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Research Artikel

BUILDING 21st-CENTURY SKILLS WITH STEAM-PjBL

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Abstract

During the 21st century, students are encouraged to develop skills that enable them to deal with real-life problems. The purpose of this study is to analyze what kind of 21st-century skills can be built during a teaching and learning process in the classroom. Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach through a project-based learning (PjBL), or STEAM-PjBL-based learning, seems to provide a promise in the development of 21st-century skills of students. This study, therefore, is conducted to reveal the kind of skills that can be built during the STEAM-PjBL learning process. Using a literature review, this study collects and analyzes relevant articles from national and international journals through several search engine systems, such as Taylor & Francis Online, Springer, etc., and indexed databases, such as SCOPUS, DOAC, and Eric, both from the period of 2014-2022. This study found that the 4Cs of the 21st-century skills, namely, critical thinking and problem solving, communication, collaboration, and creative thinking, can be built from the activities in each stage of the STEAM-PjBL learning process. While the skills are evident from the literature review, a further empirical study is encouraged to be conducted to ensure how the skills can be successfully developed and further improved.

***Keywords**: Project-based learning (PjBL), STEAM, 21st-century skills.*

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INTRODUCTION

The main role of education includes preparing students to face the challenges of life in the 21st-century. Society, nowadays, demands graduates to be able to adapt to changes, use creativity and apply innovative skills in 21st-century life (Mandumpal et al., 2022). Various government efforts have been done to support students' 21st-century skills (Ananiadou & Claro, 2009; Hilt et al., 2019; Nouri et al., 2019; Rönnlund et al., 2019). In the 21st century, students need skills-based education to deal with real-life problems (Martinez, 2022). Therefore, it is important to determine a model or approach in education (Kim et al., 2019) that can build students' 21st-century skills (Bai & Song, 2018; Nouri et al., 2019). One of the learning models that should be used is Project-Based Learning (PjBL) integrated with Science, Technology, Engineering, Arts, and Mathematics (STEAM) (Queiruga-Dios et al., 2021), or here and after it is called STEAM-PjBL. Rooted in project-based learning, the STEAM-PjBL is a method in which students gain knowledge and skills by working collaboratively to solve an authentic and often complex problem or challenge (Martinez, 2022) by considering the STEAM environment. The STEAM-PjBL is one of the learning innovations that involve all aspects needed to support students' 21st-century skills (Suryaningsih et al., 2021). The implementation of STEAM-PjBL supports the learning process to develop students' 21st-century skills through a project related to problems around them (Guo & Tang, 2021; Nurulwati et al., 2021).

Currently, STEAM-PjBL-based learning research is a trending topic in Indonesia (Dewi et al., 2021; Priantari et al., 2020; Suryaningsih et al., 2022). Much STEAM-PjBL research is also aimed to develop 21st-century skills. Rohman et al. (2021) for example, studied the STEAM-PjBL to develop science process skills and creative thinking. Other researchers engage in efforts to build creative thinking (Anggraeni & Suratno, 2021; Apriliana et al., 2018; Conradty & Bogner, 2020; Dyer, 2019; Fitriyah & Ramadani, 2021; Rahmawati et al., 2019, 2020, 2021; Ridwan et al., 2020; Weidong et al., 2020), critical thinking (Sukro et al., 2021), collaboration (Akbaş & Çakmak, 2019; Bertrand & Namukasa, 2020; Dasuki et al., 2020; Herro et al., 2017; Hussein, 2021; Nurramadhani et al., 2021; Pinheiro-Franco et al., 2016), and communication (Rismayanti et al., 2019). Other than developing the 21st-century skills, some researchers also try to study the perception and habituation of science lecturers using PjBL integrated with STEAM (Abedini, 2020; Khumaeroh & Sumarni, 2019; Mandumpal et al., 2022; Maulida, 2017; Misrochah, 2021; Safriana, 2018)

The STEAM-PjBL-based learning model, according to the teachers' training manual from the Indonesian Ministry of Education and Culture and further adopted by (Suryaningsih & Nisa, 2021), has six (6) learning stages. The stages are (1) Challenging introductory questions integrated into Science and Technology, (2) Planning an integrated project in Technology, Engineering, Art, Mathematics, (3) Scheduling the activities, (4) Supervising the implementation of integrated projects of Technology, Engineering Art, Mathematics, (5) Assessing the results of project/products integrated with Science, Technology, Engineering, Art, Mathematics, and (6) Integrating the evaluation technology and mathematics. In each stage, there is a description of activities that happen. The activity descriptions have been developed in a previous study (Suryaningsih et al., 2022).

21st-century skills have been defined as skills needed by students (Haviz et al., 2018) and also an individual to cope with the current situation. Education has long been recognized as a critical component in advancing society's common good and strengthening neighborhoods and the national economy. Many studies have emerged on the kind of skills that need to be developed. One of which is proposed by the partnership of 21st-century skills, a body that concerns the 21st-century skills of students. This body determines at least four skills to cope with the 21st-century era, namely, critical thinking and problem-solving, communication, collaboration, and creative thinking skills. Here after the skills are called four Cs. Critical thinking and problem-solving are skills in which students are encouraged to think systematically and precisely to follow logic and scientific reasoning

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(Leest & Wolbers, 2020) to find a solution for the proposed problems. Communication skill determines the ability of an individual to convey information in a way that is well understood by others and in which develop further understanding. Communication and collaboration skills are important in the PjBL-STEAM learning process. They are critical for the success of the project. Liao et al. (2016) in their research found that both communication and collaboration skills lead to other skills, especially creative and critical thinking skills. Creativity, according to Beccone (2017) as cited from many sources, is a special kind of problem-solving experience that involves rational and conscious thoughts on how to achieve solutions through a rational framework that develops a series of strategies. In short, creativity is the ability to think of new and useful ideas as well as generate alternative possibilities (Leest & Wolbers, 2020).

While much STEAM-PjBL-based learning research has been conducted in relation to 21st-century skills, research on the development of the skills at each stage of the learning model has been rarely found. Using a literature review, therefore, this research is trying to find out the kind of skills that are potentially developed in every stage of the learning process in a chemistry classroom. This study is trying to answer the research question of "what are the 21st-century skills that can be built in every stage of STEAM-PjBL-based learning chemistry according to literatures?" The result of this study is expected to be useful for planning a teaching and learning activity, especially when it is aimed at seeing the growth of certain 21st skills during the PjBL learning process integrated with STEAM.

METHOD

The research method uses the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) approach. The PRISMA stages include the processes of identification, screening, analysis, and reporting of articles, which are carried out systematically and structurally (Simamora et al., 2024; Sulisworo, 2024; Pamungkas & Rochimah, 2019; Salsabila, 2011). The next step is to select 5 articles with the highest number of citations that are most relevant to the topic.

Identification

PRISMA step: Identifying all potential articles from various database sources and search engines. Application in this research: Researchers used various sources such as SCOPUS, Sinta, DOAJ, ERIC, Mendeley, Taylor & Francis Online, Springer, Elsevier, Atlantis, and Horizon Research to collect relevant articles based on keywords such as "PjBL learning model," "STEAM/STEM," "STEAM integrated PjBL," and "21st-century skills."

Screening

PRISMA step: Filtering articles based on clear inclusion and exclusion criteria. Application in this research: Relevant articles were research articles related to the topic. Only articles in the context of chemistry education were considered for further review.

Eligibility

PRISMA step**:** Reviewing the full text of the filtered articles to ensure their relevance to the research question. Application in this research**:** The selected articles were further analyzed to map the relationship between the STEAM-PjBL learning model, 21st-century skills, and relevant learning stages.

Included

PRISMA Step**:** Articles that meet the criteria are included in the final analysis. Application in this research**:** Eligible articles are used to evaluate the learning stages of STEAM-PjBL and the skills identified in the relevant literature.

Use of the PRISMA Flow Diagram

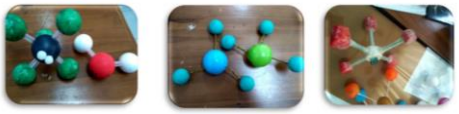
The PRISMA flow diagram illustrates the number of articles identified, screened, assessed for eligibility, and ultimately included in the analysis. This diagram ensures transparency in the literature selection process. Records Identified through Database Searching (n = 101). Records After Duplicates Removed (n = 71).

RESULTS AND DISCUSSIONS

Project-based learning (PjBL) integrated with STEAM has become a new learning model that potentially builds 21st-century skills for students, especially during chemistry learning. To see what specific skills can be built in every stage of the STEAM-PjBL learning model, a literature review was conducted. The works of literature served as empirical evidence in which the 21st-century skills can be developed. Table 1 exposes the result of the literature review.

According to Table 1, it can be seen that all the 4C skills of the 21st century can be built once students finished learning through the PjBL-STEAM-based learning model. The 4C skills have been triggered since the very beginning of the stage by introducing the students to thinking about the phenomenon of everyday life problems that relate to their experiences (Akbaş & Çakmak, 2019). Bringing about the everyday life problem might be a way to stimulate students' interest in STEAM (Akbaş & Çakmak, 2019; Ridwan et al., 2020; Walan, 2021). Once students are interested in STEAM, through project-based learning they can develop 21st-century skills.

Table 1. Aspects and examples of activities that enable the 21st century skills to be developed through project-based learning stages integrated with STEAM

Learning Stage[a]	**Description**[a]	**Aspects and examples of activities of 21st Century Skills** [b]
The first stage Challenging introductory questions integrated with STEAM	Learning begins with essential questions, namely questions that can be given assignments to students in carrying out an activity. Picking up a topic that according to the real-world reality and starts with an investigation in-depth and the topics raised are relevant to the students.	1 Critical Thinking & Problem Solving 2 Communication 3 Creativity Students are trigged to discuss current air pollution situation and they are given the fact about smoke produced by companies. Students are then encouraged to perform discussion to pick up a specific problem that interest them and find the right solution. In this learning activity, students decided to develop a smoke absorber to help reducing air pollution (Ridwan, Rahmawati, Mardiah, & Rifai, 2020)
The second stage Planning an integrated project in STEAM	Planning is done collaboratively between teachers and students. With thus, students are expected to feel "own" over the project. Planning contains the rules of the project, the selection of activities that can support in answering essential questions, by integrating various possible subjects, as well as knowing accessible tools and materials to help with project completion	1 Critical Thinking & Problem solving 2 Communication 3 Collaboration 4 Creativity Planning to create a molecule shape model, like a molymod, from trashes or used materials, such as, papers, straw, styrofoam, etc. The materials are abundant in the trash bin and they often create environmental problems. The molymod can be used as alternative learning materials for the topic of molecular chemistry. Students are encouraged to gather information on how to create molymod from many resources. In creating the molymod students should consider the shape, length, and angle of bond principles (Sukro et al., 2021). 
The third stage Schedule Activities	Teachers and students collaboratively schedule activities in complete the project. Activities at this stage include: (1) create a timeline to complete the project, (2) make a deadline for project completion, (3) bring students to plan new ways, (4) guide students when they make a way that is not related to the project, and (5) ask students to make an explanation (reason) about choosing certain method.	1 Communication 2 Collaboration In a project on innovative solution for reducing waste at convenience stores, teachers and students work on the shedule of their activities together from week 1 to week 13. Using a jigsaw group activities, a weekly-basis schedule is developed to ensure that each week they have collaborative activities. As a report, students are asked to write a group reflection and an individual reflection. At the end (week 12) students collaboratively writing and submit a gorup reflection essay (Michael et al., 2018).

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The fourth stage Supervise the implementation of integrated projects of STEAM	The teacher is responsible for monitoring student activities while completing the project. Monitoring is done by facilitating students in each process. In other words, the teacher acts as a mentor for student activities. In order to simplify the monitoring process, a rubric is created that can record all important activities.	1 Communication 2 Creativity 3 Collaboration Teacher gives rubrics in order to ensure the work of the students and to maintain students to achieve their project goal. The rubric include aspects on topic, evidence, explanation and analysis, and conclusion (Mukunda Vani et al., 2021). Inthe innovative solution for reducating waste at convenience stores, 5 mentors are assigned to observe students' work. To ensure, mentor is allowed to have 90-min face-to-face session with the students
The fifth stage Assessing the results of project/products integrated with STEAM	Assessment is carried out to assist teachers in measuring achievement standards, plays a role in evaluating the progress of each student, gives feedback about the level of understanding that students have achieved, helps teacher in preparing the next learning strategy.	1 Communication 2 Creativity 3 Collaboration Effective communication and collaboration between teachers and students are essential to ensure that assessment results are well understood and utilized to promote student progress. Additionally, the implementation of project-based learning by teachers can enhance students' understanding of concepts (Mukunda Vani et al., 2021).
The sixth stage Integrated Evaluation within STEAM	At the end of the learning process, the teacher and students reflect on the activities and project results that have been carried out. The reflection process is done well individually or in groups. At this stage students are asked to express their feelings and experiences during the completion of the project. Teachers and students develop discussions in order to improve performance during the learning process, so that in the end a new finding is found (new inquiry) to answer the problems posed in the first stage learning.	1. Communication 2. Collaboration In the project called "*Wudu Water Wise*" or using water for ablution wisely, students are asked to determine the amount of water used by most people for ablution and they are challenged to develop a tool for people to wisely use water for ablution. At the end of the project, students are assessed by Co-Measure rubrics for their collaborative work. The rubric determine aspects of peer interaction, postiive communication, multiple inquiry, and transdisciplinary approach (Nurramadhani et al., 2021).

The findings from the table above regarding the stages of Project-Based Learning (PjBL) integrated with STEAM are:

Integration Between Theory and Practice

Each learning stage incorporates STEAM elements (Science, Technology, Engineering, Arts, Mathematics) into real-life contexts relevant to students' lives. This demonstrates that PjBL with STEAM can bridge the theoretical concepts taught in the classroom with practical applications in everyday life.

Development of 21st-Century Skills

These learning stages are designed to develop critical skills such as critical thinking, problem-solving, collaboration, creativity, and communication. For example, in the initial stage, students are trained to think critically to understand the problem. The subsequent stages encourage them to work collaboratively and creatively in designing solutions.

Critical thinking and problem-solving skills, according to Ridwan et al. (2020) are developed when students are given higher-order thinking cognitive challenges. The challenges are indicated by the ability of students to propose critical questions and explore different resources in solving the problems. Another indicator is that the challenges encourage students to search for arguments against the challenges to come up with either deductive or inductive conclusions (Hikmah et al., 2016). In the first stage of project-based learning, therefore, asking students about challenges or problems to be solved can generate

their critical thinking skills (Weidong et al., 2020). Critical thinking itself, according to (Rönnlund et al., 2019) is an ability to reflect, analyze and question, and see things from different perspectives.

Student-Centered Approach

The learning process is collaborative, with the teacher acting as a facilitator. Students are given the opportunity to "own" their projects, which enhances their motivation and sense of responsibility for the outcomes of their work.

The critical thinking skill and problem-solving skills are further developed in the rest of the stages. In the second stage, for example, students are started to think about the plan for solving the problem within their groups. In this situation, a more intensive discussion happens. Students are encouraged to participate actively in providing their views to discuss, comment, provide an argument, and analyzed their views and views of others. With the help of the teacher as a facilitator, the group work discussion should lead to provoke students to have a wider perspective of a problem, especially within the context of STEAM. Students are encouraged to think critically, analyze a problem creatively, express ideas, and learn to develop skills (Ozkan & Umdu Topsakal, 2019). An exchange of views among member of the group will sharpen students' critical thinking and problem-solving skills. When the exercise of critical thinking is further developed, students' problem-solving skills can be eventually provoked (Dyer, 2019).

Flexibility and Sustainability

With a collaboratively developed schedule and evaluation rubric, students and teachers have the flexibility to adjust the project based on needs and progress. This approach ensures that the project can be carried out effectively until its completion.

Communication is the second skill that appears to be potentially developed during the PjBL-STEAM-based learning process. Communication is the ability to convey information to others both orally and in writing (Rismayanti et al., 2019). Communication in the PjBL-STEAM learning is needed to make the project done. During learning chemistry, understanding terminologies and symbols becomes important to create an easy and rational communication (Barke et al., 2012). Communication mainly happens during group discussions. Therefore, group discussion becomes one of the most important activities in project-based learning (Aslan, 2021). During the discussion, students express opinions, respond to others' opinions and understand the problem or project being discussed. Communication develops a level of trust and promotes teamwork within a group (Arfiyanti, 2013). Communication happens in many forms. Among others are teacher lecture, student lecture, teacher demonstration, student demonstration, teacher-class dialogue, discussion, group work, and pair work. between students and students as well as students and teachers (Barke et al., 2012). The teacher, in this group discussion, has a major role to ensure that the discussion is not going in another direction. The teachers' guidance for group work and within-group communication can therefore influence the group work (Hmelo-Silver, 2004).

Especially important is the communication skill related to the mathematical issue. Rismayanti et al. (2019) in their study found that students often answer correctly on mathematical problems. However, they find it difficult to verbally communicate the rationale of the answers. Putting mathematics into words is something challenging. It is, therefore, students' ability in mathematical communication is considered low (36,5% out of 100%) (Rismayanti et al., 2019).

Communication skill is also related to the depth of understanding, especially when it relates to the presentation of a thing in a different form. In the context of project-based learning, this presentation is shown by pictures, tables, or posters. In this digital era, communication can be shown in a form of social media postings. Digital technologies provide a communication channel as well as a means of sharing and supporting creative expression (Hoffmann et al., 2016). Therefore, according to van Laar et al. (2022) communication skills are required to successfully transfer information to others while taking into account the

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audience and medium. Students who have good communication skills should be able to transform information from one form to another. During the discussion on the projects, students are exposed more to the issue being solved. The more they are exposed, the more their communication skill can be developed.

Comprehensive Evaluation

Assessment is conducted not only on the final project outcomes but also on the process, including student engagement, collaboration, and reflection. This helps students learn from their experiences and improve their performance in future projects.

Collaboration is the key to success in the 21st-century era (Michael et al., 2018) because collaboration is a communication relationship between two or more individuals in a social environment, such as in a group learning environment (Graesser et al., 2017). Collaborative skill in this study is defined as the ability of students to cooperate in implementing STEAM-PjBL. This is very important for the smoothness and success of a project. The three factors of collaboration skills are teamwork, networking, and sharing (Techataweewan & Prasertsin, 2018). Collaborating to do something in groups makes students feel they need each other and help each other in completing work to the fullest. This attitude is certainly supported by other skills, namely communication skills. Without good communication in collaboration between group members, it can hamper the project work process.

Nurramadhani et al. (2021) in their study found that STEAM-PjBL learning in the category of collaboration skills has superior results in the transdisciplinary approach and communication skills. The advantages of collaboration in working on a group project reflect the fact that collaboration provides for a more effective division of labor, incorporation of solutions from group members with different perspectives, knowledge, and experiences, and improvement in the quality of solutions by the ideas of other group members (Graesser et al., 2017). The results of the study (Hussein, 2021) determine that the challenges of collaboration were successfully overcome by implementing structured project-based learning. Students use their communication skills when discussing with their peers, presenting project results, or sharing information about what they have learned (Bertrand & Namukasa, 2020). Group project-based learning positively affects students' communication skills with their group members (Akbaş & Çakmak, 2019), so that they can develop students' soft skills and social skills as the 21st-century generation (Dasuki et al., 2020). Hill (2012) emphasizes the importance of teacher guidance for effective collaborative group work in PjBL. Considering PjBL as a whole, teachers should encourage students to collaborate by playing a facilitator role during the group work (Ertmer & Simons, 2006; Hmelo-Silver, 2004; L'Ecuyer et al., 2015).

Enhancing Interdisciplinary Understanding

By integrating STEAM, students are encouraged to understand how various disciplines are interconnected and can be used together to solve complex problems.

The results of the project are made into scientific reports and posters, and they should be posted on social media such as Instagram. This activity indicates that students are encouraged to develop creative thinking skills through designing, editing, and displaying scientific reports and posters. As technology develops, the STEAM approach is increasingly popular and is used to measure creative thinking skills (Anindya, 2019; Suryaningsih & Nisa, 2021), problem-solving (Ozkan & Umdu Topsakal, 2020), and make science learning more interesting (Conradty & Bogner, 2019). In the context of the PjBL-STEAM integrated learning process, creative thinking skill is developed during group work while expressing and exchanging ideas in deciding solution for the problems. New ideas develop as a result of creative skills, and digital technologies enable the successful implementation of those ideas (Bicen & Gudigantala, 2019).

Relevance to Real-World Issues

The projects assigned are related to real-world problems, such as air pollution, waste management, or water conservation. This helps students develop solutions that are beneficial to

society while expanding their awareness of global issues.

Projects as a Medium for Holistic Learning

Each stage of learning focuses not only on cognitive aspects but also involves affective aspects (a sense of ownership and responsibility) and psychomotor aspects (creating physical models or real solutions).

Based on the findings above, it can be concluded that Project-Based Learning (PjBL) integrated with STEAM provides a deep, meaningful, and holistic learning experience. This approach not only enhances students' understanding of academic concepts but also develops essential skills for 21st-century life. Its implementation is relevant to address the challenges of modern education, where students are expected to think critically, creatively, and collaboratively when facing real-world problems.

CONCLUSION

In the world of the 21st century, educational institutions are in need to produce students who are ready to face the world. Through the development of 21st-century skills, it is hoped that students may successfully face the world. Project-based learning or PjBL is shown to be a potential way of providing students with skills needed in the 21st century. Combining with the STEAM approach, in which Science, Technology, Engineering, Arts, and Mathematics, problems that are arisen in project-based learning are challenged to the students for solutions. According to this study, all the 4Cs skills needed in the 21st century can be potentially developed during the process of PjBL-STEAM learning. Critical thinking and problem-solving skill, communication skill, collaboration skills, and creativity skills are evidence to appear and have a future to be more developed during each stage of the PjBL-STEAM learning process. To ensure and develop a more comprehensive development of such skills, it is, therefore, that this research is asked for more empirical research on further intervention. The result of this study has become a foundation for further study on our creation of PjBL-STEAM based learning activities in which each 21st-century skill is carefully designed to be developed.

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