The greatest misconceptions are related to the day-night cycle, moon phases, seasons, position of the sun in the daytime and solar eclipses. In other words, elementary-school teachers may be naïve learners of astronomy (Bektasli, 2013). Therefore, some misconceptions held by students may be transmitted by teachers.

The traditional teaching method that has dominated the teaching of science in both schools and universities is lecturing. The teacher usually describes concepts by talking and writing, while the students listen or take notes (Chang, Jones, & Kunnemeyer, 2002). Research in physics education has shown that many students learn very few concepts of physics when they attend traditional lectures. Traditional lectures as a teaching method do not successfully improve students' understanding of the central concepts of physics (Shaffer & McDermott, 1992; Engelhardt & Beichner, 2004). Some of the strategies that are recommended to enhance the quality of teaching include the use of models to promote student learning. A model is a representation of an object, a phenomenon or an idea (Gilbert, Boulter & Elmer, 2000).

In science education, there are two different types of model consisting of mental models and conceptual models. Mental models are related to what people have in their heads, while conceptual models are devised as tools for teaching understanding of systems, which can be mathematical formulations, analogies, physical diagrams, computer programmes or material objects. Ornek (2008) has categorised conceptual models as mathematical models, computer models, physical models and physics models. Scientific models are broadly used in science to represent a phenomenon that is difficult to observe directly. Students' experiences with scientific models help them to develop their own mental models of scientific concepts (Treagust, Chittleborough, & Mamiala, 2002). Using modelling in science instruction can help learners develop deeper understanding of the subject matter (Shwartz, Rogat, Merritt, & Krajcik, 2007; Shwartz *et al.*, 2009; Krell, Belzen, & Krüger, 2012).

Astronomy education is also recently new for elementary-school science teachers in Thailand. This study aimed to promote elementary-school science teachers' understanding and teaching of astronomy by using and building scientific models through teaching procedures. It gives elementary-school science teachers an idea of how to teach astronomy with specific teaching sequences and tools. In this study, the researcher examined the astronomy difficulties and needs of elementary-school teachers who participated in the 2013 teacher-training programme and discovered that the instructional design approach would fit the 2014 teacher-training programme utilising six hours for direct instruction. The training programme was designed to use one or two days during the weekend because teachers do not have the time to do learning activities in the classroom on regular school days. Using and building scientific models were examined to see if they enhanced the elementary-school science teachers' level of understanding and confidence in teaching astronomy.

OBJECTIVE

The research objective was to study and compare elementary-school science teachers' understanding of concepts pertaining to the seasons, moon phases and the eclipse phenomenon before and after using and building scientific models through the implementation of a six-hour teacher-training programme.

METHODOLOGY

The pre-experimental research with one group pre-test-post-test design was used in this research. Details of the participants, research instruments and data collection are listed below.

Participants

The participants involved in this study were 29 voluntary elementary-school science teachers from Udon Thani, Thailand in 2014.

The Research Instruments

Instructional approach

The sequence of the instruction was held over six hours, which began with the following procedures:

Introduction of common models in astronomy. There are many models in textbooks and internet sources that can be used to explain astronomy phenomena. Firstly, models of astronomy phenomena with questions regarding the function of the models were introduced (see Fig.1).

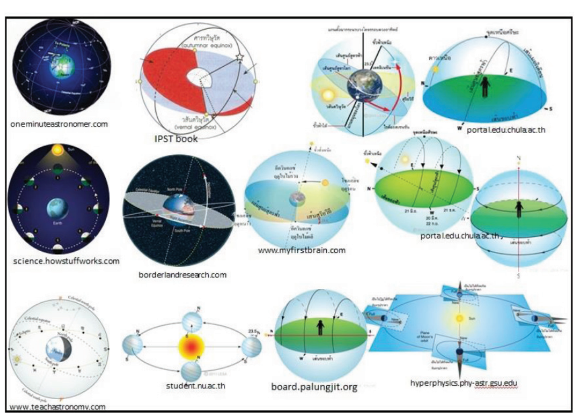

Fig.1: Models in textbooks and internet sources used to explain astronomy phenomena.

Introduction to the seasons and the path of the sun across the sky throughout the year. Previous research findings on misconceptions regarding astronomy highlighted that some teachers believed that the earth is farther away from the sun in winter and closer in summer and that the sun rises exactly in the east and sets exactly in the west every day through a year. These misconceptions were addressed for designing teaching activities. The correct concept regarding this point is that the earth's axis is tilted by 23.5 degrees, so that the northern and the southern hemispheres of the earth get different angles from the sun's direct rays, causing the northern and the southern hemispheres to *get* more and less direct rays, respectively, in the same month. In other words, the northern hemisphere receives more direct rays of the sun than the southern hemisphere in June and the southern hemisphere receives more direct rays of the sun than the northern hemisphere in December. For the teacher-training activity, the pictures showing the seasons and the appearance of the sun in different positions in the sky throughout the year were presented. Questions of what caused the seasons were asked. The sun-earth geometry models and the globe and flash light were used to explain what caused the seasons and the differences in the location of the sun's path across the sky throughout the year. To evaluate teachers' understanding of these concepts, teachers were asked to apply these fundamental principles to create their own models for teaching their students. The models used to explain what caused the seasons are shown in Fig.2(a) and the models created by the teachers are shown in Fig.2(b).

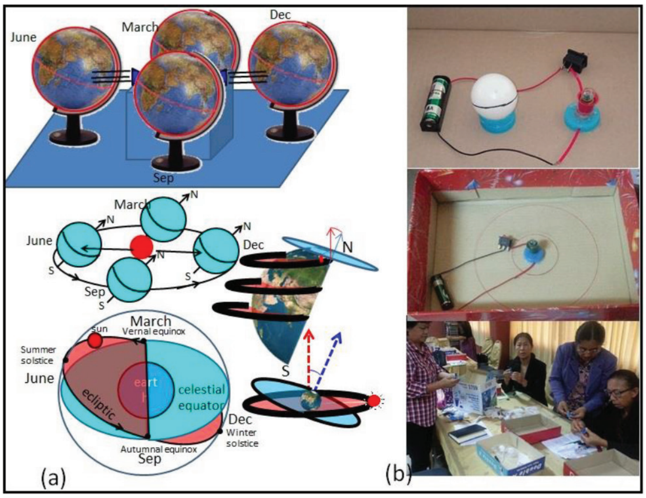

Fig.2: (a) Models used to teach teachers (b) Models created by teachers.

Introduction to the phases of the moon. The common misconception about the phases of the moon is due to incorrect information about the shadow cast on the surface of the moon by the earth. The correct concept is that the different amounts of the illuminated portion of the sun's light scattered off the surface of the moon during the moon's revolution around the earth causes different segments of the moon to be visible at different times of the month. For the teacher-training activity, pictures of the phases of the moon were shared as follows: new moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, last quarter and waning crescent. These were presented with questions of what caused the phases of the moon. The teachers were experienced in how the moon phases were produced. One teacher held a Ping-Pong ball slightly higher than his/her head, while walking in a circle around the observer. The holder was between the light source and the observer. Afterwards, they saw the various illuminated shapes of the moon as it waxed and waned, and then they drew a model to represent the shapes of the moon. The sun-earth-moon geometry models were introduced and discussed. Questions dealing with the time of the moonrise and moonset each day throughout the month were asked. The researcher asked the teachers to create a model to represent the approximate time of the moonrise and moonset each day throughout a month with 30 days. They were told to start with the new moon, when the moon and the sun both rose and set at about the same time. In addition, the moonrise, with an average of about 50 minutes later each day, was introduced. The teachers designed a model on paper, and were then asked to use materials to make the model as a toy that would interest their students. Example models of the moon phases and moonrise and moonset throughout a month with 30 days were created by the teachers (see Fig.3). The units in Thai including 'mong chao', 'bai mong', 'toom' and 'tee' were introduced, which gave the teachers time to think of how they were related to the phases of the moon. They began to see the time of the moonrise as follows: the moon between the new moon and the first quarter (waxing crescent) would rise from about 1 to 6 'mong chao' (about 7 am to 12 noon); the moon between the first quarter and the full moon (waxing gibbous) would rise from about 1 to 6 'bai mong' (about 1 pm to 6 pm); the moon between the full moon and the last quarter (waning gibbous) would rise from about 1 to 6 'toom' (about 7 pm to 12 midnight); and the moon between the last quarter and the new moon (waning crescent) would rise about 1 to 6 'tee' (about 1 to 6 am).

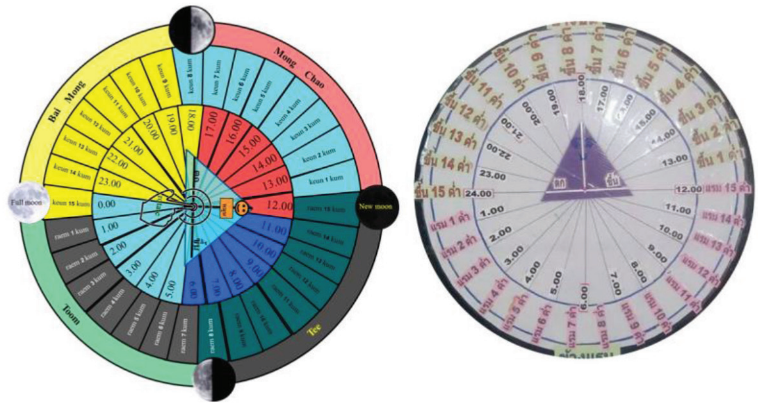

Fig.3: An example model of the moon phases, moonrise and moonset throughout a month with 30 days.

Introduction to the phenomenon of the eclipse. The sun-earth-moon geometry model was continuously used to explain how the lunar and solar eclipse was caused. With this model, teachers might think that the moon would move into the earth's shadow 12 times a year and that the sun would move into the moon's shadow 12 times a year. However, an eclipse occurs an average of about one or two times every one or two years. The teachers were asked to find how the sun, the earth and the moon are related in causing times and seasons. Then, the sun-earth-moon geometry models (see Fig.4) were presented to explain how an eclipse occurs.

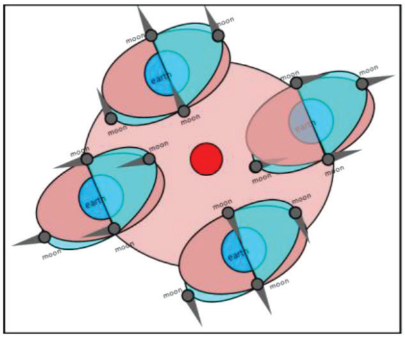

Fig.4: A model representing the ecliptic plane.

Instructional materials

Based on the findings of the 2013 teacher-training programme, it was thought best for this study to use the astronomy concepts of the seasons, the position of the sun during the daytime throughout a year and the phases of the moon (including moonrise and moonset times). Material sets used consisted of a flash light and an earth model for demonstration; 2.5 volt (V) electric bulbs, wires, 1.5 V dry cells, pieces of white cardboard paper, degree semi-circle meters, pencils, Ping-Pong balls, scissors and compasses to build the models.

The conceptual test

Twenty-five multiple-choice questions with five possible answers were used to address the teachers' understanding of astronomy concepts including the seasons and the path of the sun across the sky throughout a year, the moon phases and moonrise-moonset times and the phenomenon of the eclipse.

Data Collection

For collecting data**,** 25 multiple-choice questions with five possible answers were used to address the teachers' understanding of astronomy concepts. The data were analysed using mean, standard deviation, percentage and a dependent t-test.

RESULTS

This section focusses on the evaluation of elementary-school teachers' understanding of astronomy before and after using and building scientific models throughout the instructional time. The 25-item multiple-choice questionnaire was administered to 29 elementary-school science teachers.

Analysis of Astronomy Conception

Fig.5 displays the average percentage of correct answers among the elementary-school science teachers on the pre-test and post-test. The elementary-school science teachers' performance on the concepts regarding the seasons, the moon phases and eclipses is described.

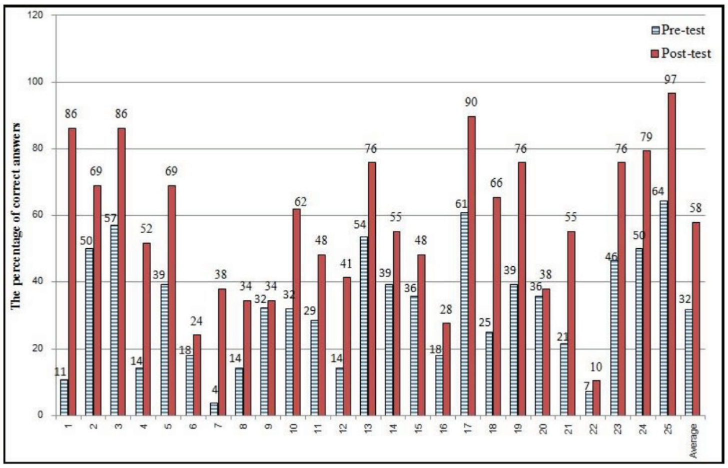

Fig.5: Percentage of teachers answering correctly before and after the instruction.

The seasons and the path of the sun across the sky throughout the year.

Questions 3, 4, 5, 6 and 7 dealt with the concept of the seasons. Questions 3, 4 and 7 were about the seasons in the northern and the southern hemisphere while Questions 5 and 6 were about what caused the seasons. Fig.5 shows that the average performance of the teachers showed an increase in the percentage of correct responses between the pre-test and the post-test for all four questions. Before the instruction, the common misconception held by the elementary-school science teachers, as supported by previous research findings, was that the earth's seasons are caused by the distance of the earth from the sun. In addition, the teachers could not understand the model depicting the seasons throughout the year. However, after the instruction they could create their own models that could be used to teach their students.

Questions 1, 2, 8, 9, 10 and 11 were on concepts regarding the path of the sun in the sky throughout the year. It was noticed that the elementary-school teachers had quite a low score on the pre-test. After the instruction using the models they had made, their performance on the post-test was quite good. However, the percentage of correct answers to Question 8, which was on the relationship between the location of the sun's path across the sky and the seasons, was not as *high* as for the others.

The moon phases.

Questions 13, 14, 22 and 23 were on how the moon phases occurred and the shape of the illuminated portion of the moon. In questions 13, 14 and 23, the teachers performed quite well both before and after the training. They seemed to know that the shape of the illuminated portion of the moon appears the same over the night. However, their performance on the pre- and post-test for Question 22, which was about the causes of the phases of the moon, was low. Many teachers still believed that the phases of the moon are caused by the earth's shadow.

Questions 12, 15, 26 and 17 were about the position of the moon in the sky throughout the month. In Thai context, the Thai lunar calendar (the Buddhist calendar) is used for calculating lunar-regulated holy days. Therefore, these questions were about the position of the moon in the sky according to the Thai lunar calendar. In a month, there are 15 days of the waxing moon, known in Thai as 'keun 1 (neung) kum - keun 15 (sib ha) kum', and 15 or 14 days of the waning moon, known in Thai as 'raem 1 kum - raem 15 or 14 kum'. The teachers' answers showed that they already knew that on the day of the new moon, the moon rises at sunrise and sets at sunset (Question 17), but that the moon is not seen on the day of the new moon. However, their performance on the other questions was not as good as for Question 7. After the teaching session, however, the average number of correct responses increased.

Questions 18, 19, 20 and 21 were about the time of the moonrise and moonset each day throughout the month. The average percentage of the correct responses to Questions 18, 19 and 21 was over 50%

after the teaching session. However, the number of correct responses to Question 20 was not high. All questions in this area were about the time of the moonrise except for Question 20, which was about the time of the moonset. The attracted answer from the teachers' responses was the time of the moonrise.

The eclipses.

Questions 24 and 25 were about how an eclipse occurred. The teachers performed quite well both before and after the teaching session. These two questions were straightforward questions taken directly from textbooks.

Comparison of Teachers' Performances on the Pre-Test and Post-Test

To analyse the teachers' understanding of the concepts of astronomy before and after using and building scientific models in the teacher-training programme, a comparison of their performance on the test before and after the teaching session was made. The average of the teachers' scores before and after their participation in the teaching session was determined. To check whether the research teaching approach promoted better conceptual understanding of astronomy topics, the pre- and post-test scores were compared (see Table 1).

TABLE 1
Mean Scores (M), Standard Deviations (SD), Percentage and p-values of the Pre- and Post-Test Results of the Test (25 items) Taken by the Elementary-School Science Teachers

	$\overline{X}$	S.D.	%	t	*p* (Sig.)
Pre-test	7.95	3.59	31.80	6.88	0.000
Post-test	14.45	4.72	57.80		

According to the teachers' responses on the test, it was notable that their performance was significantly better after the teaching session ($p < 0.01$). The post-test means score was greater than the pre-test score at a significance level of α=0.01. It can be concluded that the elementary-school science teachers who participated in the training programme had a better understanding of astronomy concepts after participating in the instruction regarding the using and building of the scientific models.

CONCLUSION AND DISCUSSION

This research aimed to study and compare elementary-school science teachers' understanding of concepts of astronomy, the teaching of which is a new experience for elementary-school science teachers in Thailand, before and after using and building scientific models through a six-hour teacher-training programme. The results of the elementary-school science teachers' understanding of the seasons, phases of the moon and the phenomenon of the eclipse showed that the misconceptions they held corresponded with those highlighted in other research findings (Sadler, 1998; Bektasli, 2013), supporting the idea that these are common misconceptions related to astronomy. Before the training programme, the most common misconception regarding the seasons, moon phases and eclipses held by the elementary-school teachers were: the earth's seasons are caused by the distance of the earth from the sun; the phases of the moon are caused by the earth's shadow; and *the plane of the earth's orbit* around the *sun* lies in the same plane as the *moon's orbit* around the *earth.* Research has found that using traditional teaching methods might not be sufficient to correct those misconceptions (Sadler, 1998) because these ideas are grounded in long-held beliefs and personal experience. In addition, if the teachers hold misconceptions, some of these misconceptions may be transmitted to students by the teachers. Research in science education has highlighted the notion that science elementary-school teachers with limited science knowledge tended to use teaching strategies that are not an appropriate way of engaging students to learn science (Appleton, 2007). Therefore, it is important to develop teaching approaches and teaching strategies that are appropriate in explaining concepts within the context of schools and students. The teacher performance in this research indicates that the teachers had better conceptual understanding of the seasons and the path of the sun across the sky throughout the year, the phases of the moon and eclipses after participating in the instructional curriculum that was designed for them. Furthermore, the teachers had better knowledge of moonrise-moonset times after the teaching session. It might be that the model used to represent this concept in this study was related to Thai time units including 'mong chao', 'bai mong', 'toom' and 'tee', with which the teachers were familiar and therefore they could better appropriate the learning points. Although this concept is excluded in the seven science sub-strands in the Basic Education Core Curriculum of B. E. 2544 (A. D. 2001) and B. E. 2551 (A. D. 2008) for the elementary-school level, it is related to a part of Thai daily life and therefore, might increase students' interest in studying school science because they would appreciate the relevance of the knowledge to their personal lives. In this study, the teachers were able to experience using and building scientific models in direct application, thereby participating in a process of learning that should help them to develop their own mental model of scientific concepts (Treagust, Chittleborough, & Mamiala, 2002). In addition, they had the opportunity to create astronomy models to evaluate their understanding of those astronomy concepts; indeed, the literature recommends that using models in science instruction can help learners develop deeper understanding of subject matter (Shwartz, Rogat, Merritt, & Krajcik, 2007; Shwartz, Rogat, Merritt, & Krajcik, 2009; Krell, Belzen, & Krüger, 2012). Therefore, using and building scientific models can be used to promote elementary-school science teachers' understanding of astronomy.

IMPLICATIONS

This study, using and building scientific models in a teacher-training programme for six hours suffered from time limitation. Most of the participants seemed to have difficulty familiarising themselves with the models, especially the use and function of models within the limited timeline of the study. The researcher recommends that some general guiding principles about the models should be provided, especially where the teacher has to build models from scratch. In addition, many of the astronomy terms in Thai are not common words. Therefore, those terms should be referred to in both Thai and English. To use this teaching procedure in an elementary classroom, teachers will need more time to conduct learning activities about astronomy for each content area (seasons, phases of the moon, eclipse).

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