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Learning outcomes of an integrated inquiry-based and problem-based learnings for grade 8 science students

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ABSTRACT

The purpose of this study aims to investigate the effects of integrated inquiry-based learning and problem-based learning for improving grade 8 student science learning achievement of force and motion, and to study students' satisfaction with the learning management plan designed using the integration of integrated inquiry-based learning and problem-based learning. The participants were 39 of grade 8 students from a public school in Thailand. The instruments were a learning management plan designed using the integration of integrated inquiry-based learning and problem-based learning, a 4-multiple choice learning achievement test, and a satisfaction questionnaire. The results of the study showed that there was an improvement in the participants' science learning achievement on the concept of force and motion after implementing the learning management plan. Additionally, the integration of inquiry-based learning and problem-based learning led to increased learning satisfaction among the participants. These findings suggest that the integration of inquiry-based learning and problem-based learning can be an effective approach to teaching science concepts, particularly force and motion, and can lead to improved student learning outcomes and satisfaction.

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1. INTRODUCTION

Science education is significant for an education system because it helps in developing students' critical thinking and problem-solving skills, which are crucial qualifications for the twenty-first century (Turiman et al., 2012). It also assists in comprehending the universe and how things function. By studying scientific concepts and principles, students can better comprehend the natural world and its operation. This can result in a stronger respect for the environment and the role of science in tackling real-world problems (Alberts, 2022). In addition, scientific education prepares students for professions in science, technology, engineering, and mathematics (STEM) (Castellanos & Rios-González, 2017). Overall, learning achievement in science classrooms is an expected result of a well-rounded education since it demonstrates that students are trained to be knowledgeable, inquisitive, and involved members of society (Ratcliffe, 2003).

In science education, force and motion are essential ideas that help students comprehend matters, energy, and their interconnections. Understanding the concept is essential for predicting the behavior of things and systems (Buaraphan, 2018). For instance, students may study the forces that act on a moving item, such as friction and gravity, and how these forces might impact the speed and direction of the object. They may also study how to apply the principles of motion, such as Newton's laws, to predict the behavior of objects under various conditions. Learning about force and motion can prepare students for further study in physics or related subjects, such as engineering and technology, in addition to enhancing their understanding of the physical world. By learning the fundamental concepts of physics, students can lay the groundwork for more advanced study and professions in related subjects (Afari, 2015).

However, one that is does not simply comprehend the concept of force and motion since there are issues to consider. During their study of the concepts, students may meet several frequent difficulties. First, they may experience trouble comprehending abstract concepts. Understanding force and motion can be challenging for learners, especially if they are abstract and not directly observed. This can make it difficult for them to comprehend the principles and apply them in the real world (Toksoy & Akdeniz, 2015). In addition, some students may have difficulty seeing and modeling scenarios, making it difficult for them to apply the principles to various situations. In addition, many scientific ideas, such as force and motion, need mathematical calculations. Students who have difficulty with mathematics may find it difficult to comprehend and apply these concepts (Kaur et al., 2022). These difficulties could result in a lack of motivation to learn the subject and undesirable learning outcomes.

In Thailand, students confront a range of obstacles when it comes to science education. The context has been criticized for its lack of resources and support for science education, a lack of emphasis on science in the school curriculum, cultural or societal factors that discourage students from pursuing science, and limited access to resources and facilities for hands-on learning and experimentation (Faikhamta et al., 2018). Thai students have never passed one-third of the national education qualifying examination (National Institution of Education Testing Service, 2019). The evidence can be supplemented with the PISA test results classifying Thailand as level 2 (The Programme for International Student Assessment, 2019). The context's concerns should be addressed for the sake of Thai education and the nation.

It can be noted that learning the concept of force and motion needs the comprehension of abstract concepts of science using visualization of how motion object operates. In this case, inquiry-based learning could be employed in the context to solve its problems. According to Caswell & LaBrie (2017), inquiry-based learning is a teaching approach that focuses on student-led exploration and investigation. The approach is designed to engage students in the learning process and encourage them to ask questions, make predictions, and test their own ideas (Bell et al., 2005). In an inquiry-based learning environment, students are given the opportunity to take an active role in their own learning and are encouraged to develop their own understanding of a concept or topic through hands-on experimentation and exploration. Moreover, the approach emphasizes the importance of questioning and curiosity, and it can help students develop critical thinking and problem-solving skills (Duran & Dökme, 2016). Inquiry-based learning is often used in science education, but it can also be applied to other subjects. This approach can be an effective way to engage students in the learning process and encourage them to take ownership of their own learning.

One of the influential frameworks in the inquiry-based learning approach is the 5Es teaching model. The consists of 5 stages: engage, explore, explain, elaborate, and evaluate which provide a structure for the inquiry process and help students engage in meaningful learning experiences (Duran & Duran, 2004; Bybee, 2009). The engage stage, students are introduced to a concept or topic and are given the opportunity to explore their own questions and interests related to the topic. This stage is designed to spark student curiosity and get them excited about the learning process. In the Explore stage, students engage in hands-on activities and investigations to gather data and explore their ideas. They may also use resources and tools, such as textbooks and online resources, to gather information. In the explain stage, students use the data they have collected to construct explanations and make sense of their findings. They may also be asked to share their explanations with their peers. In the elaborate stage, students expand upon their understanding of the concept or topic by applying their knowledge to new situations or contexts. In the evaluate stage, students reflect on their learning and assess their understanding of the concept or topic. They may also be asked to evaluate their own learning process and identify areas for improvement. Assessment methods such as tests and behavioral assessments can be applied in this stage.

The empirical evidences of the 5E model on science education has been proven by studies in science education. The method has been proven to be beneficial in improving science learning achievement (Cakır, 2017; Işcan & Seyhan, 2021), scientific thinking (Anggraeni & Suratno, 2021; Choowong & Worapun, 2021), and science teacher education (Açişli, et al., 2011)

Moreover, problem-based learning (PBL) can also be a potential solution to improving the situation of science education in the context. Problem-based learning is a teaching method that centers around the investigation and resolution of real-world problems (Servant-Miklos et al., 2019). It is a student-centered approach that emphasizes active learning and encourages students to take an active role in their own education. In problem-based learning, students work in small groups to identify and define a problem, gather information, brainstorm, evaluate potential solutions, and present their findings to the class (Fonteijn & Dolmans, 2019). The approach helps students develop critical thinking and problem-solving skills, as well as the ability to apply their knowledge to real-world situations (Moallem, 2019).

To create a PBL activity, one can begin by outlining the learning objectives and selecting a pertinent, difficult challenge. The teachers should clearly describe the issue, create a plan for the students, and assign them collaborative learning activities. Teachers may also develop instruments to assess student learning and development throughout the activity. After completing the learning assignment. Teachers could use student comments to inform their preparation for learning activities. It emphasizes active learning and encourages students to take an active role in their own education, helping them develop critical thinking and problem-solving skills and apply their knowledge to real-world situations (Blumberg, 2019). Previous studies also recognized the benefits of problem-based learning in science education (e.g., Akçay, 2008; Aidoo et al., 2016; Hasanah et al., 2018).

It can be seen that inquiry-based learning and problem-based learning are beneficial in science education. Moreover, they seem to have the potential in solving problems regarding teaching the concept of force and motion in the Thai context. In addition, the two methods could be integrated by using inquiry-based techniques to help students identify and define a problem in a problem-based learning activity (Jun et al., 2013). For example, students could use the scientific method to ask questions, form hypotheses, and design experiments to investigate a problem. They could also use inquiry-based techniques to gather and analyze information and come up with potential solutions to the problem. This integration of the two approaches allows students to apply their critical thinking and problem-solving skills in a real-world context and helps them see the relevance of their learning to their lives and the world around them. Therefore, the two principles were integrated into the current study to design a learning management plan that could improve students' learning achievement of force and motion.

2. METHOD

Participants

The participants were 39 grade 8 students from a public school in Thailand. They were selected using a purposive sampling method giving educational path and learning condition as criteria. In detail, the participants passed through the basic science education curriculum the Ministry of Education provided. None of the participants were in science-intensive programs or study abroad. None of them have learning difficulty problems. The participants were informed about project participation. Their confidential information was kept secret following the ethical issues of human research.

Research instruments

Learning management plan: The learning management plan was designed using the integration of integrated inquiry-based learning and problem-based learning. Therefore, in each lesson plan, the activities were designed to let students learn to solve real-world problems regarding force and motion. The 5Es circle of engagement, exploration, explanation, elaboration, and evaluation were employed as a sequence order of learning. The learning management plan consists of 5 lesson plans on the topics of 1) object motion, 2) sesultant force, 3) friction, 4) pressure, and 5) force field. It takes 10 class hours to complete the learning management plan. The learning management plan was evaluated by 3 experts and professional teachers in total. The results of the evaluation indicate a very high level of appropriateness.

Learning achievement test: The learning achievement test was designed in 4-multiple choice. The content of the test relates to the comprehension of force and motion context. There are 20 question items resulting in 20 maximum points. The test was tested for its content validity and the Index of item objective congruence (IOC) was 0.67-1.00. The difficulty and discrimination are 0.48-0.57 and 0.42-0.54 respectively. The reliability of the test was 0.854.

Satisfaction questionnaire: The satisfaction questionnaire was designed on the 5-Likert scale. It consists of 10 positive statements regarding the learning experience during the implementation of the learning management plan. The questionnaire contains content validity with the Index of item objective congruence (IOC) was 0.67-1.00. The discrimination is 0.49-0.54. The reliability of the test was 0.768.

Data collection and analysis

The result of the study relies on the student's performance during participating in the learning management plan and after the treatment, the comparison between pre- and post-learning performance, and the student satisfaction level towards the learning management. The statistics used in data analysis include percentage, mean score, standard deviation, and efficiency criteria with the determining criteria of 75/75, also t-test statistics for hypothesis testing.

3. RESULT AND DISCUSSION

The effectiveness index (E_1/E_2) of the integrated inquiry-based learning and problem-based learning management plan was 94.51/75.26 reaching the determining criteria of 75/75. This can be interpreted that the participants can develop their science learning achievement of force and motion both during and after the process of learning management (Table 1).

Table 1 The effectiveness index of the learning management

Outcomes	Maximum score	$\bar{x}$	SD	Percentage
Process outcomes)E_1(	50	47.26	1.53	94.51
Product outcome)E_2)	20	15.05	1.39	75.26
(E_1/ E_2) = 94.51/75.26				

The effectiveness index of the learning management plan was assessed by students' performances during the learning processes of the plan and after implementing the plan. Findings indicate that the participant's average score in process outcomes was 47.26 (SD=1.53) which accounts for 94.51% of the maximum point of 50. After implementing the learning management plan, the participant's average score was 15.05 (SD=1.39) which accounts for 75.26% of the 20 full scores.

It could be claimed that the 5Es model as a framework in the inquiry-based teaching approach positively affected students' learning achievement of force and motion. The result of the study adds evidence to support the benefits of the model in science education, and it is consistent with previous studies (e.g., Açişli, et al., 2011; Anggraeni & Suratno, 2021; Choowong et al., 2021; Cakır, 2017; Işcan & Seyhan, 2021) that discovered similar results.

This is because Inquiry-based learning is designed as a teaching approach that emphasizes student-driven investigation and problem-solving (Nuangchalerm, 2013; Caswell & LaBrie, 2017). In the current study, students learned the concept of force and motion by design and conduct their own experiments, collect data, and draw conclusions based on their observations. They are also prompted to actively engage with the material and develop a deeper understanding of the concepts. Moreover, they were encouraged to make connections between the concepts being studied and real-world situations.

The t-test was employed to determine whether there was a significant difference between the scores on a pre-test and a post-test administered to a group of 39 subjects. The t-test was conducted to evaluate the effectiveness of the learning management plan. In the current study, the results of the t-test showed a significant difference between the pre-test ($\bar{x}$=7.17, SD=2.05) and post-test scores ($\bar{x}$=15.05, SD=1.39), with a mean difference of 7.88 points and a t-value of 19.54 ($p < .05$). This indicates that the learning management plan had a statistically significant effect on the subjects' scores on the post-test (Table 2).

Table 2 The comparison between the participants’ pre and post-tests.

Test	n	Full score	$\bar{x}$	SD	t	Sig
Pre-test	39	20	7.17	2.05	19.54*	.000
Post-test	39	20	15.05	1.39		

The learning management plan was effective in improving the subjects' scores on the post-test. The results of the study can be summarized that there was an improvement in the participant’s science learning achievement on the concept of force and motion after implementing a learning management plan designed using the integration of inquiry-based learning and problem-based learning.

Problem-based learning contributed to the development of participants’ knowledge of force and motion in the current study. Therefore, the result goes in line with previous studies that similarly recognized the benefits of the method in science education (e.g., Akçay, 2008; Hasanah et al., 2015; Aidoo et al., 2016; Polyiem & Nuangchalerm, 2022). In this study, the participants were encouraged to think systematically and apply their knowledge to solve real-world problems regarding force and motion. By working through a complex problem, they must consider multiple factors and think creatively to come up with a solution (Leary et al., 2019). This helps them develop problem-solving skills and develop knowledge of force and motion as shown by improving learning.

The results of the study suggest that participants had a highest level of satisfaction with the teaching method and learning experiences designed using the integration of integrated inquiry-based learning and problem-based learning ($\bar{x}$=4.92, SD=0.18). In detail can be shown in Table 3, the learning management plan was perceived to be beneficial for students learning, and it contributed to a satisfying learning experience. Therefore, it can be interpreted that the integration of integrated inquiry-based learning and problem-based learning was well-received by the participants.

Table 3 Students' satisfaction assessment

Statements	$\bar{x}$	SD	Level of satisfaction
The teaching method helped me understand class content more	4.81	0.40	Highest
The learning material was interesting	4.81	0.40	Highest
The learning material helped me understand class content more	4.81	0.40	Highest
Learning activities were consistent with class content	4.95	0.23	Highest
Learning activities supported hands-on learning experiences	5.00	0.00	Highest
Learning activities helped me comprehend the concept of science	5.00	0.00	Highest
Learning activities were joyful and interesting	5.00	0.00	Highest
The teacher's role was appropriate	5.00	0.00	Highest
The class was open for discussion	5.00	0.00	Highest
I learned happily in class	4.86	0.35	Highest
Average	4.92	0.18	Highest

Findings also indicate participants' satisfaction during learning force and motion concepts with the learning management. This may be due to the student-driven nature of inquiry-based and problem-based learning. The two principles inspired the students to actively interact with the subject, think critically, and create real-world connections (Schmidt et al., 2019; Thaochalee & Nuangchalerm, 2023). In this study, students can take control of their own learning, investigate areas of interest, and see the consequences of their efforts. The collaboration and a sense of success boost students' motivation and engagement them to nature of science and learning science through its nature (Safkolam et al., 2023). The study suggests that the integration of inquiry-based learning and problem-based learning can be an effective approach to teaching the concept of force and motion, resulting in improved student achievement in this subject area. Additionally, the use of this instructional method may lead to increased learning satisfaction among students.

4. CONCLUSION

To sum up, in this study we integrated the principles of instructional design in inquiry-based learning and problem-based learning to develop a learning management plan. After applying a learning management strategy built with the combination of integrated inquiry-based learning and problem-based learning, the participants' science learning success on the idea of force and motion improved. The implications of these results are significant for educators who are interested in improving student learning outcomes in science. This finding has important implications for educators seeking to engage students in meaningful and authentic learning experiences that promote deep understanding and critical thinking skills. Educators can consider incorporating elements of inquiry-based learning and problem-based learning into their teaching practices to support student learning and development.

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