JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

THE EFFECTIVENESS OF THE INTEGRATED STEM-PBL PHYSICS MODULE ON STUDENTS' INTEREST, SENSE-MAKING AND EFFORT

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Abstract. *Issues like why students felt far from physics and did not choose physics as their prime learning option are familiar in education. This paper aims to study the effectiveness of the STEM-Project-Based learning module in physics on students' personal interest and sense-making and effort. 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 Form 4 students in Malaysia and 66 second-year high school students in 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-PBL physics module significantly improved students' personal interest, and sense-making and effort after the intervention. The paper also highlighted the research's implications and suggestions.*

Keywords: *integrated STEM, project-based learning, physics module, classical mechanics, personal interest, sense-making and effort*

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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 most job markets are replaced by computers and digitization. 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 (Kelley & Knowles, 2016). 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 in the fourth industrial revolution. STEM education is based on educating students in four (4) specific disciplines in science, technology, engineering and mathematics into a cohesive learning paradigm based on real-world applications (Sumintono, 2015).

Many countries accept STEM education because it provides opportunities to equip students with the knowledge and skills needed in the 21st century and cope with the challenges of the fourth industrial revolution (Suraya et al., 2017; Naudé, 2017; Brown-Martin, 2018; Türk et al., 2018). For example, Malaysia tries to adopt STEM education by introducing the Malaysian Education Blueprint (2013-2015) in 2013. Blueprint aims to raise the existing standard of science and technology education (Bakar et al., 2019). The blueprint introduction is the continuous effort to empower Malaysia to become a developed nation with a STEM-literate society, achieve a targeted highly skilled, qualified STEM workforce and meet the demands of a STEM-driven economy (Mohd Shahali et al., 2017). In Korea, the Science, Technology, Engineering, Art, and Mathematics (STEAM) STEAM education

https://doi.org/10.33225/jbse/23.22.113

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

policy was issued nationwide in 2011 by the Ministry of Education Korea purposely to promote STEAM education in primary and secondary schools (Kang, 2019). The main goal of STEAM education in Korea is to produce students with the ability to create new ideas or products formed by STEAM competencies purposely to generate a quality STEM workforce, highly technological literacy citizens and competent individuals to vitalize the national economy (Jho et al., 2016). STEAM education in Korea is in line with STEM education policy in other countries but with the inclusion of art as another discipline (Kang, 2019).

Research Problem

Despite the increasing attention to STEM education worldwide, many countries have a significant challenge in implementing STEM education in classroom settings (Holmlund et al., 2018; Gao et al., 2020; Mpofu, 2020). Many educators have dilemmas and uncertainty about what constitutes STEM education and what STEM education means in terms of curriculum and student outcomes (English, 2016; Mpofu, 2020). One of the reasons that contributes to issues in STEM education is that there is no single and concise definition of STEM (Sanders, 2009; Wang et al., 2011; Holmlund et al., 2018; Bunyamin et al., 2020). STEM education yet still lacks a clear consensus about the instructional approaches for teaching STEM (Holmlund et al., 2018). STEM teaching can take various forms depending on the type of instructional approach used, whether silo, embedded or integration (Roberts & Cantu, 2012; Vasquez, 2015). 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 (Gao et al., 2020). 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 (Chalkiadaki, 2018) in their assessment.

For STEM, one of its elements is science, and physics is one of its fundamental parts. Moreover, physics is well-known as a driving force for innovation and the development of new technologies (Lee & Kim, 2018). This is because physics strongly connects to the integrated STEM elements (Bunyamin et al., 2020). However, in secondary school, while teaching physics, fewer teachers or educators focus on students' personal interest and sense-making and effort which lead to students' preference to learn physics decreased (O'Neill & Mcloughlin, 2021; Saleh, 2014; Jeffry & Fauziah, 2016b). Therefore, secondary school's focus should first be on triggering students' interest in physics through appealing physics instruction that can enhance students' personal interest in learning physics (Walper et al., 2016). Additionally, sense-making and effort must be highlighted at the early stage of learning so that students can develop their skills throughout the semester (Thomas, 2000; Namvar et al., 2018; Cannady et al., 2019). Therefore, this research serves as a breaking point to introduce and allow secondary school students to learn classical mechanics through an integrated STEM-PBL-related approach to improve their personal interest and sense-making and effort. Additionally, this paper studies the effectiveness of integrated STEM-PBL physics modules in learning classical mechanics and whether it can improve students' personal interest, sense-making and effort among Form 4 and second-year high school students.

Research Focus

In this research, knowing students' interest in physics 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 (Hidi & Renninger, 2006; Walper et al., 2016; Laine et al., 2020). Meanwhile, the individual predisposition is characterized by the interaction between a person and a particular content (Hidi & Renninger, 2006) or an object (Walper et al., 2016). According to Rotgans and Schmidt (2017a), interest and knowledge acquisition are interrelated, and there are three different possibilities for the relationship between interest and knowledge. Interest can be the cause of knowledge acquisition, and knowledge is responsible for an increase in interest or interest and knowledge influence each other reciprocally. Interest has been recognized to be a powerful influence on learning (Ainley et al., 2002; Hidi & Renninger, 2006; Rotgans & Schmidt, 2017a) and generates positive effects on the learning processes and learning outcomes (Hong & Lin-Siegler, 2011; Uitto, 2014; Walper et al., 2016; Rotgans & Schmidt, 2017a). Research has shown that interest contributed to a significant impact on academic achievement (Rotgans & Schmidt, 2017a), course selection in school, choice of majors and careers as well as lifelong engagement (Hidi & Renninger, 2006; Walper et al., 2016; Laine et al., 2020). Therefore, to increase students' interest in learning, teachers should instruct according to students' preferences in mind. The learning

https://doi.org/10.33225/jbse/23.22.113

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 (Rotgans & Schmidt, 2017a).

Other than personal interest, another category that should alarm physics teachers is sense-making and effort, as this element may promote students' 21st-century skills capability. The conceptual associations in sense-making are driven by plausibility rather than accuracy (Hammer, 1994; Currie & Brown, 2003; Kramer, 2017), is an ongoing process of seeking the meaning of experiences through the construction and reconstruction of explanations by making sense of multiple representations and knowledge (Currie & Brown, 2003; Kramer, 2017; Cannady et al., 2019) and focuses on particular aspects to generalize the whole experience (Currie & Brown, 2003; Kramer, 2017). In addition, sense-making is associated with interpretation to retrieve and apply prior knowledge to evaluate potential solutions to a task or problem (Nokes-Malach & Mestre, 2013; Kramer, 2017) and exists due to inadequacy of understanding the information from a situation (Namvar et al., 2018; Cannady et al., 2019). Sense-making can also be associated with how meaning is socially interpretive through communication in which individuals engage in a collaborative process to gain information collectively to create a shared understanding of their experiences (Currie & Brown, 2003; Kramer, 2017). Meanwhile, scientific sense-making requires cognitive engagement with science-related content to determine the best possible explanation across representations that align with conceptual understanding to explain science-related situations (Cannady et al., 2019).

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 (Wang et al., 2011; Mpofu, 2020). According to Stohlmann et al. (2012), 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 (Roberts & Cantu, 2012; Asunda, 2014), which can exist in various forms and not necessarily include all four STEM disciplines (Stohlmann et al., 2012). Sanders (2009) 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. (2014) 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 (2016) described that integrated STEM education involves two or more STEM domains of 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 Moore et al. (2014) and Kelley and Knowles (2016) to suit the need of the study. Since there is no single and concise definition of STEM (Sanders, 2009; Wang et al., 2011; Holmlund et al., 2018) and STEM education community needs to resolve the definition of STEM acronym to prevent STEM education failures in many countries (Daugherty & Carter, 2017). 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 domains of 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 (Mohd Shahali et al., 2017) and Korea (Kang, 2019) in which the educational curriculum in both countries has focused on STEM integration to transform science and mathematics education in secondary education.

Belief Specific Category - Personal Interest

Interest is regarded as a particular type of attitude (Trumper, 2006), a unique variable (Hidi & Renninger, 2006; Hong & Lin-Siegler, 2011; Laine et al., 2020), content specific (Hidi & Renninger, 2006), and a preference for engaging in some types of activities (Trumper, 2006). Interest has been conceptualized both as a psychological state and an individual predisposition (Ainley et al., 2002; Hidi & Renninger, 2006). The psychological state is characterized by persistent effort, focused attention, and increased cognitive and affective functioning (Ainley et al., 2002). Personal interest is also known as an individual interest in literature (Hong & Lin-Siegler, 2011; Rotgans & Schmidt, 2017a).

https://doi.org/10.33225/jbse/23.22.113

Personal interest is interpreted as an enduring predisposition to re-engage particular content over time (Ainley et al., 2002; Hidi & Renninger, 2006; Subramaniam, 2009; Djudin, 2018). Personal interest is regarded to develop gradually, persist over time, and be relatively stable (Subramaniam, 2009; Hong & Lin-Siegler, 2011; Uitto, 2014; Djudin, 2018) but can change over time (Rotgans & Schmidt, 2017a). In addition, personal interest is internally driven (Hidi & Renninger, 2006), associated with positive affect (Ainley et al., 2002) and motivational state (Hidi & Renninger, 2006; Uitto, 2014), and develops in combination with an individual's knowledge and values (Subramaniam, 2009; Laine et al., 2020). Personal interest also is related to affective response, the affective response leads to persistence, and persistence tends to increase learning due to increased engagement (Ainley et al., 2002; Rotgans & Schmidt, 2017a). Personal interest in learning is conveyed as a desire to seek new knowledge and expand existing knowledge, a positive attitude, and a strong connection to achieve learning goals (Ainley et al., 2002). Research has shown that teachers have little control over personal interest in students (Subramaniam, 2009; Hulleman et al., 2010). Students come into the learning environment with a certain degree of personal interest for particular content (Subramaniam, 2009; Rotgans & Schmidt, 2017b). For instance, some students come to a science classroom with a preexisting personal interest in the subject matter, but some students do not (Hong & Lin-Siegler, 2011). Research has suggested that preexisting personal interest can help to generate situational interest when students engage in the learning task in relation to prior knowledge and value for the subject (Rotgans & Schmidt, 2017b; Laine et al., 2020). According to Subramaniam (2009), students may enter the learning environment with low personal interest, but teachers can manipulate the stimuli in the learning environment to trigger situational interest, which subsequently leads to the development of personal interest. Students can develop personal interest if they can identify the reason to be interested in the content. Instructional materials have to be in line with students' personal interest to ensure that learning is effective and relevant (Rotgans & Schmidt, 2017a). Personal interest plays a major role in students' preference to engage in a task or activity (Hidi & Renninger, 2006).

Secondary school is a critical period to develop an interest in physics since it provides students the first opportunity to learn physics (Walper et al., 2016; Wang et al., 2017). Both situational interest and personal interest can influence students to enroll in physics in secondary school (Trumper, 2006; Djudin, 2018; Laine et al., 2020). Students' personal interest in physics varies from one student to another (Trumper, 2006; Hong & Lin-Siegler, 2011). Students with a higher level of personal interest find physics as significantly interesting (Trumper, 2006; Hong & Lin-Siegler, 2011; Rotgans & Schmidt, 2017b), learn physics better, choose physics course in secondary school (Djudin, 2018), invest effort to learn physics (Laine et al., 2020), have a positive attitude towards physics, tend to pursue physics-related course and job in the future (Perkins et al., 2006; Trumper, 2006; Uitto, 2014; Wang et al., 2017) and have more favorable shifts in beliefs about physics and learning physics (Adams et al., 2006; Djudin, 2018) than students with a lower level of personal interest. Students who have a personal interest in learning physics will enjoy solving physics problems, realizing that the knowledge and skills learned in class are useful to their everyday life and will use reasoning skills to understand physics and to explain how the world works (Adams et al., 2006). Djudin (2018) also identified a significant positive relationship between students' personal interest in physics and their ability to solve physics problems, and relate physics content with real world applications. In addition, students who hold a higher personal interest in physics are tied to expert-like beliefs in learning physics (Perkins et al., 2006; Kiong & Sulaiman, 2010; Hullemen et al., 2010) that contribute to the conceptual understanding of classical mechanics (Kiong & Sulaiman, 2010). Triggering situational interest among students is particularly essential for teachers in dealing with students who do not have the preexisting personal interest towards a specific subject at school since situational interest has the potential to influence personal interest (Ainley et al., 2002; Subramaniam, 2009). Therefore, the focus in secondary school should be first on triggering students' situational interest in physics through appealing physics instruction that can enhance students' personal interest in learning physics (Walper et al., 2016). From the literature, personal interest is one of the belief-specific categories and can be measured using CLASS based on the subsets of six (6) items in CLASS (Adams et al., 2006; Heller & Heller, 2010).

Belief Specific Category - Sense Making and Effort

Sense making has gained prominence in education perspective after being introduced and popularized by Karl Weick in 1969 (Namvar et al., 2018; Cannady et al., 2019). Sense making is defined as a dynamic process in which an individual engages in selection and application of knowledge to interpret and create a representation to accomplish some goal or perform some task (Nokes-Malach & Mestre, 2013; Namvar et al., 2018). According to Namvar et al. (2018), sense making operates in a sequential form and starts when an individual gathers information of interest from a situation. Then, the collected information becomes a representation in the schema that causes the evaluation process to take place. The manipulation of representations in the schema produces insights that finally lead to action or creation of a product. Nokes-Malach and Mestre (2013) conclude that sense making operates through a three-step cyclical process in a problem-solving scenario that includes generating, evaluating, and revising. At first, an individual constructs a mental representation of context or situation under consideration by activating prolific prior knowledge to generate a potential solution to a given problem. Then, the individual evaluates the solution until sense is made. If the solution violates the constraint, the individual revises the procedures and identifies another appropriate prior knowledge to attempt a new solution. The process iterates until sense making is achieved in constructing a viable solution for a given problem. Kramer (2017) argues that sense making involves a commitment that leads to certain actions consistent with the interpretation of the experiences. A particular interpretation simultaneously creates ongoing justifications for past and future actions. Then, those actions shape further justifications and lead to additional sense making. Research has shown that sense making can provide clarity and meaning to obscure phenomena, offers a structured process in making a decision when dealing with uncertainty and generates precise predictions when conducting a task (Namvar et al., 2018).

In secondary school, sense making is useful for content learning since it becomes the foundation for constructing new knowledge, understanding the related content matter and can encourage students to spend time on further related learning activities (Thomas, 2000; Namvar et al., 2018; Cannady et al., 2019). However, each student has a different level of sense making in order to make sense of information from the same situation. Students with higher sense making can construct procedures by using abstract conceptual knowledge to solve a problem and have the ability to transfer knowledge or skills from one problem to another (Nokes-Malach & Mestre, 2013; Mensah, 2015). In addition, students with higher scientific sense making understand scientific content better, gain greater increase in science content knowledge and understand scientific practices in explaining natural phenomena (Cannady et al., 2019). Meanwhile, students with lower sense making often apply prior knowledge that has similar surface features of a situation (Nokes-Malach & Mestre, 2013) and relies on personal preference (Thomas, 2000) to solve a problem. Consequently, students with lower sense making are often unable to make inference about new phenomena (Cannady et al., 2019), have difficulty understanding the scientific content, cannot perform advanced cognitive tasks and fail to carry out their plans systematically (Thomas, 2000; Nokes-Malach & Mestre, 2013). Focusing on improvement in sense making at secondary school can benefit students and teachers should aim to support the acquisition of sense making skills by providing lessons that promote sense making activities (Cannady et al., 2019). Research has shown that instruction focuses on inquiry, conducting learning (Thomas, 2000), student-centered, hands-on activities, cognitive and affective engagement (Cannady et al., 2019), communication and collaboration (Sahin, 2010) can increase students' sense making compared to conventional approach.

Effort is a critical predictor of students' academic achievement in a secondary school in which students gain more knowledge when they put effort into learning (Carbonaro, 2005; Bonham, 2007; Schmid & Bogner, 2015; Uitto, 2014). Each student has a different level of effort in learning and varies across academic subjects (Carbonaro, 2005). Students who put high effort into learning will gain and retain high content knowledge, generate solutions towards a problem and perceive learning competence to gain more insights. In addition, students who hold expert-like beliefs exert more effort in learning to find meaning in the daily tasks by using their cognitive skills and when there is a more significant academic challenge in order to gain academic success (Carbonaro, 2005). In contrast, students invest less effort if they find learning activities are too dull (Schmid & Bogner, 2015). In addition, students who do not believe that academic success can be achieved, tend to view the effort to learn as a waste of time and unlikely to try hard in school (Carbonaro, 2005). Research has shown that instruction emphasizes on inquiry, hands-on activities, group learning, investigations, discussions, problem-solving and real-world context can increase students' effort on learning compared to traditional instruction (Schmid & Bogner, 2015). Therefore, when students put effort into learning about the world, it can be developed into a lifelong interest in a particular topic leading to professional choices (Rotgans & Schmidt, 2017a).

Sense making and effort greatly influence students to learn physics (Mistades et al., 2011; Gok, 2012; Saleh, 2014; Jeffry & Fauziah, 2016b). With sense making and effort, students may repeatedly attempt to make sense of physics topics by activating existing physics knowledge, examples from class, or everyday experience who believe to be true to understand physics concepts, explain a situation and identify physics principle deemed relevant in providing a solution for a problem (Hammer, 1994; Mistades et al., 2011; Gok, 2012; Nokes-Malach & Mestre, 2013). When students put more effort to learn physics, they gain more knowledge about physics that makes them increase conceptual understanding and improve academic achievement in physics (Schmid & Bogner, 2015) and possibly can shift them from naïve to sophisticated beliefs about physics and learning physics (Mistades, 2007; Kaymak & Ogan-Bekiroğlub, 2012). Students' effort in learning physics can be reflected by the degree that students chose to answer questions completely, described their own experiences, explained their reasoning, asked questions themselves and fully engaged themselves in the learning activities (Bonham, 2007). From the literature, sense making and effort is one of the belief-specific categories and can be measured by using CLASS based on the subsets of seven (7) items in CLASS (Adams et al., 2006; Heller & Heller, 2010).

The Integrated STEM-PBL Physics Module

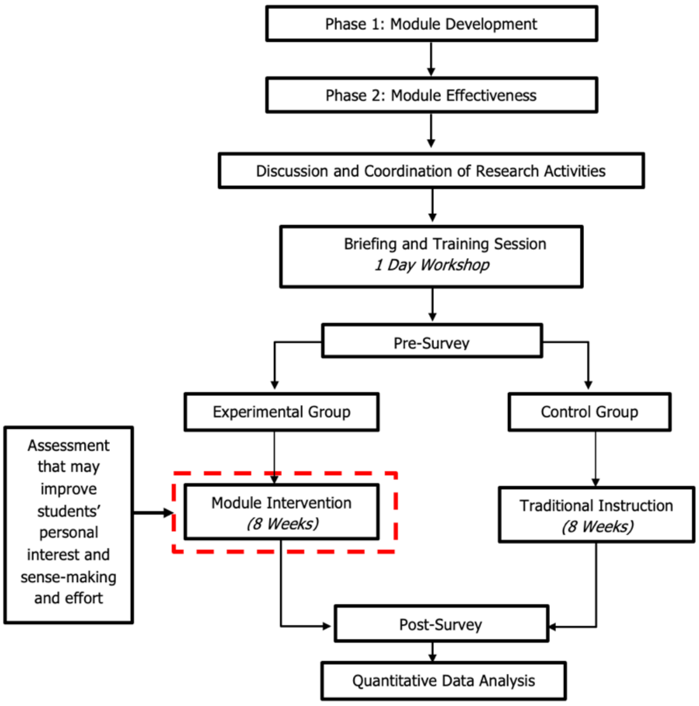
The Integrated STEM-PBL Physics Module was structured and established following a thorough process by using ADDIE instructional design model. It consists of five (5) rigid phases, e.g., analysis, design, development, implementation, and evaluation phases. Each of these phases has undergone a comprehensive 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 integrated STEM-PBL Physics Module, elements of STEM in the Integrated STEM-PBL Physics Module, reviewing the Integrated STEM-PBL Physics Module design and evaluating the module outcome (Jeffry & Fauziah, 2020); iv. The development phase, this includes the development of the Integrated STEM-PBL Physics Module, expert validation of the Integrated STEM-PBL Physics Module, and pilot study; iv. The evaluation phase, where the formative and summative evaluations were done.

In the Integrated STEM-PBL Physics Module, some activities may promote students' personal interest and sense-making and effort. These activities need students' involvement for eight weeks, e.g., only for the experimental group. First, in groups (3-4 students), students will be given a scenario; then, they must come up with solutions to overcome the learning issue. The Integrated STEM-PBL Physics Module consists of two chapters, i.e., the Egg Drop Project and the Spaghetti Bridge Project. Both modules will be given to the experiment groups of Form 4 students (Malaysia) and Second-year students (Korea), respectively.

The content of Integrated STEM-PBL Physics Module was designed based on the PBL model developed by The Buck Institute of Education (Larmer & Mergendoller, 2010). The PBL model was referred to guide the steps in implementing STEM-PBL activities and the learning objectives were integrated into the PBL model. Based on the PBL model, students had to follow nine (9) steps to achieve the learning objectives for each of STEM-PBL activity in four (4) weeks of duration. Each step had its own learning activity and students had to accomplish one step before moving to the subsequent step. After done with the first STEM-PBL activity, students repeated the nine (9) steps of PBL model once again to implement the second STEM-PBL activity for another four (4) weeks of intervention. The nine (9) steps in implementing STEM-PBL activities provide guidelines for students to develop science process skills i.e., students' interest and sense making and effort. In Step 1: Build the Culture and Step 2: Group Setting, students developed observation skill by planning events in implementing STEM-PBL activities chronologically after receiving details about the activities. In Step 3: Essential Question, students developed communication skills by brainstorming and communicating on draft solutions about the essential question and presented the draft solutions through sketches. Besides that, students developed classification skills 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 skills by constructing prototypes and carried out a simple experiment to test the prototype. Students also developed interpretation skills by interpreting the results from the experiment and consequently drawing conclusions to improve the design. In Step 5: Decision Making, students developed prediction skills 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 skills by constructing the final product as planned. In Step 7: Public Product, students developed measuring skills by measuring physical quantities by using appropriate instruments and avoiding errors when taking measurements. Besides that, students developed experimentation skills by carrying out a simple experiment to test the final product. Students also developed interpretation skills 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 skills by sharing their opinions, beliefs, and attitudes about the STEM-PBL activities. Figure 1 shows the summary of the study procedure, starting from the development of the integrated STEM-PBL Physics module until the data collection phase.

https://doi.org/10.33225/jbse/23.22.113

Figure 1
Shows the Summary of the Study Procedure



There are research studies done regarding the acceptance of learning physics, e.g., students' interest decreased in learning physics at secondary school (O'Neill & Mcloughlin, 2021), students' preferences for learning physics at the college level declined (Riskawati et al., 2022); students' beliefs towards learning physics and its influencing factors, i.e., students' beliefs to learn physics, students' attitudes towards physics, and influence of cultural belief on students to learn physics (Abebe & Ibrahim, 2020); in the other research finding, teachers should change their way of teaching physics and learning style to boost students' interest at the secondary level (Ziad et al., 2021). However, no researchers have yet discussed these two elements in-depth, i.e., students' interest and sense-making and effort, particularly comparing two nations. Therefore, this research highlighted these elements to know more about students' interest and sense-making and effort toward physics at the secondary level.

Research Aim

The research aims to study the effectiveness of the integrated STEM-PBL physics module in learning classical mechanics and whether it can improve students' personal interest and sense-making and effort among Form 4 and second-year high school students of South Korean students.

The research questions are:

1. Is there a difference in terms of personal interest and sense-making and effort among Form 4 and second-year high school students after the intervention of the integrated STEM-PBL physics module?
2. Is there a difference in terms of personal interest and sense-making and effort between Form 4 and second-year high school students in the experimental group after the intervention of the integrated STEM-PBL physics module?

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

The objectives are:

1. To research the effectiveness of integrated STEM-PBL physics module on students' personal interest, and sense-making and effort among Form 4 students and Second-Year students.
2. To determine students' personal interest, and sense-making and effort between the experimental and control groups on the post-survey for Form 4 students and Second-Year students.

The null hypothesis is:

H_{01} : There is no significant difference in students' beliefs in specific categories, i.e., personal interest and sense-making and effort between pre-survey and post-survey for Malaysian (i.e., Form 4) students and Korean (i.e., Second Year) students.

H_{02} : There is no significant difference in students' beliefs in specific categories, i.e., personal interest and sense-making and effort between experimental group and control group on the post-survey for both Malaysian (i.e., Form 4) students and Korean (i.e., Second Year) students.

Research Methodology

General Background

The quasi-experimental research design was used to collect 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 Harris et al. (2004) used as a reference for this study shown in Table 1.

Table 1
Two-Group Pre-Survey-Post-Survey Design

Group	Implementation		
Experimental	$O1_a$	X	$O2_a$
Control	$O1_b$		$O2_b$

* $O1_a$ and $O1_b$ = Pre-Survey; X = Intervention; $O2_a$ and $O2_b$ = Post-Survey

The dependent variable (O1) 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 (8) weeks of duration and the control group did not receive any intervention. A week after the intervention, the dependent variable (O2) 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 $O2_a$ and $O1_a$ for the experimental group and between $O2_b$ and $O1_b$ for the control group. Besides, the mean values of post-survey from the experimental group ($O2_a$) and the control group ($O2_b$) were compared to investigate the effectiveness of the intervention (X) towards the dependent variable.

Population and Sample Selection

The population in this research was Malaysian Form 4 students i.e., *N*= 8497, who learn physics (i.e., classical mechanics) in secondary school and Korean Second-Year high school students i.e., *N*= 317000, who learn physics

https://doi.org/10.33225/jbse/23.22.113

(i.e., classical mechanics) Book 1. This research was conducted in two selected schools in Sabah, Malaysia, and two (2) 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 Analysis

Data collection was conducted quantitatively. The Colorado Learning Attitude about Science Survey (CLASS) is the research instrument used to measure the dependent variable. The CLASS survey consists of eight main themes and two themes were covered in this research, i.e., personal interest, and sense-making and effort. 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.

Table 2
Categories and Number of Items in each CLASS Category

Categories	Item Number	Total Item
Personal Interest	3, 11, 14, 25, 28, 30	6
Sense making and effort	11, 23, 24, 31, 35, 38, 41	7

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.

Research Results

Table 3 shows the results of paired samples t- test for belief specific categories, i.e., personal interest and sense-making and effort, to evaluate the effectiveness of integrated STEM-PBL physics module intervention based on the students' scores in CLASS.

For *Belief Specific Category - Personal Interest*, from Form 4 students' perspective, there was a statistically difference increase in personal interest in the experimental group from the pre-survey ($M = 3.52$, $SD = 0.49$) to the post-survey ($M = 4.36$, $SD = 0.39$), $t(43) = -9.93$, $p < .001$ (two-tailed). The mean increase was 0.84 with a 95% confidence interval ranging from -1.02 to -0.67. In addition, there was no statistically difference increase in personal interest in the control group from the pre-survey ($M = 3.43$, $SD = 0.45$) to the post-survey ($M = 3.58$, $SD = 0.42$), $t(43) = -1.67$, $p = 0.101$ (two-tailed). The mean increase was 0.15 with a 95% confidence interval ranging from -0.33 to 0.03. For second-year high school students' perspective, there was a statistically significant increase in personal interest in the experimental group from the pre-survey ($M = 3.18$, $SD = 0.52$) to the post-survey ($M = 3.82$, $SD = 0.44$), $t(32) = -6.97$, $p < 0.001$ (two-tailed). The mean increase was 0.64 with a 95% confidence interval ranging from -0.83 to -0.45. In addition, there was no statistical significant decrease in personal interest in the control group from the pre-survey ($M = 3.12$, $SD = 0.54$) to the post-survey ($M = 3.07$, $SD = 0.40$), $t(32) = 0.53$, $p = 0.598$ (two-tailed). The mean decrease was 0.05 with a 95% confidence interval ranging from -0.14 to 0.24.

For *Belief Specific Category – Sense-Making and Effort,* from Form 4 students' perspective, there was a statistically difference increase in sense making and effort in the experimental group from the pre-survey ($M = 3.33$, $SD = 0.28$) to the post-survey ($M = 4.18$, $SD = 0.34$), $t(43) = -12.46$, $p < 0.001$ (two-tailed). The mean increase was 0.85 with a 95% confidence interval ranging from -0.98 to -0.70. In addition, there was no statistically difference decrease in sense making and effort in the control group from the pre-survey ($M = 3.38$, $SD = 0.31$) to the post-survey ($M = 3.34$, $SD = 0.33$), $t(43) = 0.48$, $p = 0.633$ (two-tailed). The mean decrease was 0.04 with a 95% confidence interval ranging from -0.11 to 0.19. For second-year high school students' perspective, there was a statistically difference increase in sense making and effort in the experimental group from the pre-survey ($M = 3.26$, $SD = 0.28$) to the post-survey ($M = 3.84$, $SD = 0.38$), $t(32) = -7.55$, $p < .001$ (two-tailed). The mean increase was 0.58 with a 95% confidence interval ranging from -0.73 to -0.42. In addition, there was no statistically difference decrease in sense making and effort

https://doi.org/10.33225/jbse/23.22.113

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

in the control group from the pre-survey (*M* = 3.23, *SD* = 0.33) to the post-survey (*M* = 3.15, *SD* = 0.38), *t*(32) = 0.83, *p* = 0.413 (two-tailed). The mean decrease was 0.08 with a 95% confidence interval ranging from -0.11 to 0.27.

Table 3

Results of Paired Samples t- test for Belief Specific Categories – Personal Interest and Sense Making and Effort

Category	Group	Survey	*M*	*SD*	*t*	*df*	*p* (2-tailed)	*MD*
Personal Interest	EG (F4)	Pre-Survey	3.52	0.49	-9.93	43	< 0.001*	-0.84
		Post-Survey	4.36	0.39				
	CG (F4)	Pre-Survey	3.43	0.45	-1.67	43	0.10	-0.15
		Post-Survey	3.58	0.42				
	EG (Y2)	Pre-Survey	3.18	0.52	-6.97	32	< 0.001*	-0.64
		Post-Survey	3.82	0.44				
	CG (Y2)	Pre-Survey	3.12	0.54	0.53	32	0.60	0.05
		Post-Survey	3.07	0.40				
Sense-Making and Effort	EG (F4)	Pre-Survey	3.33	0.28	-12.46	43	< 0.001*	-0.85
		Post-Survey	4.18	0.34				
	CG (F4)	Pre-Survey	3.38	0.31	0.48	43	0.63	0.04
		Post-Survey	3.34	0.33				
	EG (Y2)	Pre-Survey	3.26	0.28	-7.55	32	< 0.001*	-0.58
		Post-Survey	3.84	0.38				
	CG (Y2)	Pre-Survey	3.23	0.33	0.83	32	0.41	0.08
		Post-Survey	3.15	0.38				

*The mean difference is significant at $p \leq 0.05$; 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., personal interest and sense-making and effort between pre-survey and post-survey for Malaysian (e.g., 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 personal interest and sense-making and effort 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., personal interest and sense-making and effort, 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 – Personal Interest,* from Form 4 students' perspective, there was a statistically significant difference in personal interest between the experimental group (*M* = 4.36, *SD* = 0.39) and the control group (*M* = 3.58, *SD* = 0.42) in the post-survey, *t*(86) = 9.10, *p* < .001 (two-tailed). The magnitude of the difference in the means is 0.78. For second-year high school students' perspective, there was a statistically significant difference in personal interest between the experimental group (*M* = 3.82, *SD* = 0.44) and the control group (*M* = 3.07, *SD* = 0.40) in the post-survey, *t*(64) = 7.37, *p* < .001 (two-tailed). The magnitude of the difference in the means is 0.75.

For *Belief Specific Category – Sense-making and Effort,* from Form 4 students' perspective, there was a statistically significant difference in students' sense-making and effort between the experimental group (*M* = 4.18, *SD* = 0.34) and the control group (*M* = 3.34, *SD* = 0.33) in the post-survey, *t*(86) = 11.77, *p* < .001 (two-tailed). The magnitude

https://doi.org/10.33225/jbse/23.22.113

of the difference in the means is 0.84. For second-year high school students' perspective, there was a statistically significant difference in sense making and effort between the experimental group (*M* = 3.84, *SD* = 0.38) and the control group (*M* = 3.15, *SD* = 0.38) in the post-survey, *t*(64) = 7.47, *p* < .001 (two-tailed). The magnitude of the difference in the means is 0.69.

Table 4

Results of Independent Samples t-test for Personal Interest and Sense Making and Effort

Category	Group	*M*	*SD*	Levene's Test		*t-test*			
				F	*p*	*t*	*df*	P (2-tailed)	*MD*
Personal Interest	EG (F4)	4.36	0.39	0.39	0.53	9.10	86	< .001*	0.78
	CG (F4)	3.58	0.42						
	EG (Y1)	3.82	0.44	0.49	0.49	7.37	64	< .001*	0.75
	CG (Y1)	3.07	0.40						
Sense-Making and Effort	EG (F4)	4.18	0.34	0.25	0.62	11.77	86	< .001*	0.84
	CG (F4)	3.34	0.33						
	EG (Y1)	3.84	0.38	0.01	0.92	7.47	64	< .001*	0.69
	CG (Y1)	3.15	0.38						

*The mean difference is significant at $p \leq 0.05$; 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., personal interest, and sense-making and effort 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 personal interest and sense-making and effort favored the experimental group of Form 4 and Second-Year students' respectively.

Discussion

This research concerns verifying the integrated STEM-PBL Physics Module's effectiveness in raising students' belief-specific categories in personal interest, sense-making and effort among Form 4 and Second-Year high school students. Each section below discussed the effectiveness of the integrated STEM-PBL Physics Module on each belief-specific category based on the findings in the intervention.

Belief Specific Category - Personal Interest

Some students may have a certain degree of personal interest in learning physics, but some may not (Subramaniam, 2009; Rotgans & Schmidt, 2017b). To develop or increase students' personal interest in learning physics, teachers can manipulate the stimuli in the learning environment to trigger students' situational interest in physics (Subramaniam, 2009). Triggering situational interest among students is particularly essential for teachers in dealing with students who do not have a personal interest in physics (Ainley et al., 2002; Subramaniam, 2009). In secondary education settings, physics instruction should first focus on triggering students' situational interest, leading to the development or increase of students' personal interest in learning physics (Walper et al., 2016). In this study, integrated STEM-PBL Physics Module became the stimuli to trigger situational interest in learning physics among Form 4 and Second-Year high school students hoping they could increase their personal interest in learning physics. Through integrated STEM-PBL Physics Module, they had experienced a different approach in learning classi-

https://doi.org/10.33225/jbse/23.22.113

cal mechanics instead of traditional instruction. This justification is supported by Subramaniam (2009) in which students' situational interest can be triggered by modifying certain aspects of the learning environment such as teaching strategies, task presentation and structuring of learning experiences.

The findings of this research are similar to what has been reported in the literature. Previous studies had shown that integrated STEM-PBL approach (Han et al., 2015) and PBL (Capraro & Jones, 2013; Liu, 2014; Jeffry & Fauziah, 2016) could effectively increase students' personal interest in learning physics at the secondary school level. Besides that, physics instruction focuses on student-centered approach, hands-on activities (Djudin, 2018), problem solving (Hidi & Renninger, 2006), investigation, discussion (Walper et al., 2016), cooperative learning (Chang, 2005) and practical activities related to everyday life experiences (Walper et al., 2016) can improve students' personal interest in learning physics. Providing support and opportunities in asking curiosity questions, linking content to prior experiences (Djudin, 2018), social interaction, (Liu, 2014) and providing choices about what and how work is done (Sheldrake et al., 2019) also help to increase students' personal interest in learning physics. In this study, these types of instruction were consolidated and became the approach on how Form 4 and Second-Year high school students learned classical mechanics in secondary education through the module.

Physics teaching explicitly focused on note taking, written exercises and repetitions resulted in the decline of students' interest in physics at the secondary education level (Walper et al., 2016). Findings from the analysis also revealed that students in the control group had less interest in physics because they found physics was difficult, had a lot of formulas needed to be memorized and involved a lot of calculations. Students' personal interest in learning physics in the analysis phase was very much influenced by the approach used by teachers in which it was revealed that teachers often used traditional instruction to teach physics in the classroom. Besides that, participants in the control group who learned physics through traditional instruction had not increased personal interest in learning physics during the real study. Results in this study are supported by the previous studies in which the conventional teaching leads students to view physics as boring and impractical, making them lose interest in learning physics (Sahin & Top, 2015; Kortam et al., 2018). Students become less interested in learning physics through conventional teaching because they learn in an isolated manner with missing connections to crosscutting concepts (Kelley & Knowles, 2016). Traditional instruction does not promote connection with real-world applications instead of focusing on recall and copying (Trumper, 2006).

Belief Specific Category - Sense Making and Effort

Focusing on improvement in sense making at secondary school can benefit students (Cannady et al., 2019). Sense making and effort are interrelated to each other since engaging in sense making requires effort (Nokes-Malach & Mestre, 2013; Massin, 2017; Cannady et al., 2019). Sense making and effort greatly influence students to learn physics (Saleh, 2014; Jeffry & Fauziah, 2016). Some physics teaching can increase students' sense making and effort in learning physics (Blumenfeld et al., 1991; Cannady et al., 2019). The findings of this study are similar to what has been reported in the literature. Previous studies had shown that PBL can increase students' sense making and effort in learning physics (Jeffry & Fauziah, 2016b; Menzies et al., 2016; Sadrina et al., 2018). Physics teaching focuses on asking good questions and defining problems, researching, student-centered approach, analyzing and interpreting data, real world connection, modelling and discussion can increase students' sense making in physics (Cannady et al., 2019). Previous studies also reported that physics instructions explicitly emphasize peer tutoring (Alemu, 2019), challenging tasks, group work and problem solving (Bonham, 2007) can increase students' effort to learn physics. In this research, these types of teaching were consolidated and became the approach on how Form 4 and Second-Year high school students learned classical mechanics in secondary education through integrated STEM-PBL physics module.

Some physics teachings are ineffective in increasing students' sense making and effort in learning physics (Blumenfeld et al., 1991; Cannady et al., 2019). Results in this study revealed that participants in the control group who learned physics through traditional instruction had not increased in sense making and effort in learning physics during the real study. Findings in this research are supported by previous studies in which traditional instruction leads students to memorize facts rather than make sense of information learned in class (Thomas, 2000; Han, 2017). Learning physics through traditional instruction, students passively listen, write down and summarize what the teacher says without thinking about the given information (Liu, 2014; Kortam et al., 2018; Aviyanti, 2020) and most of them are silent during the learning process (Hairan et al., 2018). Students invest less effort if they find learning activities are too dull (Schmid & Bogner, 2015).

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Conclusions and Implications

Integrated STEM-PBL Physics Module effectively improved students' personal interest and sense-making and effort. These two themes are very important hence it may promote students' motivation to learn physics, specifically classical mechanics. Results from this study have proven that integrated STEM education is possible to be implemented at the secondary education level through PBL for students to learn classical mechanics and improved students' belief in personal interest and sense-making and effort, two themes that are responsible to promote students' competency. With the curriculum framework and instructional material proposed, this study can provide guidelines for secondary school teachers to develop their own STEM-PBL activities with the assimilation of several learning objectives from the discipline-based curriculum content. From the Malaysian perspective, integrated STEM education is not well established that causes many secondary school teachers are not familiar with the approach although the Malaysia Education Blueprint (2013-2025) was introduced in 2013. Therefore, this can help the Ministry of Education Malaysia achieve the aspirational target in strengthening the delivery of integrated STEM education across the education system as required in the blueprint. From the Korean perspective, many teachers have difficulties implementing multidisciplinary STEAM education approach and doubt its effectiveness towards students although it became the primary approach to promote STEAM education in Korean school after the STEAM education policy was issued in 2011. Interdisciplinary STEAM education approach is getting more attention in Korea due to its suitability for engaging students who have limited STEM knowledge and skills. However, research about interdisciplinary STEAM education approach lacks in the Korean education setting. Therefore, it is hoped this research can help the Ministry of Education Korea in designing meaningful integrated STEAM education in the form of interdisciplinary approach centered on the discipline-based curriculum especially in improving students' beliefs in specific categories, i.e., personal interest and sense-making and effort.

There are several recommendations on what needs to be done to ensure the STEM-PBL physics module in this research is applicable and favorable in secondary education settings that may raise students' belief in personal interest and sense-making and effort include. The first one is the context and work done in the integrated STEM-PBL physics module should be reflected in the examination, meaning that the examination does not just reflect students' capability of remembering theory. Still, the assessment should be holistic and continuous throughout the school session. Secondly, as the traditional approach is the method of instruction most students and teachers are familiar with, it would require effort, funds, and support from various stakeholders to improve how students learn content and subject matter meaningfully. Finally, parents must also clarify how the integrated STEM-PBL Physics module could uplift students' 21st-century skills if exposed early in secondary school. Thirdly, physics teachers should be provided with an effective professional development program to ensure they are competent to practice the integrated STEM-PBL approach in the classroom. For example, only some teachers have the competency to be a good facilitator to guide students in their classes. Therefore, continuous self-development and ready support service are crucial to prepare teachers to become competent facilitators. Finally, STEM-PBL activities can be conducted in the form of a competition where a group that constructs the best products will be given a prize and make it the school frequent activity. This will help make the learning process more enjoyable.

Acknowledgements

This study received a grant from Universiti Malaysia Sabah, coded UMSGreat_GUG0210-1/2018.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Declaration of Interest

The authors declare no conflict of interest.

https://doi.org/10.33225/jbse/23.22.113

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Received: *November 14, 2022* Revised: *January 05, 2023* Accepted: *February 09, 2023*

Cite as: Sulaiman, F., Rosales JR., J. J., & Kyung, L. J. (2023). The effectiveness of the integrated STEM-PBL physics module on students' interest, sense-making and effort. *Journal of Baltic Science Education*, *22*(1), 113-129. https://doi.org/10.33225/jbse/23.22.113

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