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# Cambodian students' and teachers' perceptions of inquiry-based learning applied in physics classrooms at an upper-secondary level

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**Abstract**

This study was conducted to understand the practice of inquiry-based learning (IBL) in physics classrooms. The study was conducted in a high school in Phnom Penh with 11 participants. A qualitative research design was employed involving semi-structured interviews. The results of this study showed that, regardless of the challenges, the teachers who taught physics were convinced of the value of IBL as it contributed to developing students' knowledge and reducing their reliance on their teachers for answers. Students also enjoyed learning through this approach because it helped them understand scientific phenomena, scientific process skills, and soft skills. This study recommends that future studies should be conducted to observe or teach students using IBL to promote their learning outcomes.

**Keywords:** Inquiry-based learning; physics classrooms; perceptions; positive outcomes; challenges

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## Introduction

Education plays an important role in contributing to the development of every country (Heng & Sol, 2022). To improve the quality of education, relevant education sectors must take responsibility to ensure that the whole education system is served with acceptable quality. In this case, teaching methodologies are included as a part of improving education, and educators must show a strong commitment to using various teaching approaches in their classrooms. Inquiry-based learning (IBL) is a teaching approach that is gaining popularity in many developed countries. According to O'Connell (2014), several actions are underway to strengthen science education in European nations by focusing on IBL. In some countries, science education centers are offering educators the opportunity to train and develop confidence in teaching science subjects and inquiry-based science education (O'Connell, 2014).

As there is an increase in the number of New Generation Schools in Cambodia (Donaher & Wu, 2020), IBL begins to receive more attention as a part of the 21st-century skills for education. According to a study by Piten and Rakkapao (2018), in physics classes, teachers attempted to use IBL to provide learning opportunities for students to develop their cognitive competencies and understanding of both physics concepts and scientific practices.

MoEYS (2016) raised common challenges in using IBL such as formulating research questions, facilitating group work, providing feedback, responding to questions that teachers have not known the answers to yet, making a good report, and distinguishing between results and inferences. In addition, students with low prerequisite knowledge of content faced a great deal of challenges in implementing IBL in physics subjects at the upper secondary level (So, 2018). Moreover, Cambodian rural schools still face many challenges, including the shortage of teaching materials and aids, libraries, and experiment labs (Heng & Sol, 2022; MoEYS, 2018; Sem & Hem, 2016). These are the challenges in the Cambodian context and can be major barriers to the implementation of IBL in science education, especially in physics classrooms.

In fact, the concept of IBL has been incorporated in the revised teacher training curriculum, and it has been implemented in all Provincial Teacher Training Centers (PTTCs) since December 2010 and adopted in all Regional Teacher

Training Centers (RTTCs) since November 2011 (Japan International Cooperation Agency [JICA], 2012). JICA conducted a survey on the improvement of the quality of science lessons of Teacher Training College (TTC) trainers, and the results showed that both pilot school teachers and TTC teachers had some technical difficulties with IBL. Similarly, pre-service teacher training programs in Cambodia have suffered from the disconnection between theory and practice (Benveniste et al., 2008; Pich, 2017; Tandon & Fukao, 2015; Williams et al., 2016). According to Tandon and Fukao (2015), "The majority of Cambodia's teacher trainers fail to provide sufficient content mastery and student-centered pedagogy" (p. 39). This has resulted in teacher trainees' limited understanding of the IBL concept, and they felt hesitant to implement this student-centered approach in schools.

Against this background, this study intended to provide an understanding of the practice of IBL from the perspectives of Cambodian teachers and students. The findings provided essential information related to the implementation of IBL in physics classrooms in Cambodia, especially in the New Generation School context. This research showed teachers' and students' perceptions of IBL in their classrooms, explained the achievements and challenges of using IBL as a teaching method in physics classrooms, and revealed how Cambodian teachers and students feel about this approach. The study can serve as a reference for further studies on similar topics. The study was guided by the following research questions:

1. At what level do physics teachers know and use IBL in their classrooms?
2. How do physics teachers process IBL in their classrooms?
3. What are the positive outcomes that teachers and students obtain during and after learning through IBL?
4. What are the challenges that teachers and students face before, during, and after using IBL in classrooms?
5. What are teachers' and students' perceptions of the IBL approach?

## Literature review

### *A brief history of IBL*

IBL is initially a methodology in pedagogy that was developed during the

discovery learning movement of the 1960s. It responded to traditional forms of instruction where learners were required to revise information from instructional materials (Barrow, 2006). In fact, the philosophy of IBL existed in constructivist learning theories and was promoted by notable scholars such as John Dewey, Lev Vygotsky, Jean Piaget, and Jerome Bruner (Snowman et al., 2009).

In the 1960s, Schwab (1960) demanded that inquiry should be divided into three distinct levels. At the simplest level, problems were presented in a manual with descriptions of ways and means to solve the problems for the students. At the second level, problems were presented in a manual without specific methods and answers for the students. At the third level, problems, methods, and answers were left open for students. This was later formalized by Marshall Herron, the founder of the Herron Scale, in 1971 to evaluate a particular lab exercise through the amount of inquiry. It was a four-point scale that ranged from level zero to level three, describing in terms of students' degree of 'openness' (Herron, 1971).

### *Definitions of IBL*

The term IBL, which stands for inquiry-based learning, "is a learner-centered pedagogy in which students play an active part in the process of knowledge discovery or acquisition" (Fernandez, 2017, p. 2). IBL is a strategy in education in which students play a role as professional scientists in order to construct knowledge (Keselman, 2003). It can be characterized as a process of discovering new causal relationships among variables, and learners formulate hypotheses and test them by conducting experiments with observations or making observations without experimental process (Pedaste et al., 2012).

### *Characteristics of IBL*

There are many different explanations for inquiry teaching and learning and the various levels of inquiry depending on contexts. Tafoya et al. (1980) and Banchi and Bell (2008) clearly outlined four levels of inquiry, as shown in Table 1.

Table 1. *Levels of inquiry on teacher agency and learner autonomy*

| | Level 1 Confirmation Inquiry | Level 2 Structured Inquiry | Level 3 Guided Inquiry | Level 4 Open/True Inquiry |
|---|---|---|---|---|
| Problem | Teacher-led | Teacher-led | Teacher-led | Student-initiated |
| Procedure | Teacher-led | Teacher-led | Student-initiated | Student-initiated |
| Solution | Teacher-led | Student-initiated | Student-initiated | Student-initiated |

Similarly, Fay and Bretz (2008) described levels of the IBL rubric for comparing laboratory activities. The rubric is based on the theory that students' freedom is at distinguishable degrees, meaning that as the four levels of IBL ranged from zero to three, students are assigned increasing responsibility in laboratory activities with decreasing instructions from their teachers. The explanation of each degree is shown in Table 2.

Table 2. *Levels of the IBL rubric*

| Level | Problem/Question | Procedure/Method | Solution |
|---|---|---|---|
| 0 | Provided to students | Provided to students | Provided to students |
| 1 | Provided to students | Provided to students | Constructed by students |
| 2 | Provided to students | Constructed by students | Constructed by students |
| 3 | Constructed by students | Constructed by students | Constructed by students |

***IBL in physics subjects***

The University of Houston piloted an inquiry-based section of introductory physics as a part of the Department of Physics, intending to improve student success (Fairbank, 2016). According to Fairbank (2016), IBL helps students learn by participating in activities that reinforce physics concepts. It works by showing students with authentic questions and observations rather than showing concepts taught by teachers. This process promotes the active

engagement of students and has been presented as results in the increased learning and retention of ideas (Fairbank, 2016).

As mentioned earlier, the concept of IBL requires students to seek answers that respond to their research questions rather than receive direct instruction from their teacher, meaning that students must have the prerequisite knowledge to conduct their inquiry (Fernandez, 2017; Keselman, 2003). Recently, there have been a few studies about promoting student understanding of projectile motion using IBL (Piten & Rakkapao, 2018; So, 2018). One study was conducted in a high school in Tbong Khmum province with more than 100 Grade 11 students (So, 2018). It was found that students' limited background knowledge and inadequate teaching infrastructure were the main challenges of IBL implementation in the physics subject.

***Common views about IBL***

There are many factors that foster teachers to increase the use of IBL in their classrooms, and all of them are related to the benefits that students will obtain from this approach. IBL increases students' achievement significantly in mathematics and science, regardless of their lower levels of self-confidence and unfavorable backgrounds (Rocard et al., 2007). IBL also helps increase students' ability through learning with understanding, and this ability contributes to the use of their knowledge in new situations and contexts (i.e., transferability of knowledge) (PRIMAS, 2012). Students can also understand how scientists generate knowledge and how the current scientific knowledge was developed and produced (Walker, 2007; Rakow, 1986).

***Challenges of IBL implementation***

Although a number of problems could contribute to the limited impact of IBL in the classroom, teachers are supposed to play an important role that can make IBL happen in the classroom. Noticing obstacles and barriers to the use of IBL is very important in professional development programs (PRIMAS, 2012). Rakow (1986) and Walker (2007) found that teachers faced many problems when applying IBL in their classrooms. These included spending too much time on inquiry-based science, teachers' loss of control, risks (e.g., electric shocks), the inapplicability of some lessons, lack of resources, suitability for only high-

ability students, students' resistance to inquiry, lack of training and support, and difficulty related to assessment.

***Teachers' and students' perceptions of IBL***

Many teachers think that an inquiry is an effective learning approach that contributes to students' learning and active motivation (Eltanahy & Forawi, 2019). It was also found that inquiry instructions could benefit all students with varying backgrounds, helping them to be engaged in the process of learning. However, the inquiry takes time and a lot of preparation to ensure its achievement (Eltanahy & Forawi, 2019; Rakow, 1986; Walker, 2007).

Eltanahy and Forawi (2019) also found that many students expressed positive perceptions and attitudes toward the inquiry learning strategy. The IBL process changes their feelings about studying science and makes them excited to engage in science classes (Rubani et al., 2017), although they have some difficulties related to time constraints (Eltanahy & Forawi, 2019). Moreover, according to Baldock and Murphrey (2020), students also raised beneficial aspects of IBL that gave them opportunities to learn by themselves, gain knowledge, be different, have an experience, use prior knowledge, and get entertained.

A workshop called 'In-Country Training on Inquiry Based Science Education in Preparing for STEM Education' was arranged in Phnom Penh in 2017. The workshop was attended by 35 people, including junior high school science teachers, science teacher trainers, and Cambodian government officials whose work involved science teacher coaching. At the end of the training, the participants felt enthusiastic about improving their pedagogy competence and the quality of science learning in the classroom which met the goal of the workshop: Enhancing students' literacy in science (Agustiani, 2017).

Another study showed that even though Cambodian university students had limited previous exposure to IBL from their high school studies, they were highly receptive and adapted quickly to inquiry strategies (Dickinson et al., 2011). It was suggested that the longitudinal effects of inquiry on student success and teaching practices need examination. Cambodian pre-service

teachers should therefore shape their future practice of teaching through an inquiry-based approach (Dickinson et al., 2011).

**Research methodology**

A qualitative case study was employed in this study to achieve the research aims. Because the current study was conducted to explore students' and teachers' perceptions of the practice of IBL in physics classrooms, the researcher collected data from physics teachers and students in a New Generation School in Phnom Penh, Cambodia. Semi-structured interviews were deemed suitable for the nature of the current study.

The researcher selected six physics teachers who taught students at an upper-secondary level and five upper-secondary students by using a snowball sampling technique (see Tables 3 and 4 for the profiles of the participants). The teachers and students selected had experience with IBL, which is one of the constructivist learning approaches introduced to the New Generation School context (Donaher & Wu, 2020).

Table 3. *Profiles of the teacher participants*

| Participant | Gender | Age (year) | Qualification | Teaching experience (year) | Length of experience in high school (year) |
|---|---|---|---|---|---|
| Teacher 1 | Male | 28 | Bachelor | 5 | 5 |
| Teacher 2 | Female | 27 | Bachelor | 3 | 3 |
| Teacher 3 | Male | 25 | Bachelor | 3 | 1 |
| Teacher 4 | Male | 24 | Bachelor | 2 | 2 |
| Teacher 5 | Male | 24 | Bachelor | 1 | 1 |
| Teacher 6 | Male | 28 | Bachelor | 3 | 1 |

Table 4. *Profiles of the student participants*

| Participant | Gender | Age (year) | Grade | Teacher in charge | Class performance |
|---|---|---|---|---|---|
| Student A | Male | 16 | 10 | Teacher 1 | Outstanding |
| Student B | Female | 16 | 10 | Teacher 1 | Outstanding |
| Student C | Female | 16 | 10 | Teacher 1 | Low-performing |

| | | | | | |
|---|---|---|---|---|---|
| Student D | Female | 17 | 11 | Teacher 6 | Outstanding |
| Student E | Male | 17 | 11 | Teacher 6 | Low-performing |

The researcher used the snowball sampling technique to choose the student participants. This means that the teacher participants were asked to assist the researcher in identifying outstanding students and those who were low performing. Outstanding students were always good at doing activities in physics classrooms, and their study results were good. In contrast, students who were less active and often found it difficult to solve physics problems were identified as low-performing. Three outstanding students and two students with poor performance were selected. Average-performing students were not interviewed because the findings received from outstanding and low-performing students could sufficiently help the researcher synthesize the data and estimate the results for average students' learning through IBL.

As this study employed a qualitative research design, semi-structured interviews were used. According to Creswell et al. (2004), qualitative data consist of both semi-structured interviews and field observations which are analyzed by coding to develop themes and categories. The researcher had planned to use an observation instrument to triangulate the information. However, due to the COVID-19 pandemic, the school was closed, and the researcher could only use the semi-structured interviews through an online mode.

After the data were collected, the researcher tried to organize, transcribe, code, and categorize them. During the analysis, responses that were considered to best represent the data and comments on participants' perceptions regarding IBL were chosen. The interesting responses were directly quoted from the interview transcripts and were put into the findings section. Furthermore, the data were analyzed case-by-case carefully and confidentially. The findings were then compared with previous studies for the purpose of discussing them.

**Findings**

The objectives of this study were to examine physics teachers' understanding of the levels of IBL and understand how they applied IBL in the classroom. The study also aimed to explore the challenges and positive outcomes of IBL. In

addition, the study aimed to understand teachers' and students' perceptions of the use of IBL.

### *Teachers' understanding of IBL and its levels*

*The definitions of IBL*

IBL is a method that allows students to be active in finding answers to what they are curious about or asked by their teachers. In this method, students are encouraged to use their critical thinking to discover knowledge by themselves through thinking, planning, and creating. Two teachers provided similar meanings of IBL; that is, it is a methodology that is applied with students and makes them active in their studies. As Teacher 1 said:

> It is a methodology that is applied to students and makes them active in their studies. When a teacher uses IBL, students start to think and participate, and these activities are part of the student-centered approach. IBL requires students to test or confirm any theory in physics phenomena.

Another definition of IBL is that it focuses on asking questions, and students are encouraged to take responsibility for finding answers to the questions from various sources or experiments.

*The level of IBL*

Table 5. *Teachers' understanding of the levels of IBL*

| Participant | Teaching experience (year) | The teachers mentioned that IBL has… | The levels of IBL range from… |
|---|---|---|---|
| Teacher 1 | 5 | 4 levels | 0 to 3 |
| Teacher 2 | 3 | 4 levels | 0 to 3 |
| Teacher 3 | 3 | 4 levels | 1 to 4 |
| Teacher 4 | 2 | 4 levels | Not sure |
| Teacher 5 | 1 | 3 levels | Easy to difficult |
| Teacher 6 | 3 | Not sure | Not sure |

Table 5 shows the information that all participants knew about the levels of IBL. Overall, their understanding of IBL was mixed, indicating their limited understanding of the levels of IBL.

***How physics teachers apply IBL in the classroom***

Figure 1 explains the process of using IBL, which started by introducing inquiry questions. In this step, the participants explained how to introduce an inquiry question in different ways based on their experience. Four of them (Teachers 1, 3, 4, and 5) talked about the process of using IBL in experiments. For example, Teacher 2 shared her experience of using IBL in an online learning context. Teacher 6, however, admitted that he hardly ever used it.

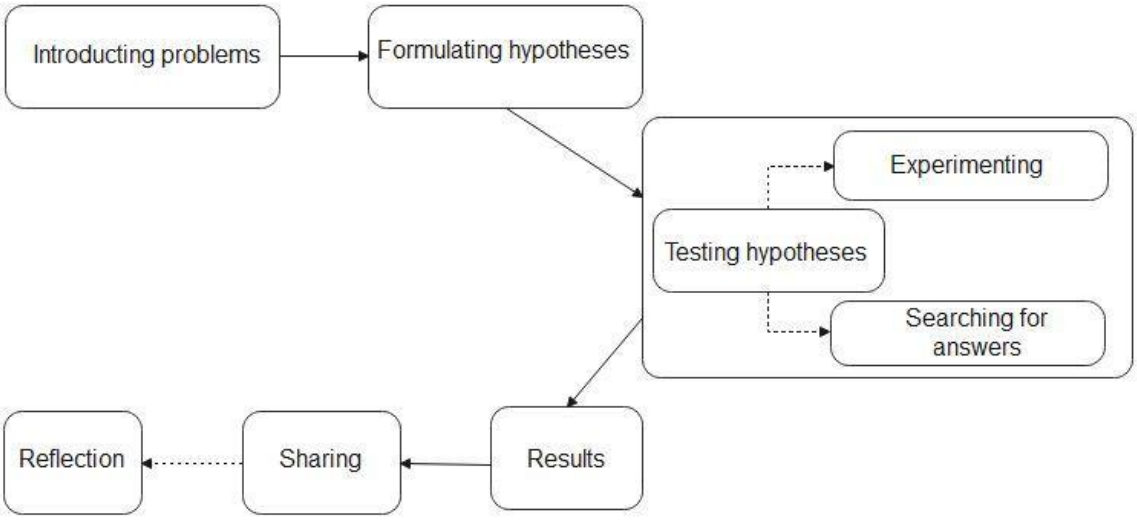



*Figure 1.* The IBL process based on the findings from the interviews

***Teachers' and students' roles in IBL***

All teachers were responsible for providing documents, problems, questions, instructions, and facilitation. Regarding students' roles, they followed their teachers' guidance and used their knowledge to find answers while having to be more active in the IBL process.

What the teachers mentioned was consistent with the responses from the student participants. According to Student A, his teacher facilitated group settings, hypothesis formulation, experiments, worksheets, and other problems. He added:

> Teacher's activities and students' activities remain the same. The teachers make an example for students, and the students just follow him. I think that students should take more actions.

***Positive outcomes obtained by the students after learning through IBL***

*Responses from the teachers during the implementation of IBL*

Students improved their physics content knowledge, participation, group work, and research knowledge. For example, Teacher 2 felt surprised by some answers from students that were better than her prepared answers. The students were good at searching on the internet to find the answers. Moreover, Teacher 3 said, "Students learned to do research using technology in connection to STEM education." In addition, Teacher 5 confirmed students' interest in learning through IBL. He said that students felt happy because they discussed, exchanged ideas, played roles, and participated actively in the class.

Regarding basic science process skills, students' improvement differed from one teacher to another. Two teachers (Teachers 1 and 2) said that students were good at observation and measurement. According to Teachers 2, 3, 4, and 5, students' abilities of observation, measurement, and using different tools improved depending on their frequency of doing them, levels of lessons, and their basic knowledge. Moreover, it was found that students also had improvements in creating hypotheses, drawing conclusions, and providing feedback.

Regarding advanced science process skills (or integrated science process skills), all responses from the participants showed that students were not good at drawing diagrams and explaining the diagrams or charts. As Teacher 2 said, only clever students could do it. Teacher 5 added that it worked best for students in higher grades. Moreover, all teachers mentioned that students tended to use inductive rather than deductive reasoning.

*Responses from the students during the implementation of IBL*

The students' responses showed that all students had more understanding of the content knowledge, and they tended to like learning physics. However,

outstanding students had more improvements in basic science and advanced science skills. Four students (Students A, B, D, and E) mentioned that they had improvements in teamwork and communication.

Regarding basic science skills, such as observing, measuring, and forming hypotheses, most students said that they could do observing. However, three of them (Students A, B, and D) mentioned that they had made measurement errors during hands-on experiments. As Student D said, "… the inaccuracy of measurement might occur in the experiments."

As for advanced science skills, two responses were received from Students A and D who said that they could draw diagrams and explain them. For other students (e.g., Student A), he did not express his ability to draw and explain diagrams as he studied through online learning. It is similar to a comment from Student C who said there were not many activities in the worksheets. According to Student E, he could not do them unless there were some explanations from the teacher. In addition, the students described their ways of solving physics problems in the form of deductive reasoning. As Student D mentioned:

> The clearest one is related to the second law of Newton [F = ma]. As mass and acceleration are given in the exercise, and force is questioned, it is easy for us to calculate the force by replacing the variables with the numbers given!

*Responses from the teachers after the implementation of IBL*

Students had improved after being taught through IBL. All teacher participants said that students developed their physics content knowledge, research skills, and teamwork. Teacher 2 added that students increased their critical thinking, and they had responsibility, independence, and confidence. Similarly, Teacher 3 mentioned that students developed their decision and confidence. He added that students could connect the lessons to real-life applications. He said:

> … for example, students learn the thermal expansion of solids when heated. Then, they observe an application of thermal expansion, showing that a sufficient number of gaps is provided

> between railway tracks joined by plates to avoid bending and causing fatal accidents.

Other teachers (Teachers 4 and 5) said that students also developed their skills in using experiment tools and improved their information and communication technology (ICT) skills.

*Responses from the students after the implementation of IBL*

The students were asked about their improvements after learning through experiments or IBL. The results showed that students remembered the lessons more clearly when they had learned them through experiments. Three students (Students A, B, and D) said that they gained new knowledge and started to enjoy learning physics. According to Student A's comments, he felt satisfied with working as a group and taking the role of a team leader. It was because he could share his knowledge with the team and learn from the team as well. Similarly, Students B, C, D, and E mentioned the importance of teamwork which helped them in learning through experiments. Moreover, all students mentioned their increasing research habits, while two students (Students A and D) said they had explored more physics concepts that they had learned from school in real-life applications. As Student D said:

> I learned about two types of centripetal accelerations… and we see them every day whenever traveling by car… We see road curves… We realize what kinds of accelerations are.

***Positive outcomes obtained by the teachers after teaching through IBL***

*During the implementation of IBL*

All teachers had improved their student management skills, mastered the content of the lessons, and improved their leadership skills. Moreover, the teachers increased their research knowledge and changed teaching styles from those without experiments to those with experiments. As Teacher 2 said:

> If the teacher does not provide students with appropriate responses, they will have no more trust in their teacher. So, the

> teacher must find the answer before students and read documents and sources as much as possible.

*After the implementation of IBL*

The teachers mentioned their improvements in different aspects. The improvements included content knowledge, research skills, and ICT skills. According to Teacher 1, "[IBL] helps increase knowledge of research continuously… When we assign projects for students, we must do more research in advance…" Moreover, he implied that his workplace is one of the factors that had helped him use IBL. He said:

> ... compared with other schools where there are not enough materials for experiments, we think teachers do not want to teach IBL.

***Teachers' challenges in the implementation of IBL and solutions***

*Challenges before the implementation of IBL*

Major issues that were raised included experiment tools, topics of experiments, worksheet writing, too extensive topics, and a shortage of materials. As Teacher 1 said, "I have problems with some topics of experiments. Of course, they are interesting, but they are hard in writing worksheets!" Forming inquiry questions is another issue. For example, a well-worded inquiry question used in IBL did not support lesson objectives. As Teacher 6 said, "Yes! Sometimes it is hard to create inquiry questions whether they meet the lesson objectives or not."

*Solutions before the implementation of IBL*

To deal with the topics of experiments, some teachers had to do more research, including the experiment process and tools. They needed help from other teachers or technical teams on how to write the experiment process, make students able to conduct the experiments, design experiment lesson plans, and prepare activities in advance for teaching. Regarding the shortage of experiment tools, they used the PhET Interactive Simulations website instead.

They also requested more teaching materials from the school or other stakeholders. As Teacher 1 said, "…but related to materials, we approached the school principal or KAPE (Kampuchea Action to Promote Education). It provides support for the teaching materials."

*Challenges during the implementation of IBL*

The teacher participants faced issues with experiment failure, student management, and time constraints. As Teacher 1 said, "Some students play with experiment tools and do not focus on experiments." Similarly, Teacher 3 added, "There are so many students in the classroom… I find it hard to control them."

*Solutions during the implementation of IBL*

To deal with naughty students, two teachers (Teachers 1 and 2) mentioned that they came closer to those students and approached them more often. Regarding experiment failures, they approached the students and supported them. As Teacher 1 said:

> … students tend to be naughty in the class; therefore, it requires teachers to control them so that they are not too playful. Once they are too naughty, the lesson objectives might not be reached.

Regarding time constraints, the responses from the teacher participants were to teach experiment lessons with a 2-hour time allocation. As Teacher 5 mentioned, "Regarding time, we conduct experiments when we have two hours because an hour is too short, and it is not enough for just installing the experiment tools."

*Challenges after the implementation of IBL*

The results showed that the participants faced different issues. Some of them could not receive the experiment report from all students because some groups had failed to experiment. This resulted in delays in feedback and reflection. Some teachers received erroneous data after the experiment, and experiment tools were broken by students during the experiment. Others had problems

with test design or issues with the IBL techniques, for example, asking questions after the experiment.

*Solutions after the implementation of IBL*

To deal with experiment reports and incorrect data, the teachers had to think and check experiment processes or conduct experiments again. They also discussed the problems with their colleagues. Similarly, the solution to the test design and questioning techniques was that the teachers needed enough time to develop them and check the questions again.

Regarding the safety of the experiment, the teachers recommended that students should be careful with experiments by wearing gloves or using fabric and setting roles clearly during the experimental procedure.

***Students' challenges in the implementation of IBL and solutions***

*Challenges during the implementation*

The results showed that the students faced similar problems: the lack of teamwork collaboration, time management, fear of experiments with electricity, and difficulties in hypothesis formulation.

*Solutions during the implementation*

When teamwork was not collaborative, outstanding students tried to motivate their members to join class activities. As Student A said:

> I explained the importance of teamwork to them and encouraged them to speak up. I explain more if they don't understand any part. If they don't share ideas, I don't know whether they understand or not. If they participate in the groups, I can help them.

As for the time constraints, what the students could do with this was to be ready for the experiment without delaying time. To deal with formulating hypotheses, according to Student B, she needed to understand the relationship

between variables through teaching explanations so that she could make them, or she could take time to conduct research.

*Challenges after the implementation*

The students seemed not to face any problems unless they did not understand the lesson or homework. Student A said that it depended on the level of topics for homework. Some topics were difficult; therefore, he had to spend more time on them. He said, "…such an experiment has been conducted, so it is easy to explore more... through Google… other topics are quite difficult… I need a lot of time learning all aspects."

***Teachers' perceptions of IBL in physics classrooms***

The teacher participants had positive thoughts about IBL. Some of them said IBL is an effective method of constructivist teaching and learning. As Teacher 1 said, "IBL helps students to be active and develop their knowledge of physics phenomena deeply. They remember the physics formula and explore physics phenomena." IBL also encourages students to use their knowledge and apply it in their real-life applications and solve problems that happen in their society. Students are motivated and oriented in science, engineering, or artificial intelligence. Before they begin studying at universities, through IBL, they gain basic skills such as teamwork, research, and how to do assignments.

Moreover, Teacher 3 claimed that Cambodia could improve its education to be like that of Singapore if teachers could apply IBL in the classroom. IBL helps teachers improve and extend their knowledge through research, thinking, and analysis. It is a very good method that encourages changes from the traditional method to learning through finding answers, conducting test experiments, and verifying what teachers have just said.

***Lesson suitability with IBL***

All participants similarly mentioned that IBL is very suitable to be used in upper-secondary classrooms. IBL can be applied to all topics, but experiment topics, finding formulas and principles, and theory confirmations were the best for students to learn through this approach. For example, Electricity and

Thermodynamics sectors are very suitable with the IBL application because they are easier to conduct experiments than other parts like Waves and Mechanics, as raised by Teacher 3, who said "Electricity and Thermodynamics are the easiest for conducting experiments. Regarding Waves and Mechanics, the experiments will need to be more extensive."

***Students' perceptions of IBL in physics classrooms***

All students were satisfied with learning through experiments in the IBL context. They remembered and gained more understanding of physics. IBL also encouraged them to enjoy learning physics courses. They could study in groups, discuss, collaborate, and exchange ideas. Moreover, they could learn, find answers, and conduct research by themselves. They received various information from many sources, and the information was significant for developing their inquiry skills. As Student D mentioned:

> Learning experiments are good because students can have questions for teachers, and the teacher knows how well students understand lessons. Moreover, I can practice experiments, write reports, and receive feedback. This helps me understand the process clearly.

However, there were some negative effects of using IBL. Student A raised his concerns about teamwork. He said each member had different ideas, so disagreements were possible in the team.

**Discussion**

Based on the findings, IBL is a method that allows students to be active in finding answers to what they were curious about or asked by their teachers. The students were encouraged to use their critical thinking to discover knowledge by themselves through thinking, planning, and creating. The findings are consistent with the results from previous research. For example, a study by Hussain et al. (2011) found that an inquiry enabled students to conduct observations, come up with questions, and examine instructional materials and other sources of information. The findings of this study also showed that the students used tools to collect, analyze, and interpret data; propose answers;

explain and make predictions; and discuss the results. These are consistent with the statements by some researchers who said, in IBL classrooms, students played an active part in the process of knowledge construction, and they worked as professional scientists to discover new knowledge (Fernandez, 2017; Jong & Joolingen, 1998; Keselman, 2003; Pedaste et al., 2012).

Regarding the levels of IBL, the responses from the teachers were slightly different. Two teachers (Teacher 1 and 2) mentioned that the levels of IBL ranged from 0 to 3, matching what Fay and Bretz (2008) found. Teacher 3 thought that IBL was ranked from level 1 to 4, which is consistent with what was found by Tafoya et al. (1980) and Banchi and Bell (2008) who examined teachers' understanding of IBL and its levels.

In IBL classrooms, students were motivated to work with their peers or classmates in the process of knowledge discovery rather than being told directly by the teachers. Teachers' roles in IBL classrooms were not to provide knowledge to students. Instead, they helped students find the answers. The results of this study are in line with Fernandez (2017) who stated that students who learned through IBL took an active part in finding and constructing knowledge. Similarly, Jong and Joolingen (1998) also showed that learners participated actively and were responsible for discovering new knowledge in IBL classrooms.

The present study revealed that students improved their physics content knowledge, participation, group work, and research skills. They gained more understanding of content knowledge, and they tended to like learning physics. These findings are in line with Rocard et al. (2007) who found that IBL gave students opportunities to develop a wide range of complementary skills such as group work, writing in verbal expressions, problem-solving skills, and other cross-disciplinary abilities. Moreover, this study's findings corroborate those of Walker (2007) and PRIMAS (2012) in terms of IBL efficiency, meaning that IBL helped students understand and remember content knowledge of science better, and they found maths and science subjects to be more interesting and exciting.

IBL also benefited the teachers in terms of student management, mastery of lesson contents, and leadership skills. Moreover, they could draw students'

attention well. For example, when they used videos, simulations, or on-hand experiments, students were interested in those activities. In addition, IBL fostered teachers to increase their research habits. These findings revealed a significant concept by Blessinger and Carfora (2015), saying that IBL enhances teachers by expanding roles from specialists of isolated subject matter to collaboratively instructional leaders who "are not just responsible for disseminating information, but also responsible for designing effective learning environment and cultivating the development of the whole student (e.g., cognitively, psychologically, socially)" (p. 9).

Despite these benefits, the participants faced issues related to a limited understanding of IBL, experiment topics, and experiment tools; a shortage of teaching aids or materials; experiment failure; and issues with student management, time limitations, late experiment data, inaccuracy in the collected data collected, broken experiment tools, and assessment. The challenges mentioned by the teachers seem to be the same as what were mentioned by the participants in studies by Walker (2007) and Romero-Ariza et al. (2020). For example, the study by Romero-Ariza et al. (2020) revealed teachers' frustration with experience, group work management, time constraints, resources for IBL, the demand for IBL curriculum, assessment, and accountability. In Cambodia, the limitations of significant teaching aids, resources, and infrastructure, such as textbooks, libraries, electricity, laboratories, teaching materials, teacher's guides, reference books for teachers, tables, and school buildings, are still hindering the education development in the country (MoEYS, 2018; Sem & Hem, 2016).

Regarding the challenges facing students in IBL, they included a lack of teamwork or collaboration, meaning that their classmates did not participate enough and did not care or see IBL as relevant to their lives. This finding is similar to what was found by Lawson (2000). The students in the present study also lacked time management, and this seems to be in line with what Romero-Ariza et al. (2020) and Walker (2007) suggested; that is, there will be a need for sufficient time if teachers wish to use IBL effectively in the classroom. Moreover, some activities in IBL such as experiments with electricity might not be safe for students. Teachers must, therefore, be careful and make sure they provide instructions clearly before experiments. In this case, only high-ability students can learn through IBL. As Lawson (2000) and Piten and Rakkapao

(2018) suggested, some students lacked background knowledge for inquiries. Therefore, efforts made by teachers and students are required to ensure that IBL classrooms are running well.

## Conclusion and implications

The findings of this study showed that the participants had positive attitudes toward IBL. Based on the teachers' perceptions, IBL is an effective method of constructivist teaching and learning. In addition, the student participants were satisfied with learning through experiments in the IBL context. They also remembered and gained more understanding of physics content and were encouraged to enjoy learning physics courses. In addition, they were familiar with the culture of studying in groups with substantial discussion, collaboration, and feedback. Moreover, IBL encouraged the students to learn, find answers, and conduct research by themselves. They learned about various information from many sources, and the information was significant for developing their inquiry skills. Thus, this study concludes that once IBL becomes more popular and increases its application in the classroom, the quality of education will be improved through students' constructivist learning styles.

Meanwhile, IBL encourages students to create new learning styles through inquiry, analysis, evaluation, innovation, and creation. This method needs considerable support for its successful application. Therefore, this study has the following implications:

### *Motivation*

It is important to focus on motivating students and teachers. Motivation is a significant part of promoting IBL in schools. School principals should motivate and encourage teachers in any aspect to use IBL in their teaching. The teachers themselves should also motivate students to learn and perform activities that are well-prepared in this method. These actions will increase the application of IBL in the classroom regardless of its challenges.

### *Professional learning communities*

As IBL has four levels, it may not be easy to implement in different contexts. Thus, professional learning communities (PLCs) should be established to contribute to IBL practices. Teachers, for example, should join PLCs to plan activities and formative assessments for IBL through Claim, Evidence, and Reasoning (CER) Model. PLCs can also help the teachers discuss their problems and share experiences related to their teaching profession to help improve their teaching ability in IBL.

### *Physical aids and professional development*

Having sufficient teaching materials, experiment tools, and internet access can support the possibility of IBL practice in schools. School principals should consider this factor by allocating enough budget to support the teaching of IBL and finding more aid from various stakeholders, such as local non-governmental organizations or international organizations, to help teachers with the diversification of teaching and learning materials and their professional development. Professional development activities for teachers should focus on teaching methodologies and the development of relevant subject content knowledge. All of these actions can ensure the sustainability of IBL implementation in schools.

### *Limitations and suggestions for further studies*

This study was conducted in only one school in Phnom Penh city; therefore, the research results at one school could not be generalized to all schools in Cambodia. Moreover, due to the small sample size, the researcher could hardly make inferences about this sample to a population of students and teachers who were in the upper-secondary level in the selected school. These limitations should be addressed by future research.

As all schools in Phnom Penh were closed due to the outbreak of the COVID-19 pandemic, the researcher could not conduct the classroom observation method as he had planned at the beginning of the data collection procedure. Therefore, the researcher could not see whether the responses from the participants were consistent with their classroom activities.

Therefore, it is recommended that future researchers who wish to conduct research on similar topics should try to conduct real-class observations to get more specific information. Moreover, quantitative or mixed-methods research employing a large sample size should be conducted. Specifically, other researchers should use some experiments to explore similar research topics. Future researchers who are teachers should also teach their students by themselves using the IBL approach and then assign tests for them. The results obtained may be more specific and reliable.

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