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Analysis of STEM-Based Project-Based Learning Model on Physics Materials Referring to the Independent Curriculum

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Abstrak. High school physics learning outcomes referring to the Regulation of the Minister of Education and Culture include aspect of understanding concept. The purpose of this study was to descriptively analyze the development and effectiveness of STEM-Project Based learning (STEM-PjBL) model in physics learning outcomes referring to the independent curriculum in Indonesia. This study used a descriptive qualitative research approach with data collection techniques through in-depth interviews, data observation, literature studies. The study was conducted in six Senior High Schools in Semarang from July 1st to August 31st, 2022. The data sources consisted of physics teachers, observation sheets and literature studies from published or perish (PoP). In the literature study, data collection was carried out based on the Scopus database with the keywords STEM Based Project based learning; Physics learning. The data analysis was carried out using Miles and Huberman (2014) model, which included the stages of data reduction, display, and verification. The results showed that most of the teachers who applied physics learning in the independent curriculum had not used the STEM-based PjBL learning model and still experienced many obstacles in developing learning scenarios, thus the outcomes of learning physics were still low. Supported by the results of literature study using *PoP*, it illustrates that the trend of physics publications from 2017-2022 is dominated by PjBL and STEM learning at the high school level. This study recommends that the availability of guides or manuals for implementing online and offline STEM-based PjBL learning model that can develop the aspects of scientific skills and product of the students learning is needed.

Key words: Physics-Project Based Learning, STEM, Independent Curriculum

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INTRODUCTION

Analysis of one of the main components in the national education standard through 2013 curriculum and independent curriculum with scientific-based characteristic emphasizes that the standard of learning process is crucial to support the success of the education implementation process. Learning process is not just a process of transferring knowledge from educators to students textually, but how education can facilitate students to have knowledge, attitude, personality, and independence. The implementation of education must be carried out to develop skill and character as well as the dignity of the nation which emphasizes that the standard of learning process is important to support the success of the education process. Characteristics of high school physics learning generally include two aspects, namely physics comprehension and process skills. These two elements can be described broadly and flexibly based on the physics learning materials. One of elements of physics comprehension that needs to be mastered by students is about energy sustainability with process skill element gained significantly including scientific and engineering skills (Aditomo, 2021; Suharto, 2017).

The industrial era 4.0 provides a challenge that learning should be able to develop 21st century skills thus students can face the globalization era well. Learning approaches that can facilitate in improving 21st century skills include flipped learning/ blended learning, metacognitive learning, independent-based learning, STEM, teacher pedagogical abilities, cultural and multicultural and cooperative-based education, (Latorre-Cosculluela et al., 2021; Karatas, 2021; Lavi et al., 2021; Rubach & Lazarides, 2021; Amzaleg & Masry-Herzallah, 2021). The 21st century skills as one of the components that must be mastered by students as a result of the development of technology and information in the industrial revolution 4.0 are totally crucial (Valtonen et al., 2021). This development is linear with the demands of technology-based learning and contextual local

wisdom.

The step for the successful implementation of project-based learning is by preparing important questions related to a material topic that will be studied. The PjBL stages in this study consisted of 6 steps, namely making project plans, making schedules, monitoring the implementation of project-based learning, conducting assessments, and evaluating project-based learning (Foundation, 2005). STEM education is carried out in three ways. They are: (1) STEM is carried out separately (separate subject of STEM), (2) STEM is taught in an integrated approach (integrative subjects approach), (3) STEM is carried out separately and integrated (separate and integrative) (Ritz & Fan, 2015). Several countries including Australia, China, Korea, and Taiwan have been developing STEM designed with a cross-disciplinary/ integrated approach (Baran, 2021). In this study, STEM education was taught in an integrated approach.

The STEM (Science, Technology, Engineering, Mathematics) approach and the PjBL (Project-based Learning) model are one of synergistic learning approaches in physics learning application. Exploration of the impact of using this model in physics learning includes critical thinking skills, creative thinking, increasing students' efficacy, concept understanding, increasing self-confidence, and making learning is more contextual (Mutakinati et al., 2018; Lou et al., 2017; Samsudin et al., 2020; Tan et al., 2021; Maher & Bailey, 2018; Chaudry, 2020). The results of the literature study using PoP (Publish or Perish) application with the keywords STEM Based Project based learning; Physics learning based on a search through Scopus starting in 2017-2022 showed that the STEM-based PjBL model is able to facilitate physics learning in which it can improve various kinds of 21st century skills as required by the achievement of physics learning in the independent curriculum.

Teachers have an important role in succeeding learning activities thus students are able to acquire 21st century abilities and skills. Based on the facts in the field, the results of the observation study in six high schools in Semarang on July 1st – August 31st, 2022 showed that in teaching physics at the high school level, the teachers did not fully implement learning activities using STEM-based PjBL. In fact, the empirical facts from the literature study show that STEM-based PjBL learning can significantly improve aspects of students' skills, knowledge and attitudes. Supported by the instruction from the Ministry of Education and Culture that the outcome of physics learning in the independent curriculum requires project-based learning in improving aspects of attitude, knowledge and skills as well as the character of the nation (Aditomo, 2021; Suharto, 2017). Based on this, the researcher feels that conducting a research on the Analysis of STEM-Based Project-Based Learning Model on Physics Materials Referring to the Independent Curriculum is undoubtedly needed.

The purpose of this study was to analyze the STEM-based PjBL learning model on physics materials based on the independent curriculum. The benefit of this research is that it provides recommendations for the availability of guidelines or manuals for the implementation of online and offline STEM-based PjBL learning model that can develop aspects of scientific skills and product of the students learning.

METHODS

This study used a descriptive qualitative approach. The research was conducted in six Senior High Schools in Semarang from July 1st to August 31st, 2022 including Senior High School 1 Semarang, Senior High School 3 Semarang, Senior High School 5 Semarang, Senior High School 7 Semarang, Senior High School 12 Semarang and Senior High School Teuku Umar Semarang. The data sources of this research included interviews from physics teachers, observation sheets, document studies and literature studies from Published or Perish (PoP). The interviewees for this study were 6 physics teachers, in which in each school, 1 physics teacher was taken as a sample. The first step was by using the interview technique. Interview technique is widely used in qualitative research to obtain primary data (Sugiyono, 2014). Interview was conducted with physics teachers with open-ended questions based on the interview instrument clues/ guidelines. The interview clues/ guidelines are shown in Table 1.

Table 1. The guideline of the interview

Variable	Sub Variable	Indicator	Question Number
Conventional learning	General model in Senior High School Physics Learning	Learning that is usually applied and the reasons for choosing other learning models by physics teachers in senior high school physics learning	1,2,3
Multidisciplinary learning	Physics learning model by integrating other related scientific fields	Physics learning that is usually applied with the integration of other scientific fields thus it can generates a contextual and comprehensive understanding	4, 5, 6, 7, 8, 9
STEM-based PjBL Model	PjBL stages in the implementation of physics learning	The teacher orients students regarding the learning materials	10
		The teacher facilitates students to formulate basic questions related to the application of physics in social life	11
		Designing project task planning in STEM-integrated PjBL-based blended learning	12
		Compiling the project task schedule according to the time allocation	13
		Monitoring the progress of the project	14
		The teacher assesses the learning process and outcomes	15
		The teacher evaluates the implementation of blended learning based on the STEM-based PjBL	16

The second step was using observation in the form of document studies which were ATP (learning objective plot) and teaching modules as well as learning activities photos. The document review in this study aimed to obtain data on the application of the STEM-based PjBL model in the implementation of the independent curriculum as well as identify various problems or obstacles faced by teachers in implementing the independent curriculum. The document review activities using the observation activity guideline is shown in Table 2.

Table 2. The guideline of *RPP* (Lesson Plan) Observation Sheet Instrument

Indicator	Name of Document
The teacher formulates learning indicators in accordance with the outcomes of physics learning	Teaching Modules, *ATP* (learning objective plot), and activity photos
The teacher formulates realistic and contextual learning objectives	
The teacher presents contextual learning materials	
The teacher uses learning media that are in accordance with learning objectives and outcomes	
The teacher uses learning methods in accordance with learning objectives and outcomes	
The teacher carries out an effective learning activity plan based on the learning stages used	
The teacher conducts authentic assessment	

The third step was using the observation sheet of the implementation of learning in the field. This observational study of the implementation of learning was an important part of a qualitative study to cross-check the data that had been obtained previously through interviews and document studies. As for the activity of observing the implementation of

learning, it was shown by using the observation guideline in Table 3.

Table 3. The guideline of Learning Implementation Observation Sheet Instrument

Indicator	Type of activity
The teacher does apperception and motivation	Observation of learning implementation
The teacher conveys competencies and activity plans	
Teacher's mastery in subject material	
Teacher's mastery in the application of educational learning strategies	
The teacher does a scientific approach	
Teacher's mastery in the use of learning resources	
The teacher engages students in learning	
Teacher carries out authentic assessments	
The teacher uses the appropriate language in learning	
The teacher reflects on the outcomes of the learning that have been carried out	

The research instrument's validity test used expert judgment techniques to 3 experts and practitioners, then quantitative analysis using Aiken's V was conducted. The calculation results for the interview instrument sheet, document observation sheet and learning implementation observation sheet ranged from 0 to 1 thus it could be categorized as high and if compared to the value of Aiken's V Table, in general the instrument that had been constructed can be said to be valid (Aiken, 1985).

The fourth step was the analysis of the literature study using publish or perish (PoP). In the literature study, data collection was carried out based on the scopus database with the keywords "STEM Based Project based learning; Physics learning" with a time span of 2017-2022 with a focus on sample selection, that was purposive sampling because it was adjusted to the research theme. The next step after getting the articles was sorting the information which was carried out on August 1st, 2022 by choosing the type of publication in the form of journals and obtaining 83 article titles containing studies based on the keywords. The research development mapping was analyzed using VOSviewer application with the aim of finding trends in scientific publications using the scopus database in the 2017-2022 interval. The focus of the mapping was PjBL and STEM in physics learning based on the keywords. The results of searching metadata via PoP are shown in Figure 1.

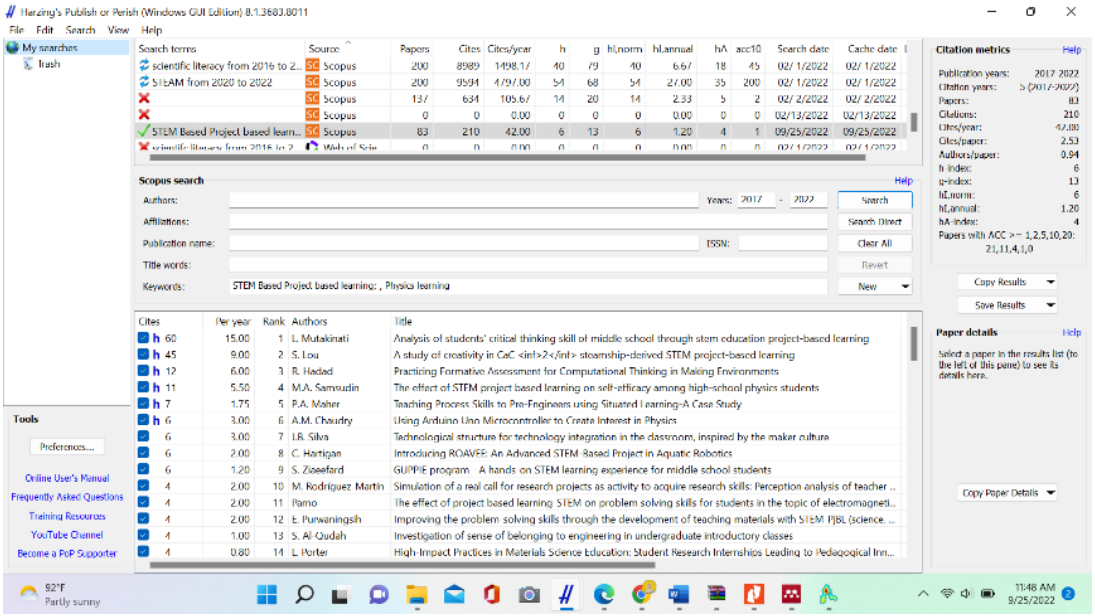

Figure 1. Metadata Search Results via PoP

The next data analysis process was the results of observation, interviews, and documentation,

then reduction and presentation of data were carried out before doing in-depth interpretation. The data collection process used the data triangulation technique, namely the technique of checking the validity of the data using cross check and professional judgment (Moleong, 2018). The data analysis stages are shown in Figure 2.

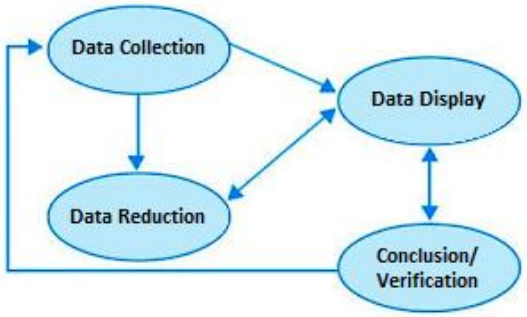

Figure 2. Qualitative Data Analysis According to Miles and Huberman (Sugiyono, 2014)

RESULTS AND DISCUSSION

Learning Models Commonly Used in Senior High School Physics Learning

The learning models that were usually applied in physics learning in Senior High School in Semarang with research subjects including 6 Senior High School in Semarang were conventional with 2-way lectures, and cooperative learning. Most teachers only used these 2 models in carrying out learning for several reasons, including: (1) teachers prefer things that are not complicated in the learning process. In this case, the teacher only emphasizes the knowledge aspect as an output that must be obtained by students, thus the significance of physics learning which is contextual is failed; (2) Teachers are less skilled in understanding various kinds of learning models and approaches. This is what makes teachers stagnant in applying varied and innovative learning models. Teachers prefer to teach with a textual system; (3) STEM-based PjBL model learning requires time and thorough preparation in classroom learning; (4) Teachers only rely on knowledge assessment thus aspects of students' skills and attitudes are hardly assessed authentically; (5) teachers only focus on monodiscipline learning, therefore inductive physics learning which should be able to be done with multidisciplinary and multicultural learning has not been carried out. These are the reasons why STEM-based PjBL model has not been implemented in physics learning.

The results of the document review in the form of *MA* (teaching modules) and *ATP* (learning objectives plot) for class X Senior High School by implementing independent curriculum were less visible in the scientific aspect in physics learning because of the teacher's lack of knowledge in directing project-based learning model. Independent curriculum textbooks, which consisted of teacher's and student's books, were still textual and tended to be lacking in directing students in project-based activities. On average, teachers were guided by the Teacher's book from the Ministry of Education and Culture without any development so that it seemed textual. Empirical evidence showed that PjBL model based on STEM becomes problem solving in learning thus it can significantly develop students' knowledge, attitudes and skills (Parno et al., 2020; Sari et al., 2021; Hasbullah et al., 2020; Parno et al., 2019).

The results of the analysis of learning during remote learning in Senior High Schools in Semarang revealed that teachers hardly trained 21st century skills to their students. It can be seen from the Learning Implementation Plan (*RPP*) made by the teacher that still measured the cognitive aspects/knowledge of students. The results of observation during learning through *google classroom, google meet, microsoft office 365* platforms showed that students tended to be passive and teachers had not provided much learning that trains 21st century skills. Based on this, STEM-based project based learning in blended learning classes is an alternative to carried out in the context of implementing the 2013 curriculum and the independent curriculum as well as a framework for scientific research on educational developments, especially in designing creative and innovative learning process.

The Implementation of STEM-based PjBL Model in Physics Learning

The results of the research based on interview and document studies showed that the teachers had not been maximal in teaching STEM-based project-based learning (PjBL). The teachers tended to only teach with conventional approaches and cooperative learning. The results of further analysis that the STEM-based PjBL model in physics learning as a result of observing the implementation of learning can be identified as follows.

Table 4. The Results of the Analysis of Learning Implementation Observation Activities

STEM-based PjBL Learning Stages	Phase	Learning Activities	Identification Result
Problem orientation	Conducting orientation to students regarding the concepts of learning materials	Students review learning materials to explore the concepts of the learning materials	Accomplished Well
Basic questions	The teacher facilitates students to formulate basic questions related to social life	Students formulate basic questions related to the study and the application of physics in social life	Quite Accomplished
Designing design project planning	Designing project task planning in STEM-based PjBL-based blended learning	Teachers and students design project assignment plans regarding the application of physics which are included in STEM- integrated PjBL-based blended learning	Not Accomplished yet
Scheduling	Arranging a project task schedule based on the time allocation	Teachers and students arrange the schedule of the project	Not Accomplished yet
Monitoring progress	Monitoring the progress of the project	The teacher does the final check	Not Accomplished yet
Assessing learning process and outcomes	The teacher assesses the learning process and outcomes	Students make product presentation	Not Accomplished yet
Evaluating experience in implementing projects	The teacher evaluates the implementation of blended learning based on STEM- based PjBL	Teachers and students do reflection	Not Accomplished yet

The results of the observation of the learning implementation showed that the teacher had succeeded in building apperception by connecting the orientation of the problems to be discussed during the learning period. The first stage of STEM-based PjBL activities succeeded in building initial knowledge, assimilation and students' curiosity about the learning material to be carried out. This activity was driven by the teacher so that students seemed to only follow the instructions provided by the teacher during the learning. In the second stage, in the form of basic questions, students had not fully done it. The learning was still teacher-centered thus only a few students were able to capture and make questions based on the assimilation of knowledge that was assosiated with everyday life. In the third to sixth stage, the teachers had not carried out the project activities and the learning process was textual so the students tended to only do learning by making a note of the formulas, and doing the practice questions. This is what makes learning physics becomes a learning that is less attractive to students. Empirical evidence showed that the STEM-based PjBL model can improve attitude, interest, enthusiasm, creativity in physics learning (Ziaeefard et al., 2017; Purwaningsih & Sari, 2020; Rugh et al., 2020).

The process of physics learning at the high school level should be carried out with a scientific approach because physics learning is closely related to natural phenomena and scientific processes that lead to problem solving. Empirical evidence showed that STEM approach is very relevant to be applied in physics learning in accordance with the contents of the independent curriculum in the form of physics learning achievements that lead to multicultural activities and improve the nation's character (Pangesti & Triyanta, 2022). So far, the results in of the field observations showed that teachers still have difficulty to integrate learning activities that link science, technology,

mathematics, and engineering. In addition, there is no guidebook for teachers in applying the STEM approach in learning.

The Mapping of the STEM-based PjBL Research Trends Development in Physics Learning

Metadata of 83 articles obtained using the PoP application with the Scopus database and using the keywords "*STEM Based Project based learning; Physics learning*", starting from 2017 to 2022, a bibliometric analysis process was carried out using VOSviewer with the aim of finding the relevance and the update of research based on the research theme raised. The mapping of the STEM-based PjBL Research Trends Development in Physics Learning as shown in Figure 3 was obtained by applying the binary method to the selection in the VOSviewer application by analyzing the appropriate themes and keywords. The minimum number of occurrences of term selected was 3 and showed that 34 met the threshold.

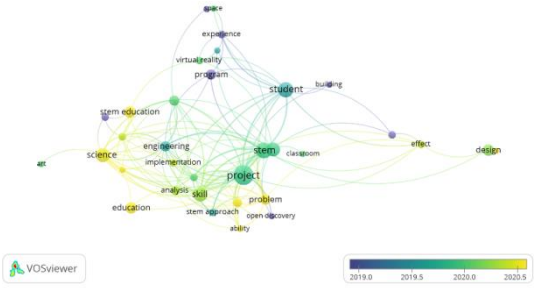

Figure 3. STEM-based PjBL Clusters in Physics Learning

The results of the visualization in Figure 3 showed that there were 8 clusters with a total of 34 research items. Cluster 1 consisted of 7 items including experience, program, space, student, success, virtual lab, virtual reality. Cluster 2 consisted of 6 items including art, implementation, mathematics, science, STEM education. Cluster 3 consisted of 5 items including classroom, development, high school student, open discovery, physics. Cluster 4 consisted of 4 items including design, effect, instrument, STEM project. Cluster 5 consisted of 4 items namely analysis, engineering, integrated STEM, technology. Cluster 6 consisted of 3 items including education, skill, STEM. Cluster 7 included 3 items, namely ability, problem, and STEM approach. The last one, cluster 8 consisted of 2 items including building and project.

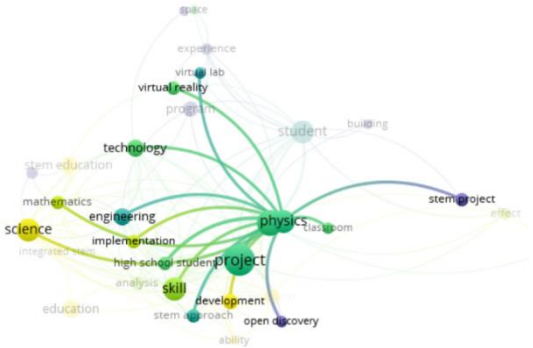

Figure 4. Clusters in Physics Learning

The results of the VOSviewer visualization in Figure 4 showed the relationship between cluster 3 which consisted of 5 items with the focus of the item which was physics including the related research network, had a total of 14 path lines. The trajectory in bold print showed the relationship of research that had been carried out quite a lot, including projects, technology, skill, science, and engineering. The rest were thin lines and small circles which showed weak relationships with physics.

CONCLUSION

The results of this study indicated that there are obstacles for physics teachers in implementing an independent curriculum, especially the application of project-based learning model at the high school level. This is because the teacher's and student's books from the independent curriculum are still lacking in project-based learning activities and are still far from contextual learning. Another reason that makes the STEM-based PjBL model has not yet widely used by teachers is the lack of information and knowledge in applying the learning model so that it has an impact on teachers' difficulties in implementing it in the classroom. In addition, it takes a lot of time and sufficient preparation in implementing the STEM-based PjBL model. The implication of this study provides recommendations for several things: 1) there is a need for a physics teacher training model in implementing the independent curriculum in the development of project-based activities and 2) it is necessary to provide a guide or manual for the application of online and offline STEM-based PjBL learning model that can develop aspects of scientific skills and product of the student learning.

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