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Developing Students' Scientific Modeling Ability and Attitude towards Teamwork through the Predict-Share-Observe-Explain (PSOE) Instructional Model

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ARTICLE INFO	ABSTRACT

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Purpose: This research aimed to develop the scientific modeling ability and attitude towards teamwork of seventh grade demonstration school students studying in their first semester in Bangkok, Thailand, using a predict-share-observe-explain instructional model (PSOE instructional model). **Methodology:** Students' modeling ability was measured before and after the experiment using a scientific modeling ability test, and their modeling practice during the learning was measured using a scientific modeling ability assessment. Moreover, students' attitudes towards teamwork were measured before and after the experiment using an attitude towards teamwork test and interviews during the experiment.
Findings: The findings were as follows: (1) the mean of scientific modeling ability of the students was higher than before the experiment (2) the mean modeling ability score from four measurements was not statistically significant (3) the mean of students' attitude towards teamwork was higher than before the experiment. The findings from the students' attitude towards teamwork revealed that there were four major themes: (1) the advantages of teamwork, (2) the characteristics of students' teamwork, (3) the problems involving teamwork, and (4) the factors affecting students' teamwork. **Implications for Research and Practice:** It can be concluded that the PSOE instructional model can develop students' scientific modeling ability and attitude towards teamwork. This research would be helpful when used in science classrooms.

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Introduction

Learning Science is fundamental to helping students formulate, revise, and develop ideas that promote long-lasting understanding. The student-centered approach focuses on active learning, where learners take opportunities to decide which aspect of the learning process to focus on, make their own timetables to be able to follow a systematic plan for learning, identify their learning goals and activities as they keep track of their own progress, and take care of their learning by reflecting on errors and successes along the way (Sunal et al., 2001). Models and modeling are highly significant in science, and an appropriate understanding and ability to use models are seen by many authors as central to the understanding of science (Gilbert, 2004; Harrison & Treagust, 2000).

The development of students' modeling ability is one of the keys to help students achieve their goals in learning science (Chang). The process of creating models should be of central importance as emphasized in science education (C. V. Schwarz et al., 2009).

In science education, models are used to explain and simplify scientific concepts for students to better understand. Moreover, scientific models are essential tools for studying science that can help students to improve on description, representation, and prediction of abstraction (Treagust et al., 2003). Scientific models are representations of real objects or phenomena. They can also be used to generate explanations or make predictions (Harrison & Treagust, 2000).

A model is a simple visual representation of an object that students cannot observe clearly in a classroom. Teachers use many types of models in science teaching classrooms. Scientific models are very useful for teaching abstract concepts. For example, using a small ball and lamp as a model for the Sun/Earth/Moon system can be helpful for students to explain the causes of the Moon phases (Lott & Wallin, 2012). Modeling is being used in teaching and learning science in many ways. Scientific modeling is being used to analyze students' understanding and ideas (Acher et al., 2007). Students are expected to have the ability to create and use various models to describe phenomenon, predict phenomenon, develop models, and revise models based on new knowledge. From the Next Generation Science Standard (NGSS) of the United States, models were determined as one of the dimensions in practical scientific skills and engineering of the educational framework (Science and Engineering Practice) to focus on in science practice; such as asking questions, creating explanations, participating in an argument with evidence, and making and using models to predict or describe phenomenon (National Research, 2012). Similarly, models are a key element in daily practice for science (Louca & Zacharia, 2012).

There are many instructional and teaching models that develop scientific modeling abilities. Normally, the teaching model that was widely used to help improve scientific models is based on Model-Based Teaching (MBT) and Generate-Evaluate-Modify (GEM), which is a form of MBT that can develop scientific modeling whereby students construct their models. However, previous results of Khan (2011) found that using the GEM model in classrooms limited the modeling process of students. Students created an initial model, but no explanation was provided on the process of how to improve their model. Moreover, there was no comparison of the models with others, and students did not present their model to their classmates. Therefore, students did not learn, or experience using a variety of models and share and change ideas with friends about model to construct the content knowledge.

MBT is most effective when students can participate in a variety of modeling operations to create, evaluate, and modify their own models. The exchange and share ideas of modeling ideas is essential to student modeling. C. Schwarz ; C. V. Schwarz et al. (2009) In contrast, there are instructional models available which can improve scientific modeling ability and sharing ideas of modeling ideas, namely the Predicted-Share-Observe-Explain instructional model (PSOE instructional model) developed by Brown and Concannon. The PSOE instructional model is used to improve students' ideas in the classroom. This instructional model can help students gain a lasting understanding and have a chance to change their initial ideas through self-reflection and collaboration with friends. Furthermore, students can explore knowledge by themselves before they summarize their knowledge. This instructional model can help students change their initial ideas through self-reflection and collaboration in the classroom by working and sharing in teams (Brown & Concannon, 2016). Hence, PSOE instructional model can fill the gap of the previous studies about sharing students' ideas of modeling. This leads to the development of scientific modeling abilities and attitudes towards teamwork.

As mentioned above, the essential issue of developing the scientific modeling ability of students in science classes is one that needs attention. The aim of this research is to study the scientific modeling ability and attitude towards teamwork of lower secondary school students who learned through the PSOE instructional model. This leads to the development of scientific modeling ability and attitude towards teamwork. Therefore, the PSOE instructional model can be a guideline for developing the scientific modeling ability and attitude towards teamwork of junior high school students.

Literature Review and Theoretical Framework

Modeling ability can be taught using several instructional models. Khan (2011) found that the GEM model, which is a form of MBT, can develop scientific modeling in classrooms. The GEM model consists of 3 stages of teaching: Stage 1 is the generating stage where students construct an initial model; Stage 2 is evaluation, where students evaluate their models; and Stage 3 is modifying stage, where students modify and change their models. However, there are limitations to the modeling process when using the GEM model with students, such as no explanation, no sharing, and no exchanging of ideas after modeling. In response to this, the PSOE instructional model was developed.

The PSOE instructional model can improve the development of modeling ability and help to fill previous gaps in research. The PSOE instructional model consists of 4 stages of teaching: Stage 1 is the predict stage, where students draw an initial model to predict phenomena; Stage 2 is the share stage, where students exchange their thoughts and ideas with classmates; Stage 3 is the observe stage, where students draw the model from observing phenomena in the classroom; and Stage 4 is the explain stage, where students use reasoning to explain phenomena. At the end of a class, students will gain accurate scientific knowledge using supporting evidence. In addition, students will work together by sharing and they have a chance to exchange their ideas with friends. Thus, this instructional model can help students change their initial ideas through self-reflection and collaboration in the classroom by working and sharing in teams (Brown & Concannon, 2016).

- *Development of the predict-share-observe-explain instructional model*

The development of the PSOE instructional model originated from the Demonstrate–Observe–Explain (DOE) model which was developed by Champagne et al. (1980). Subsequently, White and Gunstone (2014) developed the DOE model into a new instructional model which became the Predict–Observe–Explain model (POE) in 1981. Later, many educators developed their teaching into a variety of instructional models, such as the Predict–Discuss–Explain–Observes–Discuss–Explain (PDEODE) that was developed by (Savander-Ranne & Kolari, 2003), the Predict–Observes–Explain–Explore (POEE) model developed by Hilario (2015), and then in 2016, Brown and Concannon (2016) added the Share stage for students to work collaboratively by interacting with peers in class to create scientific knowledge (Brown & Concannon, 2016). Based on the, the sequence of development of the PSOE model can be shown, as in Figure 1

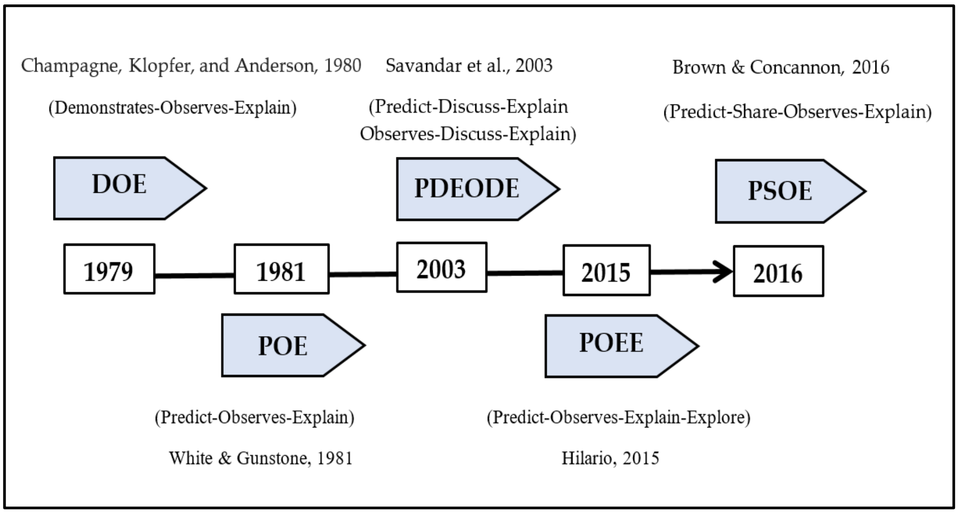

Figure 1. *Development of PSOE instructional model*

Methods

- *Research Design*

This study utilized a One-Group Pretest-Posttest Time Series Design. Dependent variables were measured four times before and after the experiment to show any trends in the change in students' modeling ability and to reveal the persistence of that change. The target group consisted of 25 Grade 7 students from a demonstration school in Bangkok, Thailand. The students were studying in the first semester of the academic year 2020 and were chosen using simple random sampling. The findings of Acher et al. (2007) indicated that encouraging the modeling process at the initial level of students is important. Thus, development of students' scientific modeling abilities for students who are studying at the beginning grade of high school will provide students with the knowledge and skills which are necessary tools to continue studying science at higher levels. During this study, classes were taught by the researcher.

- *Data Collection*

Multiple types of data were collected for this study within three stages for data collection. In the first stage, students did a scientific modeling ability pretest at the beginning of the study which consisted of a parallel exam and was characterized as a subjective exam that defined various situations. Moreover, attitudes towards teamwork were measured before learning instruction began using the attitude towards teamwork test. In the second stage, students were organized into mixed ability and mixed gender teams, where the number of students in each team was equal. Students were on the same teams throughout the research. Then, the researcher gave instruction using 10 PSOE lesson plans, which took place over a total of 20 lessons of learning and instruction lasting 6 weeks. During the instruction, students' scientific modeling practice were measured four times during classes. The timing of the assessments was one week apart to assess the practice of scientific modeling, which consisted of four components: 1) model construction, 2) model use, 3) model evaluation, and 4) model revision.

The researcher considered and classified the types of scientific models in order of science content, according to the lesson and content suitability for different types of modeling. In addition, students were interviewed four times individually about their attitudes towards teamwork using a semi-structured interview constructed by the researcher to collect attitudes towards teamwork after the practice of scientific modeling. In the third stage, at the end of the instruction, students did the scientific modeling ability test which consisted of a parallel exam and was characterized as a subjective exam that defined various situations and the attitude towards teamwork test again as a posttest to collect data.

- *Data Analysis*

In this study, data were analyzed using quantitative and qualitative content analysis. The data analysis process consisted of two major steps which were scientific modeling ability analysis and attitude towards teamwork analysis. The first step of quantitative data analysis focused on scientific modeling ability and was analyzed using 1) a scientific modeling ability test and 2) a scientific modeling ability assessment. The scientific modeling ability test provided scores for before and after the study to assess scientific modeling ability. After that, the average scores were compared with the proficiency level criteria of the scientific modeling process. Next, the scores obtained from the scientific modeling ability assessments were analyzed to perceive trends in any change in scientific modeling ability. Four components focused included model construction, model use, model evaluation, and model revision. All scores were compared with the proficiency level criteria.

The second step was devoted to attitude towards teamwork, and was analyzed using the attitude towards teamwork test, both before and after the research. After that, the average scores were compared with the level criteria of the attitude towards teamwork. Additionally, the data which were obtained from attitudes towards teamwork's interviews were analyzed for qualitative results. The content of the interviews was separated using coding schemes and content analysis. Lastly, data were described in an essay to provide additional information.

Results

In the following section, the results are presented with regards to the two major aspects—scientific modeling ability and attitude towards teamwork.

- *Scientific modeling ability*

Table 1

Difference between scientific modeling before and after the experiment

Test	M	SD	t	df	p	Level of Scientific modeling ability
Before experiment	41.00	8.89	5.55	24	0.001*	good
After experiment	50.24	4.47				excellent

* $p<.05$

Table 1 shows that the average scores of students before the experiment using a t-test for dependent samples (n=25) was 41.00 points, representing 68.33 percent, which indicates a good level. The average scores after the experiment were 50.24 points, representing 83.73 percent, which denotes an excellent level. Moreover, the results show that the scientific modeling ability of the students who learned through the PSOE instructional model was higher at the end of the experiment than before and rated at an excellent level (83.73 percent at the .05 level of significance).

Table 2

Mean and standard deviation analysis results and the proficiency level of the ability to create scientific models 4 times

Times	Topic	M	SD	Level of Scientific modeling ability
1	Boiling point of pure substances	19.24	1.16	excellent
2	Density	18.40	3.13	good
3	Classification of pure substances	19.52	1.90	excellent
4	Element Classification and Uses	19.44	1.89	excellent

Table 2 shows the consideration of scientific modeling ability four times in different lesson topics. The mean scores for overall modeling ability from four measurements were not significantly different at the .05 level, representing 79.79 percent at a good level. The data from measurements can be analyzed under four components of scientific modeling ability. We have operationalized the practice of modeling to include four elements that we targeted as Model construction, Model use, Model evaluation and Model revision.

- *Model construction*

Students can construct scientific models consistent with prior evidence and theories to illustrate, explain, or predict phenomena by themselves. They can construct scientific models spontaneously in a range of domains to help their own thinking. For example, Figure 2 shows an example of students' modeling products for air pressure at a good level, which includes drawing of air particles, which are non-observable, and text to describe air pressure at different heights.

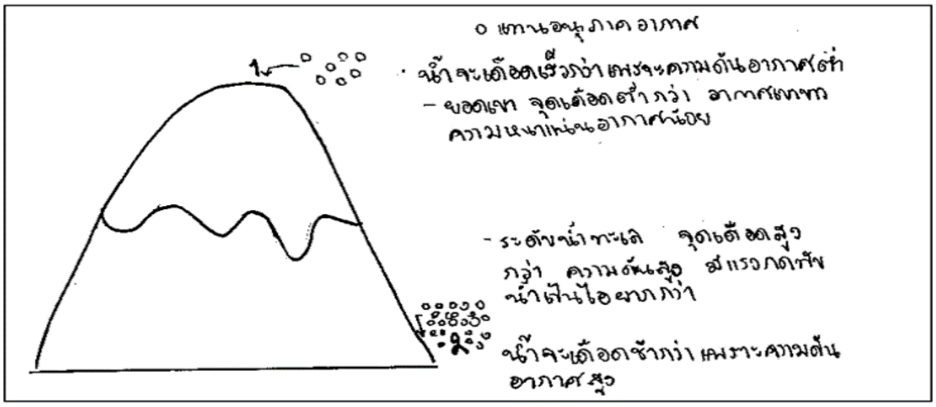

Figure 2. *Example of students' modeling product at a good level*

- *Model use*

After teaching students using the PSOE instructional model for 3 weeks, students had more choice of scientific modeling in a variety of ways. There were illustrations displaying data as a table, drawings, and writing to explain or predict various scientific phenomena that can be seen in Figure 3. Students could construct multiple models and consider alternatives in constructing models to explain phenomena.

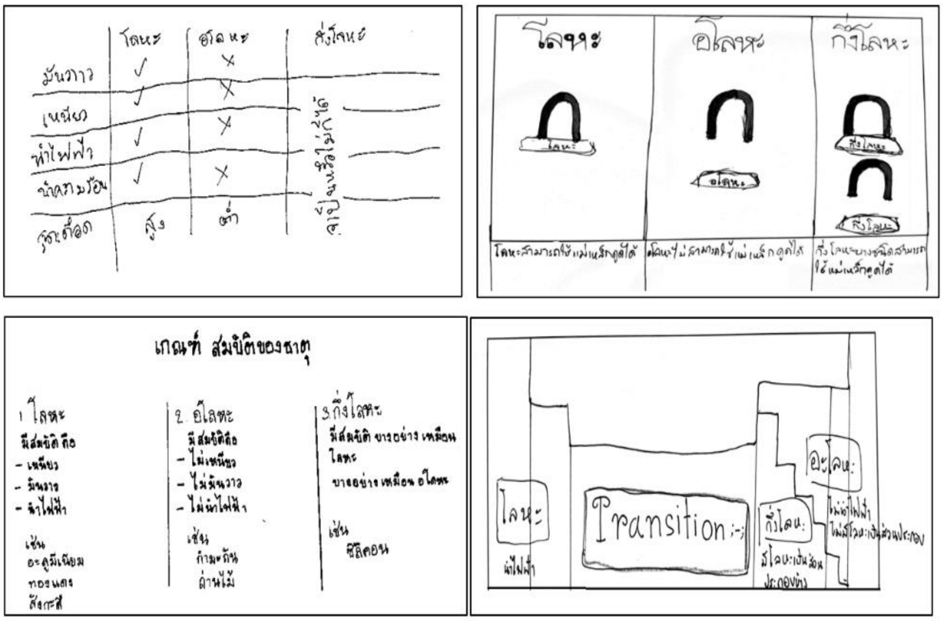

Figure 3. *Example of students' model selection in the 4th measurement*

- *Model evaluation*

Students could consider alternatives in constructing models based on analyses of the different advantages and limitations for explaining and predicting phenomena. They compared and assessed different models which were developed by themselves and between their peers. They were able to better assess the models during the third week of research, identify the advantages and limitations of their own models for explaining phenomena, compare the improved models that they had created and described, and argue for the improvements of their models.

- *Model revision*

When students can see the limitations of a scientific model, they can then improve the models. During the second week of the study, students could improve or modify a model and show better details or increased comprehension by adding text, images, table, or symbols which were consistent with the phenomenon. After that, they shared ideas with friends to improve or revise models to be more accurate. For example, Figure 4 and Figure 5 show examples of students' revised models after accuracy improvements. They increased the text and used pictorial representations to describe the phenomenon.

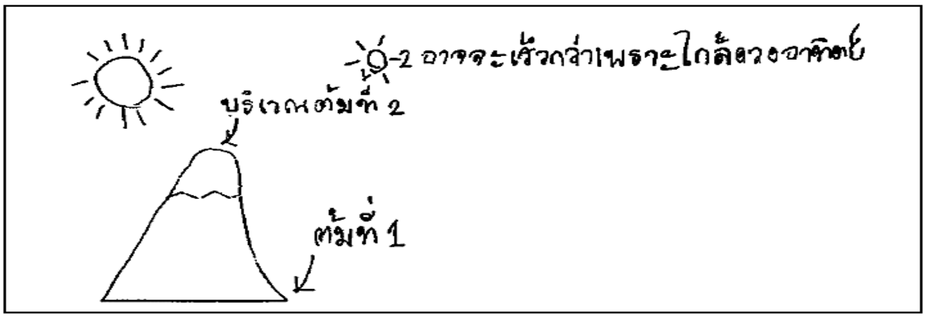

Figure 4. *Examples of students' model in predict stage*

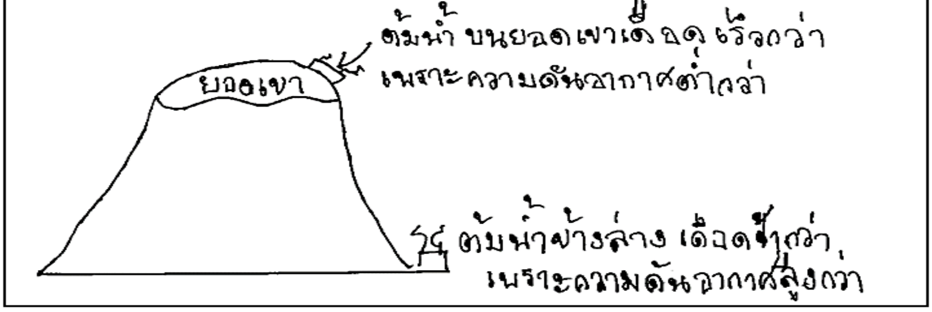

Figure 5. *Examples of students' model in share stage*

- *Attitude towards teamwork*

Table 3

Differences between attitudes towards teamwork before and after the experiment

Test	M	SD	r (p)	t	df	p
Before experiment	3.81	8.34				
After experiment	3.96	7.70	.64 (< .001)	2.26	24	.03

Table 3 shows the differences between attitude towards teamwork of students before and after the experiment using a t-test for dependent samples (n=25). The average for teamwork before the experiment was 3.81 points, representing 76.20 percent at a good level. The average scores for attitude towards teamwork after the experiment was 3.96 points or 79.20 percent, also at a good level and higher than the attitude towards teamwork as a team before the experiment at the .05 level of significance.

The findings on the students' attitude towards teamwork from interviews can be summarized into four major themes of advantages of teamwork, characteristics of students' teamwork, problem involving teamwork, and the factors affecting students' teamwork.

1. *The advantages of teamwork*

From the initial interviews, students needed to adjust to the members of their team. Some students were not familiar with other members of their team and had never worked together with them before as they came from different classes and had only moved into the same class during that semester. As a result, the students' attitude towards teamwork was not as expected. Moreover, it was found that the students had better attitudes towards teamwork in the second interview, whereby most students liked to work in teams. The advantages of working as a team from students' ideas were as follows:

i. Exchanging ideas with friends and helping each other to think of things. They could exchange opinions on various models that lead to a more accurate answer.
ii. Working as a team could save time because tasks can be divided up between team members to complete work faster.
iii. Getting to know more friends and having fun through the exchange of ideas and collaboration.

2. *The characteristics of students' teamwork*

At the beginning of this research, students were not able to manage their time or share their ideas about work as well as they should. After approximately three weeks into the study, the students' behavior and teamwork changed. The characteristics of students' teamwork are as follows:

i. Helping each other to work and dividing tasks according to duties and abilities. Some students provided feedback that teamwork may cause disagreements which could lead to conflict as there are some students who are self-centered. In addition, it may be more difficult than working alone if the tasks can be done alone, such as taking notes of experimental results or preparing equipment for an experiment. However, if tasks are difficult or complex, collaborating with teammates is probably better. Consequently, working together as a team, students can exchange and discuss ideas with friends that can lead to a closer scientific model.

ii. Having good leadership and team members is essential. A leader clearly divides the work for other members in the team. If any student feels that they do not have leadership skills, they can listen to and support their friends' opinions and ideas.

3. *The problems involving teamwork*

At the beginning of the course, most students had problems with disagreements and adaptation to other team members. They could not solve many problems by themselves and asked the teacher to solve problems for them. In the second interview, students were able to solve problems among themselves within the team. The students' problems involving working as a team highlighted in the interview are as follows:

i. There was some disagreement between students when exchanging ideas with each other. In this case, they discussed the ideas and chose the best answer for the team using most of the team's opinions, which helped them decide on the best model.

ii. Some of the teammates did not contribute. For instance, some team members played while they were working as a team. This problem was solved by assigning those team members a leadership role within the team, by clearly dividing assignments or tasks, or by encouraging friends to work.

iii. Some students felt that they were not good enough to help their friends and did not dare to make comments. Students solved this problem by asking other friends what had not been done yet and by being willing to volunteer to help students with low performance in the team.

4. *The factors affecting students' teamwork*

The information on the factors contributing to the success of each student's teamwork is different, as it depended on the nature of work, the activities, and the content of the lesson. The interview results proffered that if the students were assigned an easy task which was not complicated, they would be able to divide their work well. However, if students were assigned difficult and complex tasks that they had never done before, such as an experiment on electrolysis of water which had connected electrical circuits which students have never done before, they had more problems. As a result, students in each team needed to use unity to help each other connect the electrical circuit. Factors that promoted successful student teamwork include unity, sharing of workloads, responsibility, and willingness to work. Examples of statements from student interviews are as follows:

i. Unity in working together: working together makes the job successful and it is completed faster.

ii. Responsibility and commitment to work: if teammates intend to work and perform their duties as best as they can, the work will be completed well and will be done faster.

iii. Listening to and exchanging opinions with teammates: communication with teammates is important when there is a problem with work, and friends can help and solve problems to make tasks successful.

Discussion

According to the results, students' scientific modeling ability after using the PSOE instructional model can be discussed following the four steps. In step 1, the predict stage, students predicted scientific phenomena by creating an initial scientific model themselves, helping them to expand their ideas through self-reflection. Furthermore, students demonstrated their existing understanding of the phenomenon by visualizing the prediction or showing the relationship between things in the phenomenon in advance. In step 2, the share stage, students shared ideas to exchange their own models with other teams. Students were able to express or explain their opinions and share or change ideas and models from interactions with teammates, which allowed students to examine their own understanding alongside any faults or limitations of their own models. This allowed students to see the various perspectives of models from teammates. This is consistent with research by Brown and Concannon (2016) who used the PSOE instructional model in science subjects for students to understand about weather and climate.

The study findings found that students were able to expand their model or change their initial model through observation and self-reflection from interactions with teammates. In step 3, the observe stage, students gained firsthand and direct experience from activities, and they created models by themselves. These findings are in accordance with those identified by Acher et al. (2007); C. V. Schwarz et al. (2009); White and Gunstone (2014) who found that the pedagogical benefits of working with scientific models rests critically on having students improve or develop models to articulate their own understanding of scientific phenomenon. In step 4, the explain stage, students shared ideas with their teammates again. They could make comparisons between the models of teammates and their own, and receive information to modify or improve their own models to be more accurate. In addition, students also examined models by presenting their team's models, which were evaluated together with other classmates. This gave students the ability to assess and improve their own models, and is consistent with the research of Baek et al. (2011); C. V. Schwarz et al. (2009) who concluded that scientific modeling helps students to better understand the process of creating, evaluating and communicating scientific knowledge. For this reason, the PSOE instructional model could enhance the scientific modeling ability of the students.

As stated in the results, a total of four measurements of scientific practice was not significantly different at the .05 level. This could be due to the content in each modeling being of a different difficulty, whereby some content is abstract. Therefore, students' scientific modeling abilities were not different, which is consistent with the research of Coll and Lajium (2011) which revealed that it is not easy for students who had to draw abstract things in pictorial form that could not be seen or touched, including the need to identify various symbols and drawings to communicate things that are invisible to others. Additionally, students needed time to develop their scientific modeling ability. This is in accordance with the research of Nelson and Davis (2012), who pointed out that students need more time to be able to assess and improve their modeling through the conceptual representation concept to develop scientific modeling ability. In addition, Lehrer and Schauble (2012); Tytler and Peterson (2003) found that student modeling is content-dependent and better rendered with the phenomena being modeled.

Considering the results from the attitude towards teamwork in the qualitative phase of this research, the average score for attitude towards teamwork after the experiment was higher than before experiment at a .05 level of significance. These results showed that the PSOE instructional model could encourage students to work together collaboratively. From the results, 4 themes related to attitude towards teamwork were discussed. The first theme was advantages of teamwork. The results found that in the teaching and learning process, the exchange of ideas allowed students to work together collaboratively. Moreover, they got to know more friends and had fun through the exchange of ideas and collaboration. The study of Brown and Concannon (2016) revealed that using the PSOE instructional model with students helps explain the understanding of what has been learned through writing, sharing, and exchanging ideas. This helps to develop students' thinking and promotes students' work.

The second theme was the characteristics of students' teamwork. Students had to divide work tasks according to their abilities and manage duties within their own team. The success of the team came from everyone helping each other and creating a positive atmosphere for collaborative working to get tasks done more easily. Moreover, students had good leadership between team members. Ekimova and Kokurin (2015) posited that a positive learning experience can improve attitudes toward teamwork with peers, possibly making students more willing to participate in teams. The third theme was the problems involving teamwork theme. Students exchanged ideas with each other, offering a variety of perspectives to work and help each other in the share step. There was some disagreement between students when exchanging ideas with each other, so they discussed the ideas and chose the best answer for the team using the majority of the team's opinions. This is consistent with Ekimova and Kokurin (2015); Loo (2013) who revealed that team members with different genders and abilities can be more beneficial, and that for students to spend time studying together throughout the period without changing teammates can help them to exchange, learn, assist in and solve problems together.

The fourth theme was the factors affecting students' teamwork theme. Teamwork encourages students to exchange ideas and brainstorm opinions with other teammates, generating a wider variety of ideas and more accurate answers. In addition, this instructional model helped students to complete tasks faster as students can become acquainted with more friends through exchanging ideas and working together as a team, leading to better cohesion. This is consistent with the research of Kapp (2009); Rudawska (2017) who concluded that collaborative climate, communication and sharing allowed teams to work together comfortably and effectively. Furthermore, teammates were helpful in providing team members with feedback they needed to determine to work.

Conclusion, limitations and recommendations

This research explored the effect of scientific modeling ability and attitude towards teamwork of junior high school students. The findings have shown that scientific modeling ability and attitude towards teamwork after the experiment are better than before the experiment, and that students can share and work collaboratively with teammates. Therefore, using the PSOE instructional model is advantageous for school teachers to adopt in science classrooms.

Nevertheless, there are some recommendations from this study. The researcher found students can take more time to complete tasks in class when compared to conventional teaching methods as students tend to spend a long time creating accurate scientific models. Consequently, teachers should set an agreement or clearly define the issue for scientific modeling. Additionally, during the modeling practice, students may consider other factors, such as spending more time decorating a model rather than being concerned with the accuracy of the model to describe the phenomenon. Thus, teachers should plan and manage class time to allow students to choose and create various models according to content appropriateness for a successful teaching and learning process. Furthermore, students were arranged in mixed gender and ability in the first phase of teaching, and the data from the interview revealed that students may not be able to make decisions and divide tasks in these teams in time to finish the tasks. Mitchell et al. (2008) pointed out that to learn as a team, team members have to accept each other as this will promote a good working atmosphere. As a result, students need to have a good attitude towards working as a team.

For these reasons, teachers should encourage students to participate and comment on promoting a more effective team working atmosphere among students. In addition, some students may have different opinions to share with teammates about working as a team. In future research, students' ability to work in teams may be studied as the findings found that students in teams have a variety of different behavior traits and different ideas of working as a team. Further research may study the ability of students to work as a team.

Finally, from the results, there are many advantages of the PSOE instructional model, such as sharing ideas together with friends, helping each other to think of ideas, working as a team, having good leadership skills, getting to know more friends, and having fun through collaboration. Hence, the PSOE instructional model is a useful tool for science lessons as it can help teachers focus on important concepts and enhance the learning experience of students during scientific modeling. This leads to the development of scientific modeling abilities and attitudes towards teamwork. This study recommends that other researchers should conduct further studies in science classes.

In this research, there was only one group of students, and they were students in a demonstration school, which is a school associated with a university and used to teach training programs. It is also known as a laboratory school that provides student teachers with opportunities to practice teaching and is also used by the associated university for education research and development. This means the research cannot refer to the context of the students in general. In future research, the effect of using the PSOE instructional model should be used with a more general group of students and should integrate other topics from science lessons to develop scientific modeling ability and the attitude towards teamwork of students. In addition, the research sample could be enlarged and not taken as only one group, considering a sample of a larger population. This could be an additional field for prospective research.

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