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The effectiveness of integrated science, technology, engineering and mathematics project-based learning module

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ABSTRACT

Physics is a tricky subject to learn, especially when it comes to students applying physics knowledge to the real world and its application. This paper aims to study the effectiveness of the integrated science, technology, engineering, and mathematics project-based learning (iSTEM-PjBL) module in physics on students' belief-specific categories, i.e., real-world connection, conceptual connection and applied conceptual understanding. This research used the quasi-experimental model, employing a two-group pre-survey-post-survey design. Quantitative data were collected using the Colorado Learning Attitude about Science Survey (CLASS) instrument at two selected schools in Sabah, Malaysia, and Seoul, Korea. The sample size was 88 from Malaysia and 66 from Korea who learned classical mechanics. The students were divided into two groups, respectively, i.e., the experimental group (Malaysia=44, Korea=33) and the control group (Malaysia=44, Korea=33). Participants in the experimental group were intervened with the integrated STEM-PBL physics module, whilst participants in the control group learned physics through a conventional approach for eight weeks. Participants in both groups were then administered a pre-survey before and post-survey after the intervention. This research showed that the integrated STEM-PjBL physics module significantly improved students' real-world connections, conceptual connections, and applied connections after the intervention. The implications and suggestions were also discussed to extend the research further.

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1. INTRODUCTION

The fourth industrial revolution (4.0 IR) has changed how people live, work and interact with each other, creating ripple effects on economies, institutions, and societies. In coping with the fast-changing structures in the fourth industrial revolution, individuals must equip themselves with advanced knowledge and skills to benefit from these changes. In addition, the fourth industrial revolution demands people who can generate new ideas and innovations and the ability to use hi-tech gadgets since computers and digitization replace most job markets. In fulfilling the needs of the fourth industrial revolution, education plays a vital role in generating students with advanced knowledge and skills to ensure they stay relevant in future job markets.

In recent years, many countries have adopted science, technology, engineering and mathematics (STEM) education [1]. As a result, STEM education becomes progressively recognized as a critical driver of opportunity to equip students with STEM knowledge and skills to face the challenges of the fourth industrial revolution. STEM education is based on educating students in four specific disciplines, i.e., science, technology, engineering, and mathematics, into a cohesive learning paradigm based on real-world applications [2]. Proponents of STEM education suggest that STEM integration is the best approach for STEM instruction [3]–[7]. Teaching STEM in a more integrated way with the inclusion of real-world problems can make learning STEM subjects more relevant and less fragmented [7], [8]. Since problems that related to real-life situations are multidisciplinary and required the interconnection of multiple STEM concepts to solve the problems [4], [9]. Integrated STEM education approach often prioritized two or more STEM disciplines for developing related STEM knowledge and skills and the other disciplines act as a vehicle to deliver the learning process. Integrated STEM education approach commonly uses engineering and technological design processes to help students develop science and mathematics knowledge and skills [9]–[11]. An authentic integrated STEM education approach has the potential to aid students in drawing conclusions based on STEM knowledge and skills to solve problems in daily life situations [7].

Many countries adopted STEM education as it was proven can promote students with 21st-century skills that could cope with the challenges of the fourth industrial revolution [12]–[15]. Malaysia's government, for instance, introduced the Malaysian Education Blueprint (2013-2015) in 2013, which intends to polish existing science and technology education standards [16]. The introduction of the blueprint is a quantum leap in Malaysia's education ecosystem, showing how serious Malaysia's government is to ensure it becomes a developed nation through a STEM-literate society with a highly skilled workforce and qualified STEM employees that contribute to the country's economy [17]. The same situation happens in Korea. In 2011, The Korean Government brought up the science, technology, engineering, art and mathematics (STEAM) education policy nationwide as a preparation to STEAM-literate their primary and secondary school students [18]. From here, their ultimate objective is to produce students who can initiate new ideas, models, or products created by STEAM competencies purposely to breed quality STEM-employed, highly technological literacy nations and skilled citizens to bolster the national economy agenda [19]. The difference between STEAM education in Korea and STEM in other countries is the addition of art as another discipline that counts [18].

Despite the increasing attention to STEM education worldwide, many countries have a significant challenge in implementing STEM education in classroom settings [9], [20], [21]. Many educators have dilemmas and uncertainty about what constitutes STEM education and what STEM education means in terms of curriculum and student outcomes [21], [22]. One of the reasons that contribute to issues in STEM education, there is no single and concise definition of STEM [4], [6], [10], [20]. STEM education still needs a clear consensus about the instructional approaches for teaching STEM [11]. STEM teaching can take various forms depending on the type of instructional approach used, whether silo, embedded or integration [23], [24]. Different educational approaches in STEM cause widespread confusion and misunderstandings among teachers in choosing the appropriate educational approach, as each approach offers unique learning objectives that can enrich and differentiate the delivered content [9]. Therefore, one of the constructivist approaches, project-based learning (PBL), is fit in STEM since it promotes 21st learning skills, e.g., critical thinking, creativity, collaboration, information literacy, and leadership [25] in their assessment.

In this research, knowing students' capability to connect knowledge in the real world is essential. The affective component of interest refers to positive feelings accompanying engagement, and the cognitive element of interest refers to perceptual and representational activities related to engagement [26]–[28]. Meanwhile, the individual predisposition is characterized by the interaction between a person and a particular content [26] or an object [27]. According to Rotgans and Schmidt [29], interest and knowledge acquisition are interrelated, and there are three different possibilities for the relationship between interest and knowledge. First, interest can be the cause of knowledge acquisition, and knowledge is responsible for an increase in interest or interest and knowledge influences each other reciprocally. Interest has been recognized to be a powerful influence on learning [26], [29], [30] and generates positive effects on the learning processes and learning outcomes [27], [29], [31], [32]. Research has shown that interest contributed to a significant impact on academic achievement [29], course selection in school, choice of majors and careers as well as lifelong engagement [26], [28]. Therefore, to increase students' interest in learning, teachers should instruct according to students' preferences in mind.

The learning process should start with the arousal of curiosity, and learning should be seen as relevant and fun, making mundane tasks more challenging and supporting students in their studies [29]. Therefore in this research an integrated STEM-project based learning was developed using ADDIE instruction, as to students need to rise up their beliefs of physics particularly in making real-world connection with the knowledge and skills learned to be applied in real-life situations and complex thinking environments [30]; conceptual connection where it refer to the process of establishing connections either between disciplines, ideas or concepts on related content [33] and applied conceptual understanding. Conceptual understanding is the ability to identify the fundamental concepts in various representations and applications [34]. Applied conceptual understanding refers to the ability to apply learned concepts to interpret problems [35]. These elements were critical to benefit students with 21st-century skills. Therefore, the aim of this research is to study the effectiveness of the integrated STEM-PjBL physics module in learning classical mechanics and whether it can improve students' real-world connection, conceptual understanding, and applied conceptual understanding among Form 4 and second-year high school students of South Korean students.

The main objective of this research is to study the effectiveness of integrated STEM-PjBL physics module on students' real-world connection, conceptual understanding, and applied conceptual understanding among Form 4 students and second-year students. The next objective of this research is to determine students' real-world connection, conceptual understanding and applied conceptual understanding between the experimental and control groups on the post-survey for Form 4 students and second-year students. Thus, two hypotheses arise, which are the null hypothesis 1 (H_{01}): there is no significant difference in students' beliefs in specific categories, i.e., real-world connection, conceptual understanding, and applied conceptual understanding between presurvey and post-survey for Malaysian (i.e., Form 4) students and Korean (i.e., second-year) students. Then, followed by the null hypothesis 2 (H_{02}): there is no significant difference in students' beliefs in specific categories, i.e., real-world connection, conceptual understanding, and applied conceptual understanding, between the experimental group and control group on the post-survey for both Malaysian (i.e., Form 4) students and Korean (i.e., second-year) students.

2. LITERATURE REVIEW

2.1. STEM and integrated STEM

Integrated STEM education is a blended approach that removes the barriers among science, technology, engineering, and mathematics disciplines and amalgamates the four disciplines into a subject learning area [4], [21]. According to Stohlmann *et al.* [36], integrated STEM education involves combining the domain knowledge and skills of each STEM discipline into integrated content and skills as one cohesive entity. Integrated STEM education is an innovation with various instructional models [23], [37] in which can exist in various forms and not necessarily include all four STEM disciplines [36]. Sanders [10] described that integrated STEM education can be carried out at school by combining two or more STEM subject areas or between a STEM subject and one or more other school subjects but the learning outcomes should be at least one of the other STEM subjects. Moore *et al.* [38] defined integrated STEM education as an approach that combines some or all four STEM disciplines into a lesson with the connections on real-world problems where the learning objectives are primarily focused on one STEM subject, but contexts can come from other STEM subjects. Kelley and Knowles [1] described that integrated STEM education involves two or more STEM domain knowledge but is bound by STEM practices within an authentic context to locate connections between STEM subjects in enhancing student learning.

In this study, integrated STEM education is defined by combining the definitions that have been stated by Kelley [1] and Moore [38] to suit the need of the study. Since there is no single and concise definition of STEM [4], [10], [20] and STEM education community needs to resolve the definition of STEM acronym to prevent STEM education failures in many countries [7]. Therefore, the researcher of this study defines integrated STEM education as interdisciplinary approach that combines four STEM disciplines as one cohesive entity and the learning objectives primarily focused on one STEM subject in which two or more STEM domain knowledge bound by STEM practices within an authentic context to establish connections between STEM disciplines in enhancing student learning. The newly constructed definition of integrated STEM education is in line with the context of STEM education in Malaysia [17] and Korea [18] in which the educational curriculum in both countries have focused on STEM integration to transform science and mathematics education in secondary education.

2.2. Belief specific category-real world connection

Real world connection refers to the ability in making a connection with the knowledge and skills learned to be applied in real-life situations and complex thinking environments [39]. Students bring personal experiences with them into the classroom and have their own personal interpretations of the world that influence how the learning process in the classroom occurs [40]. Students are more engaged when the learning process is connected to real-life contexts, addresses topics that are relevant and applicable to everyday life and equip them with practical and useful skills [3], [37]. Learning that involves real-world examples is essential and can offer students an opportunity to reflect and make connections with prior knowledge and experiences [37]. In addition, learning that involves real-world problems can introduce students to the concepts in finding solutions to authentic, real-world problems [41]–[43]. Dealing with real-world problems can make the knowledge acquired relevant and help students make connections and apply their knowledge and skills to real-world situations [8], [43]. Adopting instruction with real-world relevance can spark students' desire to explore, investigate and understand their world [39]. Teachers can provide students with learning activities that focus on real-world contexts to learn the specific content matter such as through integrated STEM education approach

[5], [11], [44], [45], hands-on activities [41], ill-defined tasks paired with well-defined outcomes [43] and constructivist learning approach [3] can lead students to immerse with the world around them, spark their curiosity, have engaging learning experiences and to be active participants. Therefore, abilities to make connections with real-life situations are essential for students to get them ready for a future career as these abilities are extremely demanded by the industries that want a skillful individual to work in complex thinking environments [39].

Abilities to make real-world connections in learning physics allow students to link physics concepts and their real-world experiences [46]. Students who believe learning physics are relevant and useful in a wide variety of real-world contexts can connect the physics concepts with real-life experiences and effectively explain how the world works [46], [47]. In addition, students who are interested in learning physics can relate the physics content with real-world applications [41]. Having an interest in physics and frequently connecting physics content in everyday life experiences can influences students to develop their conceptual understanding of physics and become more science-literate [41], [48]. In contrast, students who have difficulties in learning physics often view physics knowledge as disconnected from everyday thinking. According to Wieman and Perkins [49], teaching classical mechanics in terms of general concepts and abstract presentations can lead students to think that the physics concepts learned in class do not apply to real-world applications. Effective physics instruction can encourage students to connect with what they learn in class to be applied in real-world situations [41]. Real-world connection in physics is one of the belief-specific categories and can be measured by using CLASS based on the subsets of four items in CLASS [50], [51].

2.3. Belief specific category-conceptual connections

Conceptual connections refer to the process of establishing connections either between disciplines, ideas or concepts on related content. Conceptual connections are related to epistemological beliefs and interests. Students with sophisticated beliefs and higher interests tend to make conceptual connections and maintain that connection for a more extended time [30], [52]. Conceptual connections allow students to relate information to other available information [26], make a connection in what they learn in class with real-world applications [51], [52], use prior knowledge combined with their understanding of concepts to reason and speculate solution towards particular problem [31], [53] and consolidate prior knowledge to construct new knowledge [32], [33]. Providing instruction that promotes conceptual connections among students can open up possibilities for integrated content experiences that make students think that the concepts and facts learned in class are interrelated to each other and relevant to the real-world applications [31]. As a result, students become more involved and engaged in learning [54] and remember the learning content for a longer period of time [55].

Conceptual connections in physics refer to the process of drawing out connections between physics ideas [46]. Conceptual connections allow students to conceptualize physics as a coherent structure [46], recognize physics theories or laws learned from different physics lessons as being interrelated [31], connect physics equations with physical situation associated with it, visualize the physical situation, connect prior knowledge about physics concepts to construct new physics knowledge [56] and make students aware of the connections between prior knowledge and its application in real-life situations [57]. Students who are able to make conceptual connections in physics can generate inferences from observations [58], create hypotheses between variables [3], and resolve misconceptions about physics concepts [59]. Physics instruction should encourage students to use prior knowledge to connect with new ideas in order to increase conceptual connections during the learning process [33], [58]. Hence, teachers need to help students make conceptual connections between physics concepts by providing effective physics instruction [60]. Conceptual connections in physics is one of the belief-specific categories and can be measured by using CLASS based on the subsets of six items in CLASS [50], [51].

2.4. Belief specific category-applied conceptual understanding

Conceptual understanding is the ability to identify the fundamental concepts in various representations and applications [32]. Applied conceptual understanding refers to the ability to apply learned concepts to interpret problems [33]. Every student has a distinct ability to apply their conceptual understanding to interpret new insights and experiences in a learning situation [32]. Students with higher conceptual understanding often engage in deeper learning [31] and more likely to have various abilities that include able to explain a vast range of phenomena [49], [61], discover and resolve intuitive misconceptions [62], acquire information about concepts from the environment and construct new knowledge by restructuring existing knowledge through both an individual process and social activity [32]. In contrast, students with lower conceptual understanding tend to have difficulties in understanding new concepts and facts [63] and more likely to believe that learning merely involves memorization of facts [32], manipulation of formulas and learning are less desirable [48]. Research has shown that epistemological beliefs has direct effect on students' conceptual understanding [50], [64]–[66]. Students who hold expert-like beliefs are more likely to have a higher conceptual understanding than students who hold novice-like beliefs are more likely to have a lower conceptual understanding [65]. In addition, knowledge about a subject matter becomes the foundation for students to understand new concepts and facts [62], [63]. Hence, teachers need to help enhance their students' knowledge about content subject learning areas to facilitate conceptual understanding [32].

Physics conceptual understanding refers to the ability to understand physics concepts, associate a situation with physics concepts, reason and explain the situation further with physics concepts [32]. In physics, applied conceptual understanding is related to the ability to apply physics concepts in explaining various phenomena in different situations and interpreting various physics problems [32]. Physics conceptual understanding is essential for students to master in order to learn physics better, able to apply physics concepts and principles in various situations [56], [66]–[68] and succeed in physics [61]. Students with higher physics conceptual understanding tend to view physics knowledge as a coherent system of ideas, have strongly organized physics knowledge, have the consistency of their answer across different problems [62], able to apply physics concepts in a particular situation, solve complex physics problems, transfer physics knowledge to other contexts, explain phenomena qualitatively with physics processes [32], [56], retain new physics knowledge longer [63], have greater ability to make decisions when come to deal with physics problems and become critical in every situation [47]. Meanwhile, students with lower physics conceptual understanding tend to experience difficulties in developing conceptual understanding as their conceptions remained unclear and inconsistent, memorizing facts. Hairan *et al.* [63] explained their conceptions with the definition of physics concepts or mathematical formulas, unable to relate their conceptions with real-life situations [48], have weakly organized and fragmented physics knowledge, retain misconceptions, use formula manipulation and misconceptions to solve physics problems [32], [69], unable to make decisions when come to deal with physics problems [65] tend to resist accepting new knowledge, need longer time to refine their misconceptions [70], and more likely to face challenges to succeed physics [61].

3. THE INTEGRATED STEM-PROJECT-BASED LEARNING PHYSICS MODULE

The integrated STEM-project-based learning (iSTEM-PjBL) Physics Module was structured and established following a thorough process by using ADDIE instructional design model. It consists of five rigid phases, e.g., analysis, design, development, implementation, and evaluation phases. Each of these phases has undergone a comprehensive process to ensure the quality of the module: i) The analysis phase - four different analyses are taken, i.e., thematic analysis, needs analysis, needs analysis from teachers' perspective, and needs analysis from students' perspective; ii) The design phase involves identifying learning objectives; iii) The designing and the iSTEM-PBL physics module, elements of STEM in the integrated STEM-PBL physics module, reviewing the iSTEM-PBL physics module design and evaluating the module outcome [71]; iv) The development phase, this includes the development of the iSTEM-PBL physics module, expert validation of the iSTEM-PBL physics module, and pilot study; v) The evaluation phase, where the formative and summative evaluations were done.

The iSTEM-PBL Physics Module involves learning activities that stimulate students' real-world connections, conceptual understanding and applied conceptual connections. However, only for the experimental group, in eight weeks, they must execute these activities altogether. In groups (3-4 students), students faced a provided scenario at first; they must then suggest solutions or ideas to address the learning issue. In the module, two projects were well prepared, i.e., the Egg Drop Project and the Spaghetti Bridge Project. However, only the experiment groups of Form 4 students (Malaysia) and second-year students (Korea) got the modules, respectively.

The previous PjBL model was designed and developed by the Buck Institute of Education [72] and was the primary reference for creating the current iSTEM-PjBL Physics module content. In this module, the learning objectives were integrated into the PjBL nine steps to meet the ultimate learning objectives of the module. Students had to accomplish all nine steps of learning activities, step by step, for both projects. They had to complete each project within four weeks before moving to the next one. The nine steps in implementing iSTEM-PjBL activities provide guidelines for students to develop science process skills. i.e., students' real-world connections, conceptual understanding and applied conceptual connections.

Step 1 is build the culture; In step 2 (group setting), students developed observation skill by planning events in implementing iSTEM-PjBL activities chronologically after receiving details about the activities. In step 3 (essential question), students developed communication skill by brainstorming and communicating on draft solutions about the essential question and presented the draft solutions through sketches. Besides, students developed classification skill by choosing the best design to be developed as a final product by considering the manipulative, responding and constant variables. In step 4 (sustained inquiry), students developed valuing skill by finding additional information about related physics concepts and relating the concepts into their design. Besides that, students developed experimentation skill by constructing prototype and carried out a simple experiment to test the prototype. Students also developed interpretation skill by interpreting the results from the experiment and consequently drawing conclusions to improve the design. In step 5 (decision making), students developed prediction skill by securing the ultimate design to be developed as final product after discussion was made in the group.

In step 6 (execute the solution), students developed communication skill by constructing the final product as planned. In step 7 (public product), students developed measuring skill by measuring physical quantities by using appropriate instruments and avoid errors when taking measurements. Besides that, students developed experimentation skill by carrying out a simple experiment to test the final product. Students also developed interpretation skill by drawing conclusions based on the results from the experiment. In step 8 (assess student learning), students developed forming questions and hypotheses skills by solving physics problems in the module. In step 9 (evaluate the experience), students developed communication skill by sharing their opinions, beliefs and attitudes about the STEM-PjBL activities. Figure 1 shows the summary of the study procedure. Additionally, Figure 2 shows the link to the STEM-PjBL.

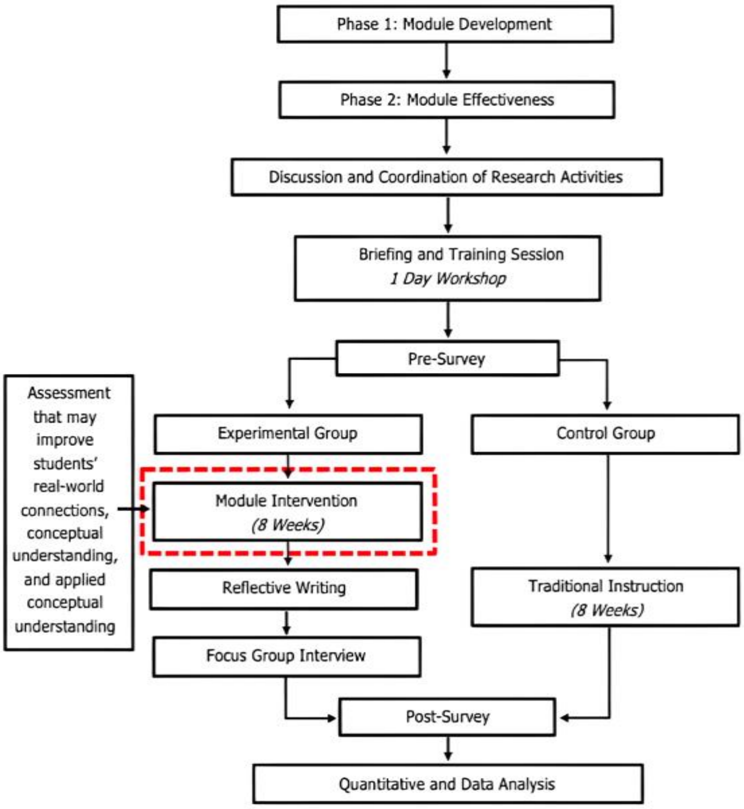

Figure 1. The summary of the study procedure

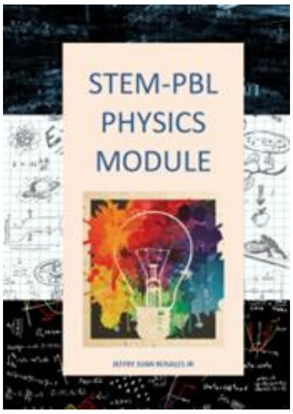

Figure 2. The interface of the iSTEM-PjBL

There are study and writing done concerning how students make a connection with what they learn in physics to the real world or simply correlate what is the conceptual connection, e.g., making connections with the real world through using a problem-based learning approach at the college level [73]; a physics teaching approach known as 5E Instructional Model supports that supports real-world science [74]; determine the contribution of teaching practices with real-life content (TPRLC) in daily life to the levels of pre-service teachers' skills to associate physics subtopic, i.e., the light and sound learning areas with daily life [75]; learning science through real-world contexts to arrest waning student interest and participation in the enabling sciences at high school and university [76]. However, no researchers have yet to discuss these three presence elements in-depth, i.e., real-world connection, conceptual connection, and applied conceptual understanding, particularly comparing two nations. Therefore, this research highlighted these elements to know more about secondary students' capability to connect what they learn in the classroom to the outside world and how it may boost their belief in physics and learning physics at the secondary stage.

4. RESEARCH METHOD

The quasi-experimental research design was used to collect the quantitative data. This research used the two-group pre-survey-post-survey of the quasi-experimental research design. The research design also allowed the researcher to draw more explicit conclusions about the causal relationship between the independent and the dependent variable. The rationale to include the control group in this research to determine any changes from the pre-survey to the post-survey in the experimental group resulted from the intervention of integrated STEM-PBL physics module. The framework of the two-group pre-survey-post-survey of the quasi-experimental research design suggested by Eliopoulos *et al.* [77] as shown in Table 1.

Table 1. Two-group pre-survey-post-survey design

Group	Implementation		
Experimental	O_{1a}	X	O_{2a}
Control	O_{1b}		O_{2b}

*O1a and O1b =pre-survey; X=intervention; O2a and O2b=post-survey

The dependent variable (O_1) in the pre-survey is using the same instrument for the experimental group and the control group. A week after the pre-survey, the experimental group received the intervention (X) for eight weeks of duration and the control group did not receive any intervention. A week after the intervention, the dependent variable (O_2) was administered in the post-survey by using the same instrument for both groups, e.g., experimental and control. Then, the results of the pre-survey and post-survey were examined to identify the improvement of the dependent variable by identifying the significant difference of the mean values between O_{2a} and O_{1a} for the experimental group and between O_{2b} and O_{1b} for the control group. Besides, the mean values of post-survey from the experimental group (O_{2a}) and the control group (O_{2b}) were compared to investigate the effectiveness of the intervention (X) towards the dependent variable.

The population in this research was Malaysian Form 4 students, who learn physics (i.e., classical mechanics) in secondary school and Korean second-year high school students, who learn physics (i.e., classical mechanics) Book 1. This research was conducted in two selected schools in Sabah, Malaysia, and two high schools in Seoul, Korea. The sample size was 88 Form 4 students in Malaysia and 66 second-year high school students in Korea. The students were divided into two groups, respectively, i.e., the experimental group (Malaysia=44, Korea=33) and the control group (Malaysia=44, Korea=33).

Data collection was conducted quantitatively. The Colorado Learning Attitude about Science Survey (CLASS) is the research instrument used to measure the dependent variable [50]. The CLASS survey consists of eight main themes and three themes were covered in this research, i.e., real-world connection, conceptual connections, and applied conceptual understanding. Table 2 shows the item numbers for each category administered pre-survey before and post-survey after the intervention to collect the quantitative data. The data were analyzed through SPSS version 26.0. Paired sample t-test was used to identify the improvement of the dependent variable within groups using the data from the pre-survey and the post-survey. The independent sample t-test was used to compare the dependent variable between groups using the post-survey data.

Table 2. Categories and number of items in each CLASS category

Categories	Item number	Total item
Real world connection	28, 30, 34, 36	4
Conceptual connections	1, 5, 6, 13, 22, 31	6
Applied conceptual understanding	1, 5, 6, 8, 21, 22, 39	7

5. RESULTS

Table 3 shows the results of paired samples t-test for belief specific categories, i.e., real-world connections, conceptual connections, and applied conceptual understanding, to evaluate the effectiveness of integrated STEM-PBL physics module intervention based on the students' scores in CLASS. For belief specific category-real-world connections, from Form 4 students' perspective, there was a statistically difference increase in real-world connections, in the experimental group from the pre-survey (M=3.37, SD=0.59) to the post-survey (M=4.09, SD=0.48), t (43)=-6.38, p<.001 (two-tailed). In addition, there was no statistically difference increase in real-world connections in the control group from the pre-survey (M=3.41, SD=0.48) to the post-survey (M=3.37, SD=0.40), t (43)=0.42, p=.673 (two-tailed). For second-year high school students' perspective, there was a statistically difference increase in real world connections in the experimental group from the pre-survey (M=3.17, SD=0.55) to the post-survey (M=3.86, SD=0.35), t (32)=-9.17, p<.001 (two-tailed). In addition, there was not statistically difference decrease in real-world connections in the control group from the pre-survey (M=3.03, SD=0.53) to the post-survey (M=3.06, SD=0.53), t (32)=-0.25, p=.803 (two-tailed).

For belief specific category-conceptual connections, from Form 4 students' perspective, there was a statistically difference increase in conceptual: connections in the experimental group from the pre-survey (M=2.96, SD=0.50) to the post-survey (M=3.74, SD=0.51), t (43)=-7.41, p<.001* (two-tailed). In addition, there was not statistically difference increase in conceptual connections in the control group from the pre-survey (M=3.01, SD=0.48) to the post-survey (M=3.09, SD=0.48), t (43)=-0.72, p=.474 (two-tailed). For second-year high school students' perspective, there was a statistically difference increase in conceptual connections in the experimental group from the pre-survey (M=2.93, SD=0.38) to the post-survey (M=3.67, SD=0.44), t (32)=-10.77, p<.001 (two-tailed). In addition, there was not statistically difference decrease in conceptual connections in the control group from the pre-survey (M=3.09, SD=0.65) to the post-survey (M=3.08, SD=0.39), *t* (32)=0.08, p=.936 (two-tailed).

For belief specific category-applied conceptual understanding, from Form 4 students' perspective, there was a statistically difference increase applied conceptual understanding in the experimental group from the pre-survey (M=2.86, SD=0.41) to the post-survey (M=3.72, SD=0.50), t (43)=-8.31, p<.001 (two-tailed). In addition, there was no statistically difference decrease in applied conceptual understanding in the control group from the pre-survey (M=2.93, SD=0.46) to the post-survey (M=2.89, SD=0.40), t (43)=0.44, p=.663 (two-tailed). For second-year high school students' perspective, there was a statistically difference increase in applied conceptual understanding in the experimental group from the pre-survey (M=3.04, SD=0.38) to the post-survey (M=3.77, SD=0.33), t (32)=-11.51, p<.001 (two-tailed). In addition, there was not statistically difference increase in applied conceptual understanding in the control group from the pre-survey (M=3.12, SD=0.57) to the post-survey (M=3.29, SD=0.42), t (32)=-1.83, p=.077 (two-tailed).

Table 3. Results of paired samples t-test for belief specific categories

Category	Group	Survey	M	SD	t	DF	P (2-tailed)	Mean difference
Real world connections	EG (F4)	Pre-survey	3.37	0.59	-6.38	43	<.001*	-0.72
		Post-survey	4.09	0.48				
	CG (F4)	Pre-survey	3.41	0.48	0.42	43	.673	0.04
		Post-survey	3.37	0.40				
	EG (Y2)	Pre-survey	3.17	0.55	-9.17	32	<.001*	-0.69
		Post-survey	3.86	0.35				
	CG (Y2)	Pre-survey	3.03	0.53	-0.25	32	.803	-0.03
		Post-survey	3.06	0.50				
Conceptual connections	EG (F4)	Pre-survey	2.96	0.50	-7.41	43	<.001*	-0.78
		Post-survey	3.74	0.51				
	CG (F4)	Pre-survey	3.01	0.48	-0.72	43	.474	-0.08
		Post-survey	3.09	0.48				
	EG (Y2)	Pre-survey	2.93	0.38	-10.77	32	<.001*	-0.74
		Post-survey	3.67	0.44				
	CG (Y2)	Pre-survey	3.09	0.65	0.08	32	.936	0.01
		Post-survey	3.08	0.39				
Applied conceptual understanding	EG (F4)	Pre-survey	2.86	0.41	-8.31	43	<.001*	-0.86
		Post-survey	3.72	0.50				
	CG (F4)	Pre-survey	2.93	0.46	0.44	43	.663	0.04
		Post-survey	2.89	0.40				
	EG (Y2)	Pre-survey	3.04	0.38	-11.51	32	<.001*	-0.73
		Post-survey	3.77	0.33				
	CG (Y2)	Pre-survey	3.12	0.57	-1.83	32	.077	-0.17
		Post-survey	3.29	0.42				

*The mean difference is significant at p≤0.05; SD=Standard deviation; DF=Degree of freedom;
EG (F4=Form 4 students in the experimental group; EG (Y2)=Second-year high school students in the experimental group;
CG (F4)=Form 4 students in the control group; CG (Y2)=Second-year high school students in the control group.

Based on the results obtained from each of belief specific categories, the null hypothesis 1 (H_{01}): There is no significant difference in students' beliefs in specific categories, i.e., real-world connections, conceptual connections, and applied conceptual understanding between pre-survey and post-survey for Malaysian (Form 4) students and Korean (e.g., second-year) students is rejected. This indicates, integrated STEM-PBL physics module was able to give a significant impact on students' belief specific categories of real-world connections, conceptual connections, and applied conceptual understanding for experimental group of Form 4 students and second-year students. However, for control group no significant difference was recorded between pre-survey and post-survey for both Form 4 and second-year students. Table 4 shows the results of the independent samples t-test for belief specific categories, i.e., real-world connection, conceptual connection, and applied conceptual understanding, between experimental and control group for both Form 4 and second-year students for the post-survey after the intervention of integrated STEM-PBL physics module based on the students' scores in CLASS.

For belief specific category-real-world connection, from Form 4 students' perspective, there was a statistically significant difference in real-world connection between the experimental group (M=4.09, SD=0.48) and the control group (M=3.37, SD=0.40) in the post-survey, t (86)=7.60, p<.001 (two-tailed). The magnitude of the difference in the means is 0.72. For second-year high school students' perspective, there was a statistically significant difference in real-world connections between the experimental group (M=3.86, SD=3.06) and the control group (M=3.06, SD=0.50) in the post-survey, t (64)=7.57, p<.001 (two-tailed). The magnitude of the difference in the means is 0.80.

For belief specific category-conceptual connection, from Form 4 students' perspective, there was a statistically significant difference in students' sense-making and effort between the experimental group (M=3.74, SD=0.51) and the control group (M=3.09, SD=0.48) in the post-survey, t (86)=6.14.77, p<.001 (two-tailed). The magnitude of the difference in the means is 0.65. For second-year high school students' perspective, there was a statistically significant difference in sense making and effort between the experimental group (M=3.667, SD=0.44) and the control group (M=3.08, SD=0.39) in the post-survey, t (64)=5.70, p<.001 (two-tailed). The magnitude of the difference in the means is 0.59.

For belief specific category-applied conceptual understanding, from Form 4 students' perspective, there was a statistically significant difference in students' applied conceptual understanding between the experimental group (M=3.72, SD=0.50) and the control group (M=2.89, SD=0.40) in the post-survey, t (86)=8.65, p<.001 (two-tailed). The magnitude of the difference in the means is 0.83. For second-year high school students' perspective, there was a statistically significant difference in applied conceptual understanding between the experimental group (M=3.77, SD=0.33) and the control group (M=3.29, SD=0.42) in the post-survey, t (64)=5.18, p<.001 (two-tailed). The magnitude of the difference in the means is 0.48.

Table 4. Results of independent samples *t*-test

Category	Group	Mean	SD	Levene's Test F	p	t	DF	t-test P (2-tailed)	Mean difference
Real-world connection	EG (F4)	4.09	0.48	1.21	0.275	7.60	86	<.001*	0.72
	CG (F4)	3.37	0.40						
	EG (Y2)	3.86	0.35	2.97	0.090	7.57	64	<.001*	0.80
	CG (Y2)	3.06	0.50						
Conceptual connection	EG (F4)	3.74	0.51	0.44	0.509	6.14	86	<.001*	0.65
	CG (F4)	3.09	0.48						
	EG (Y2)	3.67	0.44	0.13	0.721	5.70	64	<.001*	0.59
	CG (Y2)	3.08	0.39						
Applied conceptual understanding	EG (F4)	3.72	0.50	1.90	0.172	8.65	86	<.001*	0.83
	CG (F4)	2.89	0.40						
	EG (Y2)	3.77	0.33	1.81	0.184	5.18	64	<.001*	0.48
	CG (Y2)	3.29	0.42						

*The mean difference is significant at p≤0.05; SD=Standard Deviation; DF=Degree of Freedom;
EG (F4)=Form 4 students in the experimental group; EG (Y2)=Second-year high school students in the experimental group;
CG (F4)=Form 4 students in the control group; CG (Y2)=Second-year high school students in the control group.

Based on the results obtained from each of belief specific categories, the null hypothesis 2 (H_{02}): There is no significant difference in students' beliefs in specific categories, i.e., real-world connection, conceptual connection, and applied conceptual understanding between experimental group and control group on the post-survey for both Malaysian (e.g., Form 4) students and Korean (e.g., second-year) students is rejected. In conclusion, the integrated STEM-PBL physics module significantly raised students' belief specific categories for real-world connection, conceptual connection, and applied conceptual understanding favored the experimental group of Form 4 and second-year students' respectively.

6. DISCUSSION

This research investigated whether the integrated STEM-PBL physics module in learning classical mechanics could improve belief-specific categories regarding real-world connections, conceptual connections, and applied conceptual understanding among students of Form 4 and second-year high school. Each section discussed the effectiveness of the integrated STEM-PBL physics module on each belief-specific category based on the findings in the intervention.

6.1. Real world connection

Adopting instruction with real-world relevance can spark students' desire to explore, investigate and understand their world [39]. Incorporating real-world applications in physics instruction is effectively relevant to show students the significance of physics concepts about real-life experiences [6]. The findings of this research are similar to what has been reported in the literature. Previous studies have shown that an integrated STEM education approach gives opportunities for students to understand the world holistically by encouraging students to apply their knowledge of physics, technology, engineering and mathematics to explore the environment [5], [8]. Besides that, PBL effectively makes learning physics relevant by bridging classroom learning to real-life applications [41], [78]. The justification of the integrated STEM-PjBL approach also supports findings in this research can make learning physics relevant to real-world issues in secondary school and enable students to transfer their knowledge and skills in finding real solutions to real-world problems [79]–[81].

The findings in this research are supported by the justification that students bring personal experiences with them into the classroom, and their interpretations of the world influence how the learning process occurs [79], [80]. Based on the situated learning theory, the ability to connect prior knowledge with real-world experiences leads students to construct new knowledge and skills about the learning content [82]. Findings in this research are also supported by the research conducted by Liu [83], in which PjBL helps students connect physics concepts that include momentum, impulse and equilibrium of forces into real-life situations. Like Top and Sahin [78] finding, an integrated STEM-PjBL approach can make students connect classical mechanics concepts with real-world applications. The findings also showed that first-year high school students were exposed to their dream careers. Interest in STEM careers is primarily formed in secondary education [7]. Exposing secondary school students to how jobs in the industries are performed in real life will benefit them in getting ready for future careers. The ability to make the real-world connection in a work setting is highly demanded by industries that want a skillful individual to work in complex thinking environments [39]. The findings in this research are supported by the previous studies in which an integrated STEM-PjBL approach can engage students with tasks performed by engineers in the real world [79].

6.2. Conceptual connection

Providing instruction that promotes conceptual connections among students can open up possibilities for integrated content experiences that make students think that the concepts and facts learned in class are interrelated and relevant to real-world applications [33]. The findings of this study are similar to what has been reported in the literature. Previous studies have shown that the integrated STEM-PBL approach helps students realize that physics involves the interconnections of different laws and theories [31]. Besides that, the integrated STEM-PBL approach leads students to activate prior knowledge about classical mechanics concepts to conceptually connect with phenomena that happen in real-world situations [57]. Findings in this study also are aligned with the previous studies in which PjBL effectively increases students' ability to make conceptual connections in physics [84], [85]. Physics instruction that explicitly focuses on curiosity questions [28], research-based approach [85] and interdisciplinary programs [33] able to increase the ability of students in making conceptual connections when learning physics. In this research, these types of instruction were consolidated. They became the approach to how Form 4 and second-year high school students learned classical mechanics in secondary education through integrated STEM-PjBL physics module.

The findings in this research are supported by the justification that PBL provides opportunities for students to connect content ideas [85] and connect classroom learning with real-life applications [83]. Furthermore, this research's findings also align with the previous studies reported in the literature. For example, Muzzarelli [53] stated that high school students could blend several classical mechanics concepts with fundamental engineering processes in building file folder bridges during PBL. Besides that, Liu [83] also revealed that college students could blend several classical mechanics concepts with fundamental engineering processes in building the human leg model and the truss bridge model during PBL. Furthermore, students who make conceptual connections in physics can generate inferences from observations [58] and create hypotheses between variables [3].

However, most physics instruction in secondary school does not promote students to make conceptual connections due to teachers' excessive application of traditional instruction [51]. This research revealed that participants in the control group who learned physics through traditional instruction had not increased their ability to make conceptual connections in learning physics during the actual study. The findings are also supported by previous studies in which traditional instruction is ineffective in promoting conceptual connections among students [85] due to little integration of physics concepts [83], [86]. Through traditional instruction, students learn physics concepts as being independent of each other, making them struggle to make conceptual connections between physics concepts learned in class [83].

6.3. Applied conceptual understanding

Every student can apply their conceptual understanding to interpret new insights and experiences in a learning situation [32]. Physics conceptual understanding is essential for students to learn physics better and apply physics concepts and principles in various situations [66]–[68]. Effective physics instruction can facilitate physics conceptual understanding among students [50], [69]. The findings of this study are similar to what has been reported in the literature. Previous studies have shown that the integrated STEM-PjBL approach helps students to increase their ability to apply conceptual understanding of classical mechanics in explaining the phenomena in real-life situations [79]–[81]. This research's findings align with the study by Liu [83], in which PBL helps students understand physics concepts that include momentum, impulse and equilibrium of forces. Muzzarelli [53] indicated that PBL helps students increase their ability to apply conceptual understanding of forces and Newton's Laws of motion. Previous studies also revealed that physics instruction explicitly focuses on constructivist teaching methods [87], student-centered approach, discussion [32], research-based approach [88], inquiry-based activities [68], peer instruction [33], group work and technology-based approach [56], [67] can improve students' ability to apply conceptual understanding of physics. In this research, these types of instruction were consolidated. They became the approach to how Form 4 and second-year high school students learned classical mechanics in secondary education through integrated STEM-PjBL physics module.

PjBL-related activities provide opportunities for students to apply conceptual understanding in different settings [89], [90]. Students with higher physics conceptual understanding can explain situations qualitatively with physics processes and transfer physics knowledge to explain various phenomena in different situations [32], [56]. The integrated iSTEM-PjBL approach can help students enhance their understanding of physics concepts and increase their ability to explain what is happening in daily life scientifically [57], [81] since PjBL-related activities emphasize constructing products as representations of knowledge acquisition and conceptual understanding [5], [41], [84], [91]. Based on the situated learning theory, when students can understand the implications of knowledge, they learn about the conditions for applying knowledge [92]. According to Schmid and Bogner [92], when students put more effort into learning physics, they gain more knowledge about physics, which can increase their conceptual understanding of physics.

Traditional instruction is commonly reported to be ineffective in helping students develop physics conceptual understanding [63], [65]. Similarly, findings in this study revealed that participants in the control group who learned physics through traditional instruction had remained the same in the ability to apply conceptual understanding in physics during the actual study. Besides that, students needed help understanding the topics related to classical mechanics because their teacher often used traditional instruction and relied too much on a textbook to implement hands-on experiments and short activities to teach physics. These research findings are also in line with previous studies in which traditional teaching of classical mechanics [63] and laboratory work [48], [66] unable to increase students' ability to apply conceptual understanding of physics and leaving them to have many significant misconceptions in physics.

7. CONCLUSION

The iSTEM-PjBL physics module effectively improved students’ real-world connection, conceptual connection, and applied conceptual understanding. These three essential elements can motivate students to learn physics, specifically classical mechanics. Results from this research have shown that iSTEM education can be implemented at the secondary education level through PjBL for students to learn classical mechanics and improve students’ belief in these three elements, which is responsible for promoting students’ competency. The curriculum framework and instructional material proposed in this research can guide secondary school teachers to develop their STEM-PjBL activities by assimilating several learning objectives from the discipline-based curriculum content.

From the Malaysian perspective, integrated STEM education introduced in 2013 needs to be better established and revised. Many secondary school teachers are forced to become more familiar with the approach, and the ministry must look at the curriculum holistically and frequently. From the Korean perspective, many teachers need help implementing a multidisciplinary STEAM education approach and doubt its effectiveness towards students. However, it became the primary approach to promoting STEAM education in Korean schools after the STEAM education policy was issued in 2011. Therefore, it is hoped this research can help the Ministry of Education Korea design meaningful, integrated STEAM education in the form of an interdisciplinary approach centered on the discipline-based curriculum, especially in improving students' beliefs in specific categories, i.e., real-world connection, conceptual connection, and applied conceptual understanding. Some recommendations from the research findings there are: i) the context and work done in the module should fully appear in the final grade and final marks, e.g., in the formative continuous assessment; ii) cooperation, effort, funds, and support from various stakeholders to improve how students learn content and subject matter meaningfully and minimize the traditional approach; iii) parents must also be well-versed in the module, which could uplift students' 21st-century skills if exposed early in secondary school; and finally, iv) top management should provide continuous professional development and skills programs to prepare physics teachers, ensuring they can effectively practice the integrated iSTEM-PjBL approach in the classroom.

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