Research Article doi: 10.12973/ijem.6.4.745

International Journal of Educational Methodology
Volume 6, Issue 4, 745 - 758.
ISSN: 2469-9632
https://www.ijem.com/

Investigating In-service Science Teachers Conceptions of Astronomy, and Determine the Obstacles in Teaching Astronomy in Thailand

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Received: June 29, 2020 ▪ Revised: September 9, 2020 ▪ Accepted: November 4, 2020

Abstract: Astronomy concept is regarded as one difficult topic in both teachers' and students' perspective even though it strongly appeals to the human mind. This concept requires imagination and the ability to use various skills and knowledge, for example, actual motion, relative position, and coordination of views from several points on the Earth to generate an explanation. As mentioned in the literature, the teacher plays a vital role in the teaching and learning process. Therefore, this study aimed to investigate 45 in-service science teachers' understanding of astronomy concepts in a professional development program and to diagnose the misconceptions regarding astronomy concepts. A two-tier test, open-ended questions, and a semi-structured interview were used to gather information on the understanding and misconceptions, particularly on celestial motion concepts. The data were analyzed both qualitatively and quantitatively. The results pointed out that after the four-day professional development program, in-service science teachers gained significantly higher two-tier test scores. The highest progression was in the topic of the Sun's apparent motion. However, most in-service science teachers still held some misconceptions relating to the concept of the seasons. The obstacles in teaching astronomy were also discussed. The study's findings lead to the improvement of the professional development program for in-service science teachers required to teach astronomy concepts nationwide.

Keywords: *Astronomy, celestial motion, misconception, in-service science teacher, professional development program.*

To cite this article: Jansri, S., & Ketpichainarong, W. (2020). Investigating in-service science teachers conceptions of astronomy, and determine the obstacles in teaching astronomy in Thailand. *International Journal of Educational Methodology*, *6*(4), 745-758. https://doi.org/10.12973/ijem.6.4.745

Introduction

Astronomy is the oldest of the natural sciences which appeals to the human mind and imagination. Studying astronomy requires understanding the actual motions and relative positions of celestial objects to describe phenomena and make predictions of phenomena, such as seasons and the celestial sphere. These are relatively complex and require the coordination of views from several points on the Earth and outside the Earth (Plummer et al., 2011). Astronomy was introduced in the school curriculum in many countries (Trumper, 2006), including Thailand. Astronomy was first added to the Thai science curriculum in 2001 and in 2008, the Basic Education Core Curriculum of Thailand was revised significantly. The new topics, such as the celestial sphere, the astronomy coordinate system, and the Sun's apparent motion, were introduced into all levels of science classrooms. For example, at the elementary level, the basic concept of celestial motion concerned the apparent motion of the Sun, the stars and the Moon, the process of day and night, solar systems, and moon phases. In addition, there were no astronomy classes available at the lower secondary level. Only one chapter on the topic of earth and space was mentioned in science textbooks. High school students learned celestial motion concepts again such as the celestial sphere, astronomy coordinate system, and the Sun's apparent motion (Ministry of education Thailand, 2008). However, there were quite different implementations of this curriculum in each school. Some schools emphasized these topics as a core subject, while other schools considered elective subjects for science students interested in astronomy. While astronomy topics have appeared in all levels, only a few science teachers have taken astronomy courses in high school or university. This information implies that most astronomy teachers lacked content knowledge of astronomy as well as teaching experience in astronomy (Brunsell & Marcks, 2005). Moreover, those teachers seem not to use a suitable strategy to motivate students or encourage them to learn astronomical ideas (Buaraphan, 2012). In summary, the obstacle for teaching astronomy might be because of the complexity of the content and the teacher's pedagogical content knowledge.

As mentioned, it is evident that science teachers require a professional development program concerning both enhancing their content knowledge and teaching strategies. The researchers conducted a teachers' professional development program to allow teachers to gain appropriate knowledge and strategies to apply in their classrooms

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(Grossman & Richert, 1998). To ensure the effectiveness of the professional program, the researchers investigated both their understanding and misconceptions regarding astronomy concepts.

Literature Review

The Barriers in Teaching Astronomy

Several research studies revealed that a number of teachers who taught outside their areas of specialization did not feel confident in teaching. Those teachers expressed they are unable to construct explanations of the lessons and cannot respond to students' questions, particularly in topics for which they do not have background knowledge. Teachers encountered problems when they returned from training to the actual classroom, which contrasted with the training's demonstrated classroom. In the real classroom setting, there were also differences among each classroom in terms of student numbers, students' ability, and class period. Lastly, because the teachers are unable to organize the learning activities, it is difficult to improve the quality of science teachers in order to increase the students' achievements (Moore, 2007; Sandholtz & Ringstaff, 2016). This information confirmed that the teacher is the crucial factor affecting the student's learning. So, the lack of conceptual understanding of astronomy is the key barrier resulting in teacher's confidence in teaching and leading to the students' academic results.

Needs for enhanced professional development in astronomy

Professional development is seen as an essential way to improve teaching practices (Segall, 2004). The challenges in teaching astronomy are: 1) to seek the best practice to motivate students to learn the astronomy lessons; 2) to engage them in the astronomy classroom; and 3) to inspire students to study astronomy concepts. Teachers who want to develop their teaching astronomy skills need opportunities to participate in a meaningful and effective professional development program. The program should be well designed to develop both conceptual and pedagogical understandings as well as to help the teachers improve their teaching practice. Moreover, an effective professional development program must engage all teachers in developing concrete teaching tasks and teachers' experiences with students. The program also must encourage the teachers to change their behaviors and bring the knowledge and skills to implement in the classroom (Supovitz & Turner, 2000). The prior research studies indicate that the positive effects of the well-design professional development program enhanced science teacher knowledge and encouraged them to practice and learn from other teachers.

Learning Cycle and the Role of Teacher

The learning cycle model is an inquiry-based learning approach developed based on the constructivist theory of learning and the developmental theory of Jean Piaget Learning cycle was firstly described by Karplus and Thier (1967) based on three phases consisting of exploration, concept introduction, and concept application. In the exploration phase, teachers should allow students to explore the concept or investigate science phenomena through direct experiences. In this phase, teachers should raise questions, prepare the necessary materials for use during an activity, and guide each student to collect quality data (Marek et al., 1990). The concept introduction phase is designed to guide students in the interpretation of their collective data. Teachers should help students construct the meaning of the concept from their own experiences and make observations through questioning and discussion. The concept application is the phase that provides opportunities to students via the application of the concept to new situations. In this phase, teachers facilitate the use of the concept in different contexts and encourage students to apply the concept to everyday experiences. Renner et al. (1988) pointed out that the learning cycle model is a good teaching approach that guides teachers in designing curriculum and developing instructional strategies and materials in teaching science concepts. Many publications indicated that the learning cycle is an effective teaching approach that enhances student outcomes, raises reasoning ability, and promotes a positive scientific attitude (Gerber et al., 2001; Hanuscin & Lee, 2008; Qarareh, 2012). Therefore, the learning cycle model was selected to use as a learning approach that allows teachers develop their understanding of scientific concepts, explore and discuss their understandings, and apply the concept to explain the astronomy phenomena or new situations.

Misconception in Astronomy

A misconception has been used to describe a concept inconsistent with scientifically acceptable ideas (Atwood & Atwood, 1996; Hills, 1989). Misconceptions may occur from instruction, interaction with environment, and daily life experiences (Vosniadou & Brewer, 1994). From the literature, pre-service and in-service teachers hold various science misconceptions (Kanli, 2014; Narjaikaew, 2013; Ozkan & Akcay, 2016; Trumper, 2006). Many research studies the astronomy misconceptions in elementary through high school students (Korur, 2015; Plummer et al., 2011; Vosniadou & Brewer, 1990) In comparison, several studies have focused on pre-service and in-service teachers (Atwood & Atwood, 1996; Brunsell & Marcks, 2005; Frede, 2008; Kikas, 2004; Plummer et al., 2010). Some research studies showed that pre-service teachers and science teachers did not hold scientific conceptions in introductory astronomy. For example, Plummer and Maynard (2014) found that children and adults cannot explain the Sun's path change between summer and winter, and the change in the Sun's altitude. Kanli (2014) identified the misconceptions of 117 pre-service teachers about astronomy. The results showed that most teachers believed that the Sun passes overhead at noon every day and the Earth's elliptical orbit is the cause of seasons. Starakis and Halkia (2014) stated that both students and pre-service teachers explained the cause of seasons lies in the distance from the Sun to the Earth. Several studies have shown that both students and science teachers hold scientific misconceptions in giving reasons for the cause of seasons and cannot give scientific explanations of the Sun's apparent motion. These are also the same research results in Thailand; both science teachers and students encounter difficulty in learning and alternative concepts of astronomy. Dahsah et al. (2012) found that most Thai high school students cannot explain the relationship between Earth-Moon-Sun models. Anantasook et al. (2015) also stated that grade nine Thai students could not relate their knowledge from the classroom to explain the relation of the Sun, the Moon, and the stars. Narjaikaew et al. (2016) reported that Thai science teachers held many misconceptions about astronomy phenomena such as the seasons on the different areas of the Earth.

From the above, it seems that the limited understanding of the concepts have a negative effect on future teaching. Teachers may feel uncomfortable in teaching a particular topic (Bektasli, 2014). Even though most of the science teachers had experiences of teaching astronomy in high school, they still held alternative conceptions regarding astronomy that may lead to students' misconceptions (Cox et al., 2016; Ladachart et al., 2010). Lack of teachers' knowledge and understanding of contents caused the disappearance of confidence in teaching and led to an inability to develop students' interest in the subject. Howitt (2007) stated that teachers' knowledge affects teacher confidence and student outcome. This also leads to students' disappointments in class and also affected students' interest in learning science. Several methods commonly used in education to identify misconceptions such as multi-tier tests (Kanli, 2014; Korur, 2015; Trumper, 2001), open-ended questions (Bulunuz & Jarrett, 2009), and drawing also have been considered as simple methods to assess misconception and understanding (Eshach & Schwartz, 2006; Sözen & Bolat, 2011). It has been observed that there are a lot of misconceptions concerning the Sun's apparent motion and seasons on science teachers. Only a few studies related to misconceptions of Thai science teachers' understanding of the celestial sphere and the Sun's apparent motion. This study was conducted to explore conceptual understanding and misconception of in-service science teachers on astronomy using two-tier tests, opened-ended questions, and semi-structured interview questions.

Methodology

Qualitative and quantitative approaches were used to achieve the research goals (Cohen, 2007). A 20 questions-two-tier conceptual test was used as a quantitative data source to gather the in-service science teachers' conceptual understanding and identify the misconceptions. In terms of qualitative data, four open-ended questions and four main questions of a semi-structured interview were conducted to gather in-depth information of the in-service science teachers' misconceptions. Moreover, a semi-structured interview was also used to explore the teacher's perspective on the obstacles of teaching astronomy in Thailand. These three data collection tools were used to achieve the three research goals stated below. Then, the detail of data collection and analysis was described.

Research Goals

1. To examine the misconceptions of in-service science teachers on astronomy concepts before participating in a professional development program.
2. To identify the conceptual understandings of in-service science teachers on astronomy concepts before and after participating in the professional development program
3. What are the obstacles of teaching astronomy in Thailand?

Sample and data collection

This study was conducted during a four-day professional development program. Regarding the program, 45 high school science teachers from different schools throughout Thailand participated in the professional development. All teachers taught astronomy at the secondary school level, but their educational background was not related to astronomy. Their demographic information is presented in Table 1.

Table 1. Demographics of the participants

Demographic		Number of participants (45)
Gender	Male	11
	Female	34
Age	Under 30	7
	30-40	10
	40-50	16
	50-60	12
Educational backgrounds	Bachelor's degree in science	
	- Physics	6
	- Biology	3
	- Chemistry	4
	- General science	9
	- Physical science	4
	Bachelor's degree in education	5
	Master's degree in education	14
Years of teaching experience	Less than 1 Year	4
	1-5 Years	7
	5-10 Years	8
	10-15 Years	3
	More than 15 Years	23
Years of teaching astronomy	Never	11
	Less than 1 Year	6
	1-5 Years	23
	5-10 Years	5

In order to achieve the three research goals, the two-tier conceptual test, open-ended questions, and interview were administered to teachers before and after participating in the professional development program. The open-ended questions were conducted to gather science teachers' misconceptions before participating in a professional development program. The two-tier conceptual test was administered to all teachers before and after participating in the professional development program to determine their conceptual understanding of astronomy concepts. Only ten in-service science teachers were randomly selected to participate in semi-structured interviews to gather more in-depth information to examine science teachers' conceptual understanding of astronomy. During the interviews, science teachers were allowed to use a clear plastic hemisphere to demonstrate their own understanding of celestial motion. The semi-structured interviews were used to gather the problems and obstacles of teaching astronomy in Thailand.

Learning cycle activities for the professional development program

In this study, the learning cycle was employed to frame the activities implemented in the four-day professional development program for in-service science teachers. In summary, these activities included three phases, which were:

1) Exploration: The science teachers constructed the astronomy model, which is a hands-on model to explain the astronomy concepts and using the astronomy model to observe the astronomy phenomena
2) Concept introduction: Assisting the science teachers in formulating the concept from their own exploration through questioning and discussion
3) Concept application: To describe and apply the astronomy concepts to real situations such as building a solar house model. The astronomy contents included the celestial sphere, the celestial coordinate systems, the Sun's apparent motion, and seasons. These activities allowed science teachers opportunities to experience the learning cycle approach and activities for science teachers to apply in their classrooms.

Data Analysis

In terms of data analysis, the responses of the two-tier conceptual test responses from the science teachers were considered when they completed both parts of each question of the test item. If the science teachers made a correct answer only in the first tier, then the first tier was coded (1-0). If the science teachers provided a correct explanation only in the second tier, then the second tier was coded (0-1). If the answers were right in both tiers, then it was coded (1-1). If the answers were incorrect in both tiers, then it was coded (0-0). One aim of using the two-tier test was to identify science teachers' misconceptions in astronomy. If the teachers understood the concept, they should select the correct answer in both tiers. If they marked the wrong answer in the first tier or gave a wrong explanation in the second tier, it would be interpreted that they might hold some misconceptions.

The questions were developed by researchers based on the basic Thailand science curriculum (2008). The two-tier conceptual test questions consisted of 20 questions that covered four topics: 1) the celestial sphere, 2) the celestial coordinate systems, 3) the Sun's apparent motion, and 4) seasons. The two-tier conceptual test questions were reviewed by three experts who specialized in teaching astronomy and by science educators. The test's reliability was ensured by trying out the test with 25 pre-service teachers to make necessary improvements before conducting this study. The Cronbach's Alpha was found to be 0.79. In terms of quantitative analysis, the data from the two-tier conceptual test were analyzed using SPSS software to make statistical comparisons between the pre-test and the post-test scores. Before analyzing the score, the Kolmogorov-Smirnov test had been used to test the normality. The result of Kolmogorov-Smirnov test showed that the pre-test and post-test scores of the first tier as well as the pre-test and post-test scores of the both-tier were not normal distribution (p-value < 0.05). The second tier's pre-test score showed no normal distribution (p=0.016) while the second tier's post-test score showed normal distribution (p=0.062). So, the Wilcoxon signed-rank test was used to compare scores within the group.

The open-ended questions were used to determine science teachers' misconceptions before participating in the professional development program as found in their written responses and drawing diagrams to reflect their thoughts. The open-ended questions were validated by three experts–two experts in astronomy and one expert in physics education. After collecting and analyzing data from open-ended questions, ten science teachers were randomly selected to interview to gather more in-depth information regarding teachers' understanding of celestial motion. The answers from the open-ended questions and interviews were analyzed by organizing them into categories according to their level of understanding. The rubric was based upon the categorization scheme adapted from Plummer et al. (2011) and Simpson and Marek (1988). The researchers categorized all codes into five categories as follows: No conceptions (NC); Confused (C); Incomplete understanding (IU); Partial understanding (PU); and Complete understanding (CU). To ensure the question's analysis's validity, the rubric to evaluate the answers was constructed based on the content knowledge. The rubric was also validated by two Astro-scientist experts having experience in teaching astronomy in the school and university for more than ten years. These categories are shown in Table 2

Table 2. The categories used in the analysis of open-ended questions

Theme	Level	Category	Responses
Celestial sphere	0	No conception	Teachers are unable to respond to the question.
	1	Confused	Teachers can tell a few referent points on the celestial sphere (1-2 points) but they can't plot it on the clear plastic hemisphere.
	2	Incomplete understanding	Teachers can draw and describe the referent points on the celestial sphere, but there are presence of alternative concepts during explanation.
	3	Partial understanding	Teachers can draw and describe the referent points on the celestial sphere at least 3 points. There are no alternative conceptions presence.
	4	Complete understanding	Teachers can draw and explain referent points on the celestial sphere more than 3 points correctly.
Celestial coordinate system	0	No conception	Teachers are unable to respond to the question.
	1	Confused	Teachers can tell azimuth or altitude, but they cannot draw the position on the clear plastic hemisphere.
	2	Incomplete understanding	Teachers can draw and describe the azimuth or the altitude of the star on the clear plastic hemisphere. There are alternative conceptions present.
	3	Partial understanding	Teachers can draw and describe the azimuth or the altitude of the star on the clear plastic hemisphere. There are no alternative conceptions present.
	4	Complete understanding	Teachers can draw and describe the azimuth and the altitude of the star on the clear plastic hemisphere. There are no alternative conceptions present.

Table 2. Continued

Theme	Level	Category	Responses
The Sun's path	0	No conception	Teachers are unable to respond to the question.
	1	Confused	No difference between the Sun's paths in the summer and the winter.
	2	Incomplete understanding	Teachers draw the Sun's path that demonstrates the difference between the Sun's path in the winter and the summer, but there are no change in the sun's rising and setting point. Teachers draw the Sun's path pass through the zenith every day.
	3	Partial understanding	Teachers draw the Sun's path is tilted towards the south. The Sun's path in the summer is higher than in the winter. The sunrise/sunset position is shifted to the north of east/west in the summer and is shifted to the south of east/west in the winter.
	4	Complete understanding	Teachers draw the Sun's path is tilted towards the south. Summer sun's path is higher than the winter Sun's path up to a degree. The Sunrise/sunset position is shifted at least 15 degrees to the north of east/west in summer and is shifted to the south of east/west in the winter.
Cause of seasons	0	No conception	Teachers are unable to respond to the question.
	1	Confused	Teachers do not know that the Earth's axis is tilted. They explained that the causes of the season caused by the Earth's distance from the Sun.
	2	Incomplete understanding	Teachers express understanding that the cause of seasons caused by the Earth's axis tilt, but they could not explain by using the accurate explanation of the cause of the seasons.
	3	Partial understanding	Teacher recognizes that the Earth's axis is tilted impact of the angle of the Sun's rays striking the Earth's surface, but are unable to elaborate on their response.
	4	Complete understanding	Teachers provided clearer explanations about the cause of seasons.

Findings

In-service science teachers' misconceptions before participating in a professional development program`.

The in-service science teachers' responses to the open-ended questions before participating in the professional development program were categorized according to the levels of understanding presented in Table 3.

Table 3. Percentage of the in-service science teachers' levels of understanding

Questions	Level of Understanding				
	NC	C	IU	PU	CU
1. Can you draw the referent positions on the sphere when looking from Bangkok, Thailand (latitude 15ºN)? Explain why.	4%	13%	47%	23%	13%
2. How do we identify the position of stars on the celestial sphere? Can you plot the position of star A (Azimuth 90°, Altitude = 45°) and star B (R.A= 6 ^{h}, dec = + 45°) on the clear plastic dome	0%	9%	42%	31%	18%
3. Draw and explain the path of the Sun at the solstices and equinoxes for the location of Bangkok, Thailand (latitude 15º N).	0%	11%	69%	13%	7%
4. What is the cause of seasons?	0%	42%	33%	16%	9%

In more details relating to question 1, the responses of science teachers found that 47% of the science teachers showed an incomplete understanding of the referent points on the celestial sphere. Most of the science teachers were able to draw the zenith on the plastic dome correctly. However, they gave alternative explanations, such as they understood that the Polaris star is near the zenith and other science teachers drew the Polaris star on the horizon. It was 36% of the science teachers were able to mark Polaris's position from the perspective of an observer in Thailand correctly (above the horizontal about 15 degrees). More than half of the science teachers (54%) still were confused about the celestial equator. They understood that the celestial equator was the same line with the equator on the Earth. They drew the celestial equator starting from the east pass through the zenith to the west. An example of science teachers' drawing is illustrated in Figure 1. Only a few teachers (13%) held complete understanding; they could draw all the reference points on the celestial sphere correctly (zenith, horizon, meridian, NCP, celestial equator, and Polaris).

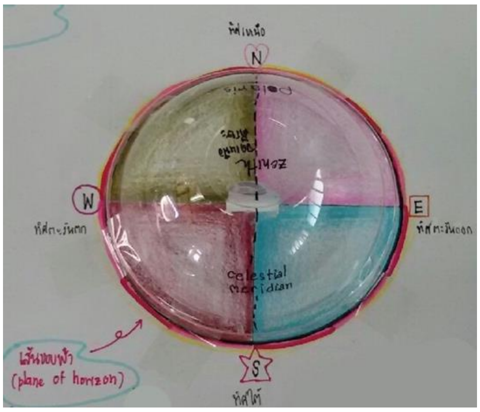


Figure 1. Example of teacher's drawing to explain the referent points on the celestial sphere

In terms of question 2, the science teachers were provided with a plastic dome to demonstrate their understanding. The result found that most science teachers were confused about the coordinate system on the Earth and the coordinate system on the celestial sphere. The Earth's coordinate system uses latitude and longitude, while on the celestial sphere we use the celestial equator and ecliptic as reference points. Science teachers (42%) had inaccurately described the stars' positions in the horizontal coordinate system; they could explain a star's altitude, but they could not explain the azimuth of a star. Thirty-one percent of science teachers held partial understanding; they could explain the position of star A in terms of horizontal coordinates correctly, but they struggled to explain the right ascension and declination of star B on the celestial sphere model. Only 18% of the science teachers could draw the position of star A and star B correctly.

In terms of question 3, all teachers were asked to draw the path of the Sun over a year when looking from Bangkok, Thailand on a clear plastic dome to demonstrate their understanding of the Sun's path change throughout the year. The results found that only a few science teachers (7%) could accurately draw the Sun's path correctly. Most of the science teachers (69%) held incomplete understanding; they drew three parallel lines to represent the path of the Sun. They used the middle line to represent the Sun's path during the equinox, which was drawn through the zenith, and two other parallel lines were drawn to represent the summer solstice and the winter solstice. The sunrise and sunset are perpendicular to the horizon every day. The teachers in this group were aware that the Sun passes directly overhead every day. Some of the science teachers were confused about the Sun's path changes and seasons. They drew three lines to represent the Sun's path: The middle line was applied to represent the Sun's path during summer, and two other lines were drawn to represent the winter and rainy seasons. They thought that the Sun always rises/sets at the same place and the Sun passes overhead at noon during summer. The followings are examples of the answers of science teachers who have this thought:

T3: I think the Sun's directly overhead during summer. The Sun's path will shift towards the north during winter and shifts towards the south during rainy seasons.

R: How about autumn and spring seasons? Is the Sun's path changed?

T3: Umm…I don't know because it doesn't have spring and autumn seasons in Thailand.

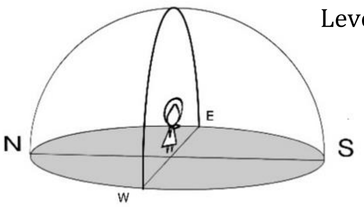
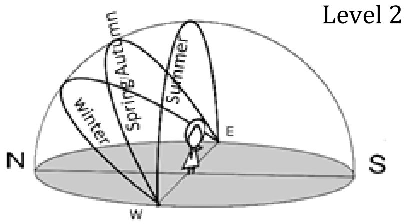
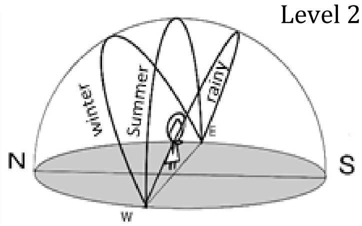
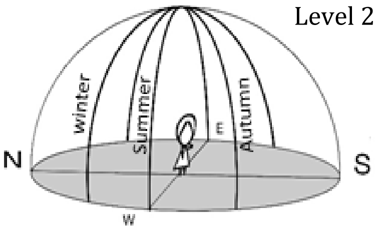
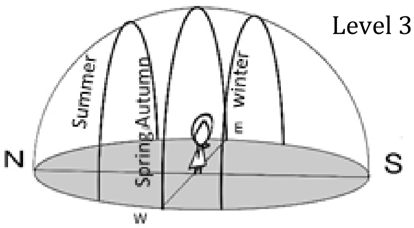
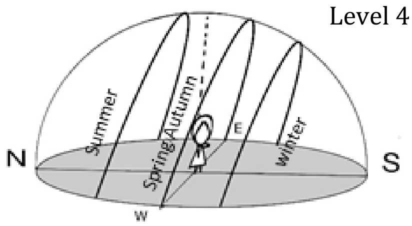
Nearly half of the science teachers (40%) understood that the Sun always rises in the east and sets in the west (at the same points throughout the year). Only a few teachers were aware that the Sun's path and Sun's position changes in each season, but they couldn't explain why it changed because they have limited knowledge and that knowledge may not be relevant to their experiences. Some of science teachers' responses are given below:

T2: I read in the book that describes the sunrise/sunset position changes a little bit every day, but I couldn't explain how it changes. I always saw the Sun rises due east and sets due west every day.

T7: I think that the position of the Sun changes in each month as it is observed from a changing of light that pass through the window panes of my classroom. In some months it shifts towards one way, and in another month it moves towards another way. I am not sure why it happens in that way

To clarify their misconceptions relating to the Sun's path change at Bangkok, Thailand (latitude 15^0N), the summary of in-service science teacher' responses is shown in Table 4

Table 4. Percentage of the in-service science teachers' misconceptions on the Sun's path change

Pattern of Teachers Drawing	Misconception	Percentage of Response
Level 1 	• The Sun's path never changes. • The Sun passes directly overhead at noon every day. • The Sun rises due east and sets due west every day.	9%
Level 2 	• The Sun rises due east and sets due west every day. • The Sun's path always shifts towards the north. • The Sun's path is directly overhead at noon during summer.	18%
Level 2a 	• The Sun rises due east and sets due west every day. • The Sun's path is directly overhead at noon during summer. • The Sun's path shifts towards the north during winter and shifts towards the south during the rainy season.	22%
Level 2b 	• The sun is directly overhead at noon every day. • The Sun rises north of east and sets south of west during autumn. • The Sun rises south of east and sets north of west during winter.	13%
Level 3 	• The Sun's path is directly overhead at noon every day. • The length of Sun's path never changes over the year.	33%
Level 4 	No misconception	5%

In terms of the in-service science teachers' understanding of the cause of seasons in question 4, they were asked to draw the diagram representing their understanding of the cause of seasons. The result revealed that only a few science teachers (9%) were able to explain the cause of seasons correctly. Forty-two percent of the science teachers were confused about the cause of seasons. They described that seasons occur due to the Earth's distance from the Sun. The science teachers' explanation is illustrated in the following excerpt:

T2: Because the Earth moves its elliptical orbit around the Sun. Therefore, when it goes closer to the Sun, it is summer and when it goes away from the Sun, it is winter.

T4: The distance between the Sun and the Earth is change. These can influence the amount of light reaching the Earth's surface.

T9: The Earth revolves around the Sun along an elliptic orbit. When the Earth goes closer to the Sun, then the path of the Sun is longer than when the Earth goes away from the Sun.

Around 33% of the science teachers held incomplete understanding; they explained the cause of seasons by using the tilt in the axis of the Earth, which is accepted as the scientific explanation. They could explain that when the Earth's axis is tilted toward the Sun, the northern hemisphere receives more of the Sun's energy than the southern hemisphere, and it is summer in the northern hemisphere and winter in the southern hemisphere. However, none of the teachers mentioned there is an impact of the angle of the Sun's rays striking the Earth's surface.

Furthermore, some science teachers, around 13%, explained the cause of seasons by combining two ideas together, including the tilt of the Earth's axis and the Earth's distance from the Sun. They explained that the tilt of the earth's axis caused the change in distance from the Earth to the Sun. The paragraphs below show an example of a teacher's understanding regarding the cause of seasons.

T1: When the Earth's axis tilts towards the Sun, then the Northern hemisphere is getting closer to the Sun and the Southern hemisphere is farther from the Sun. Therefore, it is summer in the Northern hemisphere and winter in the Southern hemisphere.

Remaining teachers were confused about the seasons on the Earth and the seasons in Thailand due to the fact that there is no spring and fall season in Thailand. They explained that the Earth orbits around the Sun along an elliptical path. It is summer in Thailand when the Sun is closer to the Earth. When the Earth moves far away from the Sun, it is winter and rainy seasons in Thailand. A science teacher's drawing that supports this explanation regarding the cause of seasons is shown as an example in Figure 2.

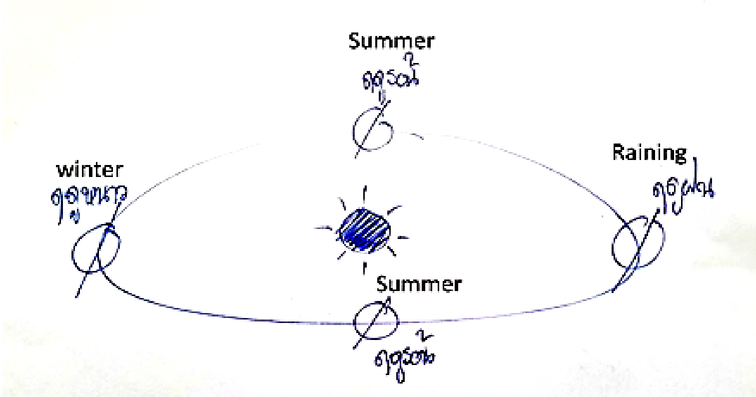


Figure 2. Example of the science teacher's alternative conception of the cause of seasons in Thailand.

In-service science teachers' understanding of celestial motion

To answer the second research question on in-service science teachers' understanding of celestial motion, the results from test scores show that the post-test scores were significantly higher than the pre-test scores (Table 5). This indicates that the professional development program was effective in developing science teachers'understanding of the astronomy concepts. Moreover, this result also indicated that even though the science teachers provided the correct answer in the first tier, they might not offer corresponding right explanations in the second tier. This could imply that teachers might be able to answer "right or wrong" questions in given situations, but they could not use a scientific explanation for why they agreed or disagreed. The effect size (Cohen's d) was calculated to indicate the standardized difference between the two means because the p-value was smaller than 0.05. The results are also indicated in Table 5.

Table 5. Wilcoxon Signed-rank test of pre-test and post-test score (Total score=20)

	First-tier		**Second-tier**		**Both-tier**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Pre-test	10.66	2.49	8.64	2.27	6.08	2.16
Post-Test	17.20	1.77	15.67	1.82	12.82	2.30
Z	5.85		5.80		5.86	
p	0.000*		0.000*		0.000*	
Effect size (Cohen's d)	2.62		3.10		3.11	

*$p < 0.05$

Table 6 shows a summary of the mean scores of each topic before and after participating in the professional development program. The results indicate that the professional development program improved science teachers' understanding of astronomy in all topics, particularly on the Sun's apparent motion.

Table 6. Pre-test and post-test score when in-service science teachers responded correctly to both parts of the item

Topic	Score (Max 5)				Progress (%)
	Pre-test		Post-test		
	Mean	SD	Mean	SD	
1. The celestial sphere	2.07	0.72	3.53	0.79	29.2
2. The celestial coordinate systems	1.71	0.73	3.40	0.81	30.6
3. The Sun's apparent motion	1.28	0.81	3.32	0.88	40.8
4. Seasons	1.02	0.72	2.57	0.76	31.0

Table 7 shows the summary of misconceptions of the in-service science teachers determined from two-tier conceptual tests before and after the professional development program. According to the findings, before participating in the professional development program, most of the teachers held misconceptions about the Sun's apparent motion. It was found that 78% of science teachers believed that the Sun rises and sets in the same position. More than half of these teachers (60%) understood that the Sun passes directly overhead during summer after participating in the professional development program. Twenty-nine percent of the teachers still believed that the celestial equator is a line starting from the east passing through the zenith to the west. Only a few in-service science teachers (4%) still understood that the Sun passes directly overhead at noon every day.

Table 7. Percentage of responses by the in-service science teachers who hold misconceptions detected by the two-tier conceptual test (N=45)

Topic	Misconceptions	Pre (%)	Post (%)	Difference (Pre-Post)
Celestial sphere	-The Polaris will be at the same angle below the zenith as your latitude.	47	15	32
	-The Polaris will never change its position when looking from the Earth at a different latitude.	53	18	35
	-Stars never move, we can see the same stars every night appearing at the same position.	42	11	31
	-The celestial equator is a line starting from the east passing through the zenith to the west	64	29	35
	-The people who live in the North Pole can observe all stars in the sky.	38	18	20
	-The Earth is rotating clockwise about its axis	34	9	25
The celestial coordinate system	-The altitude and the azimuth of stars never change	68	20	48
	-The right ascension and declination of stars never change when looking from different latitude and longitude on the Earth.	53	15	38
	-The people in ~~the~~ any latitude can see the same stars at the same position.	49	18	31
The Sun's apparent motion	-The Sun passes directly overhead at noon every day.	47	4	43
	-The Sun rises due east and sets due west every day.	78	13	65
	-The Sun passes directly overhead during summer	60	22	38
	- The Sun's path never changes over the seasons	36	7	29
Seasons	-The Earth's distance from the Sun causes the changing of seasons.	62	18	44
	-The Earth's movement around the Sun causes the seasons.	38	11	27
	-The Earth revolves around the Sun in an elliptical orbit. This phenomenon makes the length of days shorter in the winter and longer in the summer.	49	16	33

The obstacles of teaching astronomy in Thailand

With respect to the interview data with in-service science teachers who participated in the professional development program revealed the problems and obstacles in teaching astronomy in Thailand into three main factors include:

In-service science teachers lack experiences and basic knowledge in astronomy. These issues affected science teachers' confidence in teaching astronomy. The following excerpts from the interviews with the science teachers exemplify these issues:

T5: *"I think the main problem was at teachers, because they were not proficient in astronomical contents. From my own experiences when I firstly began my teaching, despite checking with textbooks, I doubted myself whether I have taught correct contents. Sometimes, when students asked simple questions, I don't know how to reply to them. Most of science teachers didn't graduate from astronomical field, so it is difficult for them to teach and do the activity in the classroom". T7: "When I studied at the university, I took astronomy only for 1 course, so I didn't know much about this. Astronomical contents are difficult, and thus I had to read it many times until I finally comprehended it. It was also hard to explain to all students to make them understand such texts thoroughly within a few minutes. I was worried because I was not accurate at those contents and not sure if what I understood was correct."*

T7: *"I had no confidence in teaching astronomy because I couldn't comprehend the contents in the textbook and had no idea how to teach students. I just stood in front of the classroom and explained what are described in the textbook or wrote what the students supposed to know on the blackboard. I realized that they were unhappy with this subject, but I did not really know what to do."*

Some in-service science teachers perceived astronomy subject is difficult when compared with other subject areas. They mentioned that the Thai astronomy curriculum contains so many topics for students to learn. Moreover, they were not familiar with the new topics, so they saw it is difficult to teach and explain astronomy phenomena to students. Some in-service science teachers thought that astronomy is not as necessary as physics, chemistry, and biology to be included in the secondary school curriculum.

T3: "Astronomical contents are really difficult. That's why students don't like and don't want to study this topic. This leads to an emergence of problems that affect both students and teachers. Teachers can't genuinely motivate students. For students, they basically pay attention to basic astronomy as they emphasize this for the examination. Most of the students always asked me why they have to study astronomy. I also don't know how to answer this question. Basic astronomy is a part of the Ordinary National Education Test, so this is the particular motivation for them to study".

T4: "Astronomical textbooks are not interesting and containing too many details, and students have no ideas of how to connect the scientific knowledge with their daily life."

T8: "The astronomy subject needs high imaginations; which students are not capable of. They always far misunderstand this matter, especially those who live in the city, where the sky is closed and cloudy, resulted in the failure of the observation of the Sun's and stars' positions."

The other main problems and obstacles that in-service science teachers had encountered were lack of learning material, learning facilities, time for the class.

T2: "I confronted several problems when I taught astronomy in the first year. For example, when I touched on the celestial coordinate system topic, I began to clarify this topic. Do you believe this? Until student's imaginations were visualized after all pictures or whatever had been shown, we nearly ran out of time. Some even forgot what they had learnt when other subjects came."

T7: "I had to arrange extra time for students to complete all the activities described in the textbook, but I couldn't explain all activities in the very limited time period"

T9: "My school lacks science equipment, so I just chose only simple activities for students to carry out because I couldn't find other learning materials."

Discussion

The results of the in-service science teachers' understanding of astronomy concepts show that the post-test mean score was significantly higher than the pre-test mean score. It means that the learning cycle activity implemented in the professional development program affected science teachers' understanding of astronomy concepts. Before participating in the professional development program, the two-tier conceptual test scores were low in the apparent motion of the Sun and the celestial coordinate systems topics. Moreover, science teachers still hold misconceptions about the Sun's apparent motion and seasons. Most of them understood that the Sun appears overhead at noon every day, and the Sun rises and sets in exactly the same position every day. The results were similarly reported by Atwood and Atwood (1996), Kanli (2014), Küçüközer (2007), Ozkan and Akcay (2016), Starakis and Halkia (2014), and Trumper (2006).

Most of science teachers lacked an initial understanding of the Sun's path change because in Bangkok, Thailand (latitude 15 degrees) the Sun's path is only shifted towards the north and south slightly near the zenith across the seasons so most of the science teachers perceive that the Sun's path never changes. Most science teachers also believe that the Sun always rises due east and sets due west every day because they can't observe firsthand the shift of sunrise and sunset positions. Teaching in elementary science curricula, they are typically taught that the Sun rises in the east and sets in the west. With regard to the understanding of seasons, the science teachers failed to acknowledge that the changing intensity and direction of sunlight caused seasonal changes. Rather, most of the science teachers mentioned that seasonal changes occurred because of the distance from the Earth to the Sun. In addition, Thai science teachers don't know about spring and fall seasons since they do not occur in Thailand. In the Thai science curriculum, students have to study four seasons; summer, winter, fall, and spring. But, according to geology textbooks, the seasons in Thailand are generally classified into three seasons; hot, cool, and rainy season. These textbooks are unsuitable for explaining the seasons in Thailand. This is why some teachers are confused about this topic. In this case, textbooks may promote misconceptions both in students and teachers (Papageorgiou & Sakka, 2000). In terms of teaching on the topic of seasons, science teachers have to discuss the effect of monsoon on the seasons in Thailand in order to help students understand the seasons in the Thai context.

The result of written reflections and semi-structured interview transcripts on the obstacles of teaching astronomy in Thailand indicated that there were three main themes of the obstacle of teaching astronomy in Thailand. First, the qualifications of a science teacher in astronomy and content knowledge. Even though most of the science teachers had experiences in teaching astronomy in high school, they still held misconceptions in astronomy that could make science teachers lack of confidence in teaching and led to inability to develop students' interest in the subject. This also led to students' disappointments in class and also affected students' interest in learning science. The second was about the difficulty of the astronomical concepts described in the curriculum, students' textbooks, and the teacher guidebooks. From the science teachers' points of view, those documents and materials should carefully select details to make lessons easier to study and comprehend among astronomy teachers. The third was about the lack of learning materials and the limit of lesson period. Since each teacher has different classroom environments, in terms of student numbers, student's abilities, and the time period of each lesson. As a result, most in-service science teachers encountered problems when they finished the training program and returned to the actual classroom. Because the lesson period was insufficient, and materials were not adequate to carry out activities. Thus, it was difficult for a science teacher to implement the activities in their classrooms. The teaching of astronomy should encourage both students and science teachers to undertake activities involving the observation of astronomical phenomena. In teaching astronomy, science teachers should allow the students to observe the actual sky to improve their understanding of celestial motion. The curriculum content should be linked to their societal and cultural contexts (Anantasook et al., 2015).

Conclusion

With respect to the above results, it can be concluded that most of the in-service science teachers held misconception of the Sun' apparent motion, and seasons. Most in-service science teachers in this group were aware that the Sun passes directly overhead at noon every day and they believed that the Sun rises definitely in the east and set in the west every day. Moreover, they described that seasons occur due to the distance between the Earth and the Sun. After the four days professional development program, the in-service science teachers gain higher scores in all topics. This result indicated that the professional development program's activities help the science teachers understand the contents better. Several factors cause the obstacles in teaching astronomy: first was a science teacher's lack of comprehensive content knowledge in astronomy. The second was about the difficulty of the astronomical concepts described in the curriculum. The third was about the shortage of learning materials and the limit of the lesson period.

Recommendations

Based on this study's findings, we recommend determining the misconception at the beginning of the lesson for preparing suitable learning material and teaching and learning strategy. The teachers' professional learning community should be added to enrich the learning environment in the professional development program. Again, the learning cycle model, one of the effective learning and teaching strategies, should be used during teachers' professional development to provide science teacher opportunities constructing the concept from their observations and discussion. Moreover, the researcher should establish long term observations, activities involving observations of the Sun's path change, models building, and computer simulations for developing a conceptual understanding of the science teachers in a professional development program. Finally, in the science classroom, a science teacher should connect the class knowledge with the real situation or their daily life or use other situations for more engaging students to learn.

Acknowledgment

The authors would like to thank Dr. Patcharapan Siriwat for her comments on an early version of the manuscript. We also thank Asst. Prof. Namkang Sriwattanarothai for her comments on the revised version. We also thank Dr. Parames Loasinchai for his fruitful comments on the statistical interpretation of the research results. We also want to thank the Institute for the Promotion of Teaching Science and Technology (IPST) for their financial support granted through the research.

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