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Promoting College Student's Twenty-First Century Skills through a STEM Learning Project

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Abstract: There is a need to prepare college students with non-cognitive or 21st Century skills to prepare them for successful college and future careers. As the number of applied STEM in Indonesian education increases, research is needed to understand how STEM learning projects promote student 21st Century skills. This study used a case study and mixed-methods conversion design to convert qualitative data into quantitative data by applying pre-established rubrics. This study provides evidence that STEM learning projects are beneficial to promote students' 21st Century skills, which are: (a) knowledge construction, (b) real-world problem solving, (c) skilled communication, (d) collaboration, and (e) self-regulation. The result shows that students demonstrate the highest grade on collaboration and the lowest on knowledge construction. Although most of the student work introduced multiple 21st Century skills and the overall scores were satisfactory, student knowledge construction still needs improvement.

Keywords: 21st Century Skills, Collage Student, Learning Project, STEM.

INTRODUCTION

Education is one aspect of life that is influenced by the development of science and technology in the twenty-first century. In order to succeed, students must acquire comprehensive knowledge and skill. Strengthening the foundation of students' subject knowledge, academic skills, and non-cognitive skills is one strategy for encouraging them to persist in their university courses(Berger et al., 2012). Students can engage at higher levels of cognition with content knowledge when they have academic skills such as analysis and problem-solving abilities. Students' competence to learn content and apply their academic skills to solve issues is enhanced by non-cognitive skills. The Partnership for 21st Century Learning has recognized these abilities as 21st century skills(Partnership for 21st Century, 2017).

It is essential to ensure that students who graduate are proficient in 21st Century skills in order for them to be successful in this modern workforce. Employers prefer graduates who have 21st century skills(National Research Council, 2012). In addition to assisting students in succeeding in all aspects of formal education and the workplace, 21st century skills are also crucial for a person to adapt and thrive in a world that is continuously changing.

There are numerous similarities among the many categories or interpretations of 21st-century skills, even though there are considerable distinctions. Most studies share the same abilities regarding critical thinking, problem-solving, and information literacy(Ching Sing et al., 2020). The Partnership for 21st Century Learning created a framework that includes (a) life and career skills; (b) learning and innovation skills; (c) information, media, and technology skills; and (d) key subjects. Those skills are critical for students to develop to prepare for both college and future employment.

Adult-age students in Indonesia underperform, especially in developing these non-cognitive skills(Nambiar et al., 2019). Additionally, the student's scores for International Student Assessment (PISA) needed improvement in cognitive or non-cognitive aspects. Students showed four non-cognitive variables whose mean values were more significant than the cut-off point. Meanwhile, five other variables are below(Lee, 2020).

There is a strong need to provide a central education system that initiatives students' 21st century skills. Southeast Asian education strategies put special focus on 21st century Skills, which many education authorities have set as the future goal(UNICEF, 2018). Instead of conventional didactic learning approaches, successful 21st century education programs usually adopt constructivist student-centered approaches with a strong emphasis on students' active participation, one of which is STEM education(Peters-burton & Stehle, 2019). The integrative STEM approach plays a key role in this because it teaches exactly those skills that are crucial for the 21st Century Skill.

STEM stands for science, technology, engineering, and math, and it is an integrated field of study that is expected to be able to help fulfill the needs of the 21st century(Ng, 2019). One movement embracing the need to develop student 21st Century skills is the proliferation of STEM applications in learning. The core purpose of STEM application in learning is to train students to solve daily or societal problems, making learning more meaningful and contextual.

As the number of applied STEM in Indonesian education increases as time goes by(Nugroho et al., 2019), there is a need to understand the way STEM applications promote student 21st Century skills. This paper aims to explore how STEM learning project engages and develops students' 21st Century skills. Because these skills have fluid interpretations and may not be directly observable, this study used 21st century skills consisting of knowledge construction, real-world problem-solving, collaboration, and perseverance(Partnership for 21st Century, 2017).

METHOD

Research Design

This study used a case study that can address a specific problem or phenomenon of an occurrence and account for its effects in a real situation(Yin, 2009). This study aimed to explore how STEM learning project engages and promote students' 21st Century skills. This study used a mixed-methods conversion design(Creswell, 2010), in which qualitative data were converted into quantitative data by applying pre-established rubrics.

STEM learning projects are applied for five weeks. Students worked together in a group of five to create one product in an attempt to solve everyday problems. This STEM learning project was conducted through seven-step which are (1) identifying socio-scientific issues, (2) collecting information, (3) imagining possible solutions to problems, (4) designing a product, (5) trialing and evaluating the product, (6) redesign the product, (7) product exhibition(Lin et al., 2021). The 21st Century skills addressed in this study, (a) knowledge construction, (b) real-world problem solving, (c) collaboration, (d) self-regulation, and (e) communication are essential facets of STEM learning(P21, 2019).

Population and Sample

The research subject was 73 college students from the biology and physics education department who enrolled in a science and technology fundamentals course, all of whom were sampled in this study. The students who enroll in this course have completed a precondition course, so they have a basic understanding of science, how to do science, how technology work, and used to mathematics models. It is the main reason STEM learning projects can be applied in this course.

Table 1. Participants Demography

Demographics Variable	N	%
Gender		
Male	14	19.18
Female	59	80.82
Department		
Biology Education	50	68.5
Physics Education	23	31.5

Research Instrument

This study documented the extent to which each of the 21st-century skills was present in both students' work and products. All documents related to students' work and products were collected through students' worksheets and observation sheets. In addition, questionnaires and interviews were conducted to find out the reasoning behind student work and products.

In order to find instances of evidence within student work and products relating to the designated 21st Century abilities, document analysis was performed. Furthermore, the rubric was used to grade the skill displayed in the document (ITL Research, 2014). Meanwhile, the questionnaire data analysis used descriptive statistics while the interview data analysis used thematic analysis.

RESULT AND DISCUSSION

Result of Research Procedure

Finding a document to which each of the 21st-century skills was present in both students' work and products have graded as shown in table 2. The average score for student work was in grade 4 and grade 3. Students demonstrate the highest grade on collaboration and the lowest on knowledge construction. This result indicates that students conduct 21st-century skills during STEM learning projects.

Table 2. The 21st Century skills Score for Students Work and Product

The 21st Century skills	Grade	Score per Grade				
		1	2	3	4	5
Real-world problem solving	1-4	0	13.3	33.3	53.4	
Knowledge construction	1-5	13.3	20	26.7	33.3	6.7
Collaboration	1-5	0	0	33.3	26.7	40
Communication	1-4	0	0	46.6	53.4	
Self-regulation	1-4	0	0	13.3	86.7	

Figure 1 illustrates the number of 21st Century skills in each student's work. Nearly 86% of the student work included at least one 21st Century skill, and 57 % addressed two or more 21st Century skills. Although most of the student work introduced multiple 21st Century skills and the overall scores were on high grade, student knowledge construction still needs to improve.

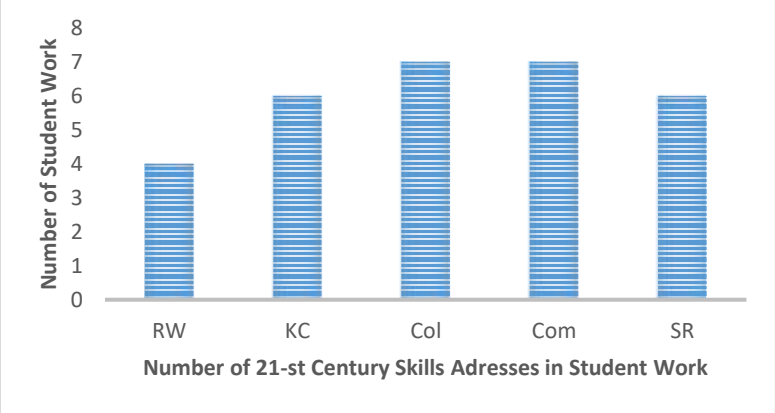

Figure 1. Distribution of Number of 21-st Century Skills Addressed in a Student Work.

Real-world Problem Solving

Students were trying to deal with problems that don't currently have a solution and where they can use their strategy define real-world problem-solving(Shear et al., 2010). In this STEM learning project, students must identify socio-scientific problems they find in everyday life. Furthermore, they must complete tasks that need to know a response or solution and work on solving real problems. This STEM learning project encourages students to conduct their 21st-century skills, as shown in figure 2.

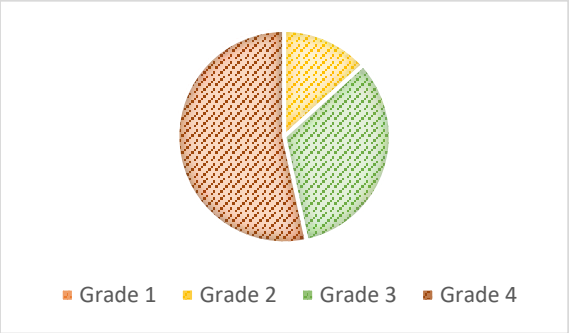

Figure 2. Distribution of Student Grades on Real-world Problem Solving.

No students were found in grade 1 because students' main work showed problem-solving. Students in grade 2 show problem-solving work, but the issue relates to something other than socio-scientific such as mental health issues and reading interest. Students in grade 3 showed problem-solving work associated with the socio-scientific theme but still limited or needed to innovate. Their idea of solving the problem is already known before. Meanwhile, students in grade 4 showed innovation or at least modification solutions for real-problem issues. Students gain knowledge in a meaningful way when they engage in real-world problem-solving(Brady et al., 2015). Students can engage in 21st Century skills and generate a more positive attitude toward STEM by designing solutions to real-world problems(Williams & Mangan, 2016).

Knowledge Construction

In this STEM learning project, students must develop new knowledge independently instead of copying or just digesting information. This project is designed to raise students' knowledge construction. Knowledge construction makes students develop a deeper comprehension of the content(Shear et al., 2010). Despite the fact that knowledge construction aids in the development of deeper understandings, many students are unfamiliar with this method of instruction and frequently require scaffolding to take joint responsibility for learning(Peters, 2010). This matter also occurs in this study, as shown in figure 3.

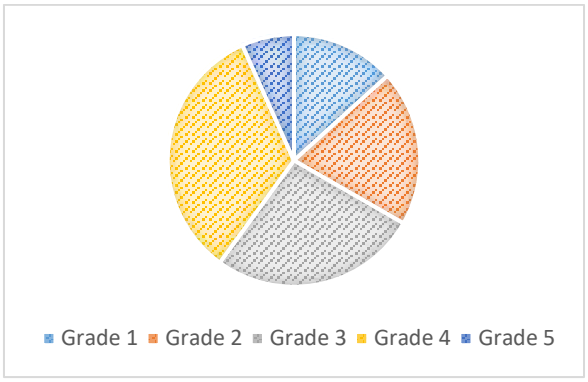

Figure 3. Distribution of Student Grades on Knowledge Construction

Students' knowledge construction varies, starting from grade 1 until 5. Among other skills, students show the most variety in knowledge construction. Besides that, students demonstrate the lowest performance regarding this skill. Students in grade 1 (7%) reproduce information and use standard or familiar procedures when solving problems. Knowledge construction happens when students do more than reproduce what they have learned.

Students in grade 2 (20%) have tried to develop the new concept as part of knowledge construction activities but are still limited to one content; meanwhile, STEM projects need integration with other content. Besides, students spend more time finding information than analyzing what they find. So, the student's primary effort during learning project is not knowledge construction.

Students in grade 3 (27%) demonstrate stages of knowledge construction, such as interpreting, analyzing, synthesizing, and evaluating ideas. But, students' work does not demonstrate conceptual understanding appropriate for the student's age. College students are expected to perform a more complex understanding of concepts. Meanwhile, this study simplifies students' work more similarly to high school student work. Students failed to complete a deeper understanding of the content they worked on.

Students in grade 4 (33.3%) start applying the knowledge they have constructed to support another knowledge construction task in a new context, especially in designing solutions for socio-scientific problems. But students' work is not interdisciplinary required by STEM learning projects. Interdisciplinary student work involves content, essential ideas, or methods from different academic subjects covered by STEM (such as science, technology, engineering, and mathematics).

Students in grade 5 (6.7%) have shown knowledge construction as the main effort to solve the problems, and their work demonstrates conceptual understanding appropriate for their age as college students. Also, students' work covered the interdisciplinary requirements of STEM learning projects. Promoting 21st Century skills is anchored by knowledge construction since students need background knowledge to apply the abilities in a real-world setting. Promoting 21st Century skills is anchored by knowledge construction since students need background knowledge to apply the abilities in a real-world setting. Together,

knowledge construction and real-world problem solving create the foundation for students to engage in the rest of 21st-century skills(Peters-burton & Stehle, 2019).

Collaboration

As students take on roles and interact with one another in groups to create a result, collaboration happens(Shear et al., 2010). Collaboration is an essential skill for students in school and their future careers in the workplace. This student work rubric looks at collaborative work during STEM learning projects, such as working together, negotiating their ideas, and sharing the task fairly. Students' collaboration in this study can be seen in figure 4.

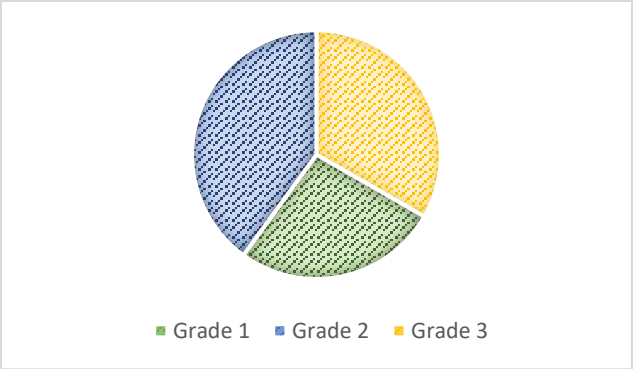

Figure 4. Distribution of Student Grades on Collaboration

None of the students are in grades 1 and 2 because all students require to work in a group of five in this STEM learning project and share responsibility. Students in grade 3 (33%) share responsibility but do not make substantive decisions together. Through observation and interviews, we found that only one or two people decide for the entire team, and the rest follow the leaders' instructions. For example, there is one student in a group with different opinions, and one of the students decides for the entire group without considering other students' views.

Students in grade 4 (27%) make substantive decisions together, but students' work products are interdependent. Interdependent indicates that all group members contributed to the final product and integrated their work coherently. Meanwhile, through observation and interviews, we found that each student created a page for a presentation, and one student assembled the pages for the final presentation. Another one, only one student doing the essential part of the product. Other student work on a non-important part of the product; this is not considered interdependent.

Students in grade 4 (40%) show how all group members work well together, and their product is interdependent. There is proof that students collaborated on plans and considered others' work while they created their own. Students who work together to solve issues do so better than those who work alone because they react to questions and comments to provide solutions that

more closely match the problem(Care et al., 2016). Collaboration is a crucial skill in improving problem-solving and knowledge development. Peer interactions that imitate verbalized thinking can help students learn to control their learning(Peters-burton & Stehle, 2019).

Communication

Communication is used to convey or explain information. Effective communicators present their ideas and show how they use relevant data(Shear et al., 2010). This student work rubric looks at communication as representing a set of related concepts, not a single simple thought. Also, whether students produced prolonged or multimodal communication and whether the communication contains a convincing argument, examples, or other supporting data. Similar to collaboration, effective communication is a requirement for knowledge construction and real-world problem solving.

Students demonstrate a satisfactory grade in this skill, as shown in Table 1. While presenting their problem and submitting a solution, they include supporting evidence or examples when explaining their ideas and reasoning. Students use more than one type of communication tool to communicate a coherent message. For example, students create a presentation that integrates video and text or embeds a photograph into an online post. Students also make a poster about their product designed to suit the target audience. The students must accomplish this while considering the media and the concepts they are presenting to ensure it is appropriate for the audience(van Laar et al., 2017).

Self-Regulation

Self-regulation is a crucial 21st-century skill for independent learners. Students who possess self-regulation to organize their approach to problem-solving, track their progress, and review the criticism received for their work(Shear et al., 2010). The first step of self-regulation is awareness of learning goals for the STEM activity and how they will be assessed. In the next step, students take responsibility for planning their work and improving the quality of their work by incorporating feedback or self-reflection.

Students demonstrate a righteous grade in self-regulation, as shown in Table 1. This situation occurs mainly because of the teacher's role. Students are guided by the teacher's instruction in almost all seven steps of STEM project learning, including self-reflection. In contrast, these skills usually take time for students to develop. Therefore, long-term projects such as STEM provide better stimulation to perfect these skills than short-term projects(Peters-burton & Stehle, 2019). The student becomes self-regulated in learning when they can use the learning approach independently. Employers in the STEM industries favor students who have mastered self-regulated learning because they are proactive in building their knowledge and solving problems(Huang et al., 2022).

Discussion

This study aims to promote student 21st-century skills through STEM learning projects. The following is a discussion of the result and the implications of this study. Overall, the students' work collected during STEM learning projects showed evidence of addressing 21st Century skills. Although nearly all steps in the learning project stimulate students' skills, the rubrics score for fundamental skills (knowledge construction and real-world problem solving) is still limited or needs improvement. These two skills are related to students' prior knowledge of the subject matter. So, it was challenging to develop significantly through only one project.

STEM learning projects that require students to work within groups promote their collaboration and communication skills. Our findings reflect the findings of other researchers. When students work in groups, they develop their abilities for communication and teamwork while building knowledge and resolving issues(Xu et al., 2023). Another research finding states that students collaborate when teachers include peer feedback in learning projects. Students who get peer feedback can modify their work in response to criticism, improving self-regulation(Law et al., 2016). Self-regulation guides the students' individual connections, reflections, and revisions between knowledge construction and real-world problem solving(Carpenter & Pease, 2013). In summary, putting students in groups, arranging peer feedback, and having students design solutions for a particular issue allows students to practice 21st Century skills.

Students must master the six 21st Century skills listed above to be ready for college and future careers. Skills for the twenty-first century don't exist in separation. One skill can be strengthened by developing another. Self-regulation, for instance, can improve problem-solving in the actual world and knowledge construction. Likewise, effective communication is necessary for teamwork to increase knowledge and resolve issues. These abilities combine to create the essential toolset for independent learners.

Knowledge construction and real-world problem solving are the key and represent the two main goals of this STEM learning project. Students are encouraged to build process skills through real-world problem-solving, whereas knowledge construction symbolizes conceptual formulation. Collaboration and communication serve as a bridge between knowledge construction and real-world problem-solving. Meanwhile, self-regulation is an internal process that takes place concurrently. The student's specific linkages, reflections, and revisions between knowledge construction and real-world problem-solving are guided by their self-regulation.

There were a few limitations placed on this study. The students' gathered work is a snapshot of the work they performed during the STEM learning project, and it does not offer a clear longitudinal assessment of student growth over time. By only analyzing paper copies of the student work, it was not possible to determine an accurate collaboration score. Videotape observation is recommended for future study for thorough observation.

CONCLUSION

This study provides evidence that STEM learning projects are beneficial to promote students' 21st Century skills, which are: (a) knowledge construction, (b) real-world problem solving, (c) skilled communication, (d) collaboration, and (e) self-regulation. The result shows that students demonstrate the highest grade on collaboration and the lowest on knowledge construction. Although most of the student work introduced multiple 21st Century skills and the overall scores were satisfactory, student knowledge construction still needs improvement. This study is a small step toward and a concrete example of implementing the STEM framework in the larger educational context shortly.

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