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## **The Growth of Vocational High School Students' 4C Skills on the Use of PjBL STEM-Based Physics Digital Module**

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### **Abstract**

The Partnership for 21st Century Learning (P21) developed the Framework for 21st Century Learning to help education practitioners integrate skills into lesson teaching. This framework describes the skills, knowledge, and expertise that students must master in order to succeed in work and life. One of the skills that must be mastered by students in facing the 21st century is the 4C skill which consists of critical thinking, communication, collaboration, and creativity skills. This study aims to analyze the growth of the 4C skills of SMK students as the effect of implementing the use of PjBL STEM-based digital physics modules. This research is an experimental study with the before-after method, which compares the conditions before and after the implementation of learning activities. Data was collected by filling out a questionnaire with a Likert scale by students. The results showed that the 4C skills of vocational high school students grew significantly.

## INTRODUCTION

Entering the 21st century which is characterized by rapid technological advances, students are expected to have 21st century skills. The Partnership for 21st Century Learning (P21) develops a 21st century framework known as the Framework for 21st Century Learning which describes the skills, knowledge, and expertise that students must master to succeed in work and life. One of the skills referred to is the 4C skills which include critical thinking, communication, collaboration, and creativity. Students must become skilled communicators, creators, critical thinkers, and collaborators (4C) in order to compete in a global society (Nawawi *et al.*, 2022). Hidayatullah *et al.* (2021) revealed that achieving 21st century skills can be done with several efforts, including by encouraging communication and collaboration, emphasizing problem or project-based learning, and designing learning activities that are relevant to real life.

In order to equip students with 4C skills for the future, these skills need to be integrated into classrooms, schools and areas across the country to produce citizens and employees who are sufficiently prepared to face the 21st century (Erdoğan, 2019). The importance of 4C skills affects the mindset and performance of students in the future. Students are enabled to interact competently and respectfully with others with communication and collaboration skills. These interactions can be across cultures, in diverse and multinational workplaces and communities in the global and digital era.

Creative thinking skills are essential in supporting students to think outside the box, construct new scenarios, and produce amazing work. In today's digital era, many jobs are growing and industries are developing that depend on creativity. Critical thinking skills and problem solving abilities allow students to assess incoming information every day, whether on websites, in the media, at home, at work, etc. However, Le & Wang (2022) revealed that the need for improving students' digital skills must be balanced with a well-structured online learning environment that involves intuitive navigation prompts.

The module is an independent learning package in the form of a series of learning experiences that are systematically planned and

designed to help achieve learning goals for students. The module contains materials, methods, limitations, and ways of evaluating that are designed in an attractive way to achieve the expected competencies. Some of the characteristics possessed by the module, including self-instructional, self-contained, stand-alone, adaptive, and user friendly. With these characteristics, the module can help students learn independently without depending on other parties. Yamin in Al Fatihah (2016) revealed that the application of independent learning to students has implications for bringing positive changes to students' intellectuality.

STEM (Science, Technology, Engineering, and Mathematics) is a learning approach that is able to integrate several skills needed to prepare for the 21st century (Widayoko, 2020). STEM integrates the scientific fields of science, technology, engineering, and mathematics in a comprehensive complex learning that will develop students' knowledge and skills. STEM learning leads to contextual learning that brings students to real-world situations. With learning that originates from these 4 scientific fields, it is hoped that students will get used to looking at all information and problems with a complex outlook and be scientific. Science learning experiences based on STEM education will develop students' abilities to understand science content, the ability to innovate and solve problems, as well as soft skills, such as communication, collaboration, leadership (Matondang, 2019).

The application of STEM in textbooks brings benefits to students' independence and critical thinking skills (Agnezi, 2019). One learning model that is very feasible to apply to increase the effectiveness of the STEM approach is PjBL (Project Based Learning) (Diana *et al.*, 2021). The application of an approach like this encourages students to pay attention to things that happen in everyday life because students are faced with problems that require students to find solutions to these problems (Hadinugrahaningsih, 2017). The application of the project-based learning model (PjBL) also helps improve student learning activities and productive competencies (Jalinus *et al.*, 2017). In Asia itself, the application of STEM that is integrated with project-based learning is preferred (Wahono, 2020).

PjBL STEM according to Laboy-Rush (PPPPTK BOE, 2018) has a learning model syntax as shown in Table 1.

**Table 1.** STEM PjBL Learning Syntax

Syntax	Explanation
Reflection	This stage aims to bring students into the context of the problem and provide inspiration so that students can immediately carry out investigations which also intend to connect what is already known and what students need to learn.
Research	This stage is a form of student research. The teacher guides the discussion to determine whether students have developed conceptual and relevant understandings based on the project (Satchwell & Loepp, 2002).
Discovery	The discovery stage bridges research and information that is already known. Students are divided into small groups to determine solutions to problems encountered, collaborate with each other, and build cooperation.
Application	This stage aims to test the product/solution presented to solve the problem. Students test products made from previous provisions, then the results are used to make improvements.
Communication	The final stage in each project is carried out by communicating between friends and classes. Presentations are an important step in developing communication and collaboration skills, as well as the ability to receive and apply constructive feedback.

STEM that is fully integrated with PjBL can increase teaching effectiveness (Jamali, 2017). PjBL STEM implementation as a whole has a major impact on students' science achievement across ethnicities and gender (Erdoğan, Navruz, Younes, & Capraro, 2016). Tseng et al. (2013) in their research revealed that the combination of PjBL and STEM can increase effectiveness and produce meaningful learning, as well as influence students' attitudes in pursuing future careers. This PjBL STEM integrates engineering design principles that enhance real-world application and helps prepare students for post-secondary education, with an emphasis on what STEM professionals do in their field of work (Capraro & Slough, 2013).

According to Ministry of Education (2003), teaching materials are materials that students must learn as learning tools. Teaching materials can be in the form of many things that can be used to increase students' knowledge or experience, such as reading books, student worksheet broadcast materials, digital materials, photos, videos, even conversations by inviting native speakers.

Modules are teaching materials that are complete, stand-alone, and consist of a series of learning activities to achieve clearly formulated goals (Kosasih, 2020). The module contains a discussion that is arranged in a systematic, operational and directed manner to be used by students independently. To maximize its function, the module is also equipped with a user guide for teachers.

The characteristics possessed by the module make it different from other teaching materials. Some of the characteristics of the module are described as follows.

- a. Self-instructional, students can learn independently without relying on other parties by utilizing modules.
- b. Self contained, all material in learning from one competency unit is presented in one complete module as a complete unit. The distribution of material is carried out by paying attention to systematics correctly according to the scientific hierarchy.
- c. Stand alone, the use of the module does not depend on the use of other sources or media.
- d. Adaptive, modules are adaptive to development so that their contents are not rigid and provide room for improvement by adding, replacing, adjusting, and enriching material.
- e. User Friendly, the module pays attention to the interests of its users so that every instruction, task, and information presented is oriented towards the diverse interests of its users.

Digital teaching materials are teaching materials that use digital devices such as computers, smartphones, laptops, and the like (Kosasih, 2020). The content of digital teaching materials is not much different from printed teaching materials, the difference is the presentation in digital form, usually in the form of PDF which can be opened via digital devices. The strength and weakness of digital teaching materials are presented in Table 2.

**Table 2.** Strengths and Weaknesses of Digital Teaching Materials (Kosasih, 2020)

Strength	Weakness
1. Can present in full various forms of graphics, animation, audio, and video.	1. Requires the availability of adequate electricity network.
2. Students are involved interactively and will be more active in the learning process so it is not boring.	2. Its use requires a special device or a specific program.
3. Can collect information on the activities of each student directly for the purposes of assessment.	3. It tends to be more effective when used individually and more difficult to use in groups.
4. Presenting additional information more easily and completely through internet access (links) to various sources (websites).	4. Requires relatively expensive costs in setting up the device.
5. Utilization is faster and more practical.	5. Requires mastery of certain programs.
6. Does not require a large space or special space for storage.	6. Requires an adequate internet connection.

The use of digital teaching materials can have some following positive impacts. It can increase the effectiveness of learning, in which students are actively involved in the learning process. It also can increase the efficiency of self-learning, in which students can study material in digital teaching materials in a flexible space and time.

As the main foundation in the world of engineering, physics subjects study several materials that are closely related to technology and engineering. Mastery of mathematics is necessary to be able to master physics so that one can easily solve physics problems (Haryadi, 2016). However, not all material in learning can be carried out using the STEM approach. Optical material, whose utilization covers many fields such as science, technology, and industry, is one of the materials in physics that can be taught using the STEM approach. Based on the curriculum documents in the 2013 Curriculum, Core Competency (KI) and Basic Competency (KD) for the Technology and Engineering field of expertise contain material on optical geometry which is described in KD 3.16 (Applying the properties of mirrors and lenses to optical devices) and 4.16 (Planning manufacture of simple optical instruments by applying the principles of reflection to mirrors and refraction to lenses). As for the field of Information and Communication Technology expertise, it is outlined in KD 3.5 (Analyzing physical optics and geometry) and 4.5 (Presenting experimental results on physical optics/geometry). In this study, the digital physics module used is a digital module based on PjBL STEM on optical material.

Research related to the development of teaching materials to develop 4C skills has been carried out by Susanti (2019). The research results show that the development of the textbook has a significant effect on students' 4C abilities. Besides that, based on the results of the analysis, it was concluded that the textbooks developed were valid, practical, effective, and could be used in learning.

Yulianti *et al.* (2020) was developing teaching

material based on STEM. The results of the study show that the developed teaching materials are suitable for use in learning and are easy to understand. The results of the analysis of critical thinking skills, creativity, communication, and collaboration show high development.

There are many ways to practice the integration of STEM disciplines in the implementation of learning and industry. There are three patterns of STEM learning approaches, namely silo, embedded, and integrated approaches. In this study STEM was carried out using an Embedded approach; is an approach pattern that emphasizes knowledge obtained through the study of real-world problems and problem-solving techniques in social, cultural, and functional contexts (Chen, 2001). In this research, an embedded approach is carried out by presenting various STEM problems in the digital physics module related to the material being studied, namely optical material.

## METHODS

Physics learning using digital modules based on PjBL STEM is carried out in class X TKJ 5 SMK Negeri 1 Binangun on optical materials and optical devices. The method used in this study was to compare the initial and final conditions of students after carrying out physics learning activities by using a questionnaire. The study was the growth of 4C skills in SMK students during learning activities using the PjBL STEM-based digital physics module is calculated using the  $t_{\text{test}}$  with the following hypothesis formulation.

$H_0$  = there is no significant 4C growth between before and after learning activities

$H_a$  = significant 4C growth occurs between before and after learning activities

Decision making is done with the following criteria. If the significance value is  $> 0.05$  then  $H_0$  is accepted and if the significance value is  $< 0.05$  then  $H_0$  is rejected.

## RESULTS AND DISCUSSION

The 4C skill aspect is the main focus in this

research. Students carry out a self-assessment of the 4C skill aspects through a questionnaire. The results of students' self-assessment of the 4C skills at the pretest and posttest are shown in Table 3.

**Table 3.** Results of Student Self-Assessment of 4C Skills

No	4C Aspects	Pre Test	Post Test	t-test
1	<b>Critical Thinking</b>			
	Average	66.31	70.47	6.35
	Minimum	55	57	
	Maximun	80	83	
2	<b>Creativity</b>			
	Average	68.74	72.83	4.67
	Minimum	52.73	52.73	
	Maximum	81.82	83.64	
3	<b>Communication</b>			
	Average	75.59	79.54	4.51
	Minimum	65.88	65.88	
	Maximum	91.76	91.76	
4	<b>Collaboration</b>			
	Average	80	90	4.48
	Minimum	66.67	66.67	
	Maximu	100	100	

The results of the analysis show that the growth of 4C skills in the aspects of Critical thinking, Creativity, Communication, and Collaboration has experienced significant growth. From the table 1 above, it can be seen that the  $t_{\text{count}}$  value of the growth of each aspects of 4C skills are much larger than the  $t_{\text{table}}$  value of 1.69 for the 95% confidence level (this value can be seen in t table for degree freedom 35). For example, the  $t_{\text{table}}$  of the growth of critical thinking aspect is 6.35 which is much larger than 1.69.

Physics learning activities on optical materials and optical devices in class X TKJ 5 are carried out by applying the use of PjBL STEM-based digital physics modules which have been developed and have been validated by lecturers and material expert teachers and media experts. The digital module that has been developed is used as a reference for learning activities, because it is equipped with instructions, KI/KD, learning objectives, to learning activities that need to be carried out by students.

In general, physics learning activities using digital modules based on PjBL STEM run smoothly and quite efficiently. Students can take part in learning activities either face-to-face or independently by following the learning steps that have been designed in digital modules. However, there were several obstacles encountered during the learning activities. The constraints referred to are described as follows. time limitations, installation

constraints on devices with certain brands, signal difficulties.

Based on the 4C skill questionnaire analysis research on the application of the PjBL STEM-based digital physics module in physics learning at SMK, the results show that the growth of 4C skills in all aspects is significant. Growth in successive  $t_{\text{count}}$  values from the largest is in the aspects of Critical thinking, Creativity, Communication, and finally Collaboration.

### a. Critical Thinking

Critical thinking skills are potentials that can be measured, trained, and developed by everyone (Lambertus, 2009 in Susilawati et al., 2020). Fajriah (2021) states the challenges faced in developing students' critical thinking skills were the difficulty of the teacher in determining the appropriate learning method, lesson plans, methods, and learning models and the difficulty to stimulating students to think critically.

In this study, efforts to cultivate students' critical thinking skills were carried out through the use of PjBL STEM-based physics digital modules. The use of digital modules provides opportunities for students to be able to access all information related to the material being studied, whether written, simulated with animated videos, or explained clearly through audiovisual experiences from YouTube videos which also support multi-representational

learning experiences. Grace *et al.* (2019) in his research revealed that there was an increase in critical thinking skills quite well after implementing learning using the multi-representation-based Problem Based Learning model for high school students in Bandung.

Critical thinking skills revealed in this study include aspects of understanding physics concepts, relationships between physics concepts, assessing physics problems, how to analyze and find solutions to these problems, connecting, processing, and drawing conclusions based on information in physics subjects, suggesting ideas and creative ideas, as well as the ability of students to adapt to existing conditions. The results showed that the growth of critical thinking skills occurred significantly, as evidenced by the  $t_{\text{count}}$  of 6.35. This value is far greater than the  $t_{\text{table}}$  value of 2.03 at a significance level of 0.05. These results, as revealed by Samsudin (2020) in his research, that PjBL STEM positions students in a simulated real-world context and helps develop the ability to use scientific reasoning to complete assignments.

#### **b. Creativity**

Creativity skills are one of the 4C skills needed by students to be able to face the challenges of the 21st century. Kivunja (2014) describes several creative skills that can be developed in learning, including the ability to solve problems, openness and curiosity, the ability to analyze, evaluating, elaborating, and creating, as well as the ability to use a variety of creative thinking strategies to discover and express new ideas.

In this research activity, efforts to cultivate students' creative skills are carried out by project assignments. Students are faced with a problem that must be solved by making a simple optical device. Students are required to solve problems and find out how to solve problems encountered from various sources. After that, students in their groups try to analyze to create simple optical tools needed in the problem. Based on a questionnaire analysis of Creativity Skill or creativity skills in this study showed a significant growth. This is evidenced by the  $t$  count which is greater than the  $t$  table at a significance level of 0.05, which is equal to 4.67.

The results of this study are in line with research conducted by Hanif (2019) where STEM project-based learning has a good impact on student creativity. Likewise Pratiwi (2021) revealed that the creativity of students who used the PjBL model of natural science learning tools with the STEM approach was better than students who used conventional learning tools. In addition, Samsudin (2018)

through his research also revealed that PjBL STEM can further develop students' problem-solving skills to achieve a higher level of achievement in the mechanics physics test. Likewise, Purwaningsih *et al.* (2020) who revealed an increase in students' problem-solving skills after participating in learning using learning tools developed with the integrated TPACK (Technological Pedagogical Content Knowledge) PjBL STEM model. In this study, PjBL STEM was integrated into digital physics modules used in learning activities.

#### **c. Communications**

The next 4C skill which is very important for students to master in order to face the challenges of the 21st century is communication skills. Trilling & Fadel (2009) suggest strategies for teaching 21st century communication skills effectively, namely: 1) students must be taught how to convey thoughts and ideas verbally, in writing and nonverbal communication skills, 2) students must be taught how to engage in active listening, 3) students must be taught how communication can be used for different purposes, and 4) students must be exposed to various media technologies and taught how to use them.

In this study, efforts to cultivate communication skills were carried out by completing projects in small groups. Students in their groups discuss to each other express their ideas and ideas to solve the problems they choose. In an effort to take advantage of this media technology, students are asked to present project reports in the form of videos that are uploaded to the YouTube channel. Thus, it is hoped that students can improve their communication skills directly through group discussions, and virtually through videos.

The results of the questionnaire analysis showed that the growth of communication skills in learning activities using the PjBL STEM-based digital physics module developed previously was significant. This is indicated by the  $t_{\text{count}}$  value which is much larger than the  $t_{\text{table}}$ , which is equal to 4.51. These results are consistent with Yulianti's research (2020) which shows that there is a great development in critical thinking skills, creativity, communication, and collaboration in students with the development of STEM-based teaching materials.

#### **d. Collaboration**

The last 4C skills that are important for students to master in facing the challenges of the 21st century are collaborative skills (Collaboration). Collaborative skills that can be

developed in learning as stated by Kivunja (2014), include responsibility in working with others, respecting and respecting different opinions, the ability to work effectively and flexibly in groups, and the ability to compromise with other group members to achieve the goals that have been set.

In this study, students' collaborative skills were developed by working together in groups. Activities intended to complete projects in groups, give students the opportunity to build cooperation in teams, respect each other's opinions, compromise with each other, and work together in teams so that the goals set by the team can be achieved. Lee et al. (2015) in their research revealed that the social skills of a group are more important than individual social skills, where members with high social skills can actively resolve conflicts among members and lead other members to collaborate more smoothly.

The results of the questionnaire analysis on the growth of collaborative skills in physics learning using the PjBL STEM-based digital physics module show significant growth. This is shown by the  $t_{\text{count}}$  value of 4.48, far greater than the  $t_{\text{table}}$  of 2.03 for a significance level of 0.05. The results of this study are consistent with the results of Yulianti's research (2020) which shows that there has been great development in the aspect of student collaboration with the development of STEM-based teaching materials.

In general, there was significant growth in 4C skills in all aspects, both aspects of critical thinking, creativity, communication, or collaboration, which were significant in this study. In other words, the use of PjBL STEM-based digital physics modules in learning activities is able to foster 4C skills in SMK students as evidenced by the t test, where the calculated t value for each aspect is far greater than the  $t_{\text{table}}$ .

## CONCLUSION

Based on the research results, it can be concluded that the use of PjBL STEM-based digital physics modules in learning physics on optical material in class X TKJ 5 SMK Negeri 1 Binangun for the 2021/2022 Academic Year fosters 4C skills. Based on the t test, the increase in 4C skills before and after learning activities using the digital physics module shows a significant value, as evidenced by the  $t_{\text{count}}$  value which is greater than the  $t_{\text{table}}$  value.

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