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Exploring the characteristics and effectiveness of project-based learning for science and STEAM education

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Abstract
The purpose of this article is to determine project-based learning (PjBL) from the characteristics, effectiveness and implementation aspects of science and science, technology, engineering, art and mathematics (STEAM) education. Eric database was used in order to investigate key words. Thus, this mini review reviewed 36 articles on PjBL for science and STEAM education based on the available Eric database reference. The data obtained were analyzed using content analysis methods. The results showed that on average PjBL can be categorized as a learning model that can improve student learning outcomes in science learning and train students in problem solving (critical thinking). The review reveals that PjBL has an influence on student learning, especially in science and STEAM education. From this article, it can be concluded and can be recommended three recommendations related to the essential success of PjBL in schools.

Keywords: project-based learning, science education, STEAM education, learning outcomes, critical thinking

INTRODUCTION

Project-based learning (PjBL) helps students develop problem-solving skills and other meaningful learning content by incorporating self-directed learning to help students build their knowledge, process and complete their work in a realistic manner and showcase their own products (Ibragimov, 2021). This is a teaching model that enables you to put your own ideas into practice. Thus, project-based learning is a process-oriented learning approach that requires interactive classroom environments. Students can work individually or in groups during the project-based learning process. In project-based learning, students engage in original, program-related and often interdisciplinary group work to solve problems (Belayneh, 2021). They decide for themselves how they proceed and what activities they undertake. Students learn many things with projects because they enjoy learning more and can learn through experience have a better understanding of the subjects. In project-based learning, topics are close to reality and daily-life. In this context, it is important that projects are realistic and that students learn authentically and valuably in this model because they acquire knowledge on their own. In addition, project-based learning is an effective means of improving basic science education and STEM Education (Chen & Tippett, 2022; González et al., 2020; Kim & Kim, 2021; Viro et al., 2020). By increasing participation, students' science literacy and problem-solving skills will help develop the confidence

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Contribution to the literature

- The article promotes PjBL as a valuable teaching approach for science and STEAM education providing evidence-based arguments for the benefits of PjBL and encourages teachers to consider using PBL in their classrooms.
- This article emphasizes the importance of student-centered learning in PjBL explaining how PjBL can empower students to take and develop ownership of their learning.
- This article promotes the importance of real-world connections in PjBL and states how PjBL can be used to connect classroom learning to real-world problems and situations, making learning more relevant and meaningful for students.

and academic foundation necessary for success in higher education.

Science education and project-based learning are powerful tools when it comes to helping students engage in the process of learning and developing understanding. The combination of project-based learning and science education allows students to not only engage their understanding of scientific concepts, but also use creative problem solving to design and develop an project based around the concept. By allowing students to explore concepts through projects, students gain greater understanding of the material and a stronger appreciation for the scientific process.

In conclusion, science education and project-based learning are a powerful combination when it comes to providing engaging, meaningful learning opportunities for students. By providing the opportunity to explore scientific concepts through hands-on inquiry and project-based development, students are able to gain a greater understanding of the material while also developing higher-level critical thinking skills.

Krajcik and Czerniak (2018) stated five essential features of the project-based approach for science learning: (1) Establishing relevance to students' lives through exploring and asking questions for investigations; (2) Engaging students in the practices of science and engineering such as conducting investigations, analyzing data, and constructing models; (3) Collaborating with peers, teachers, and community members to find solutions; (4) Using technology tools to learn science; and (5) Creation of artifacts to show what students have learned.

The goal of this study is to determine project-based learning (PjBL) from the characteristics, effectiveness and implementation aspects of science and STEAM education. This study was focused on how project-based learning can be a powerful way to introduce science education to students by allowing them to explore scientific topics through integrated projects and how they can develop a greater understanding of scientific concepts. Furthermore, this study aimed that how project-based learning can provide students with the opportunity to think critically about scientific topics and collaborate with others.

METHOD

This study is a literature review related to project-based learning in science and STEAM education. PjBL, science and STEAM education were used as keywords. Keywords were searched and 36 articles were found by selecting full text and peer reviewed articles in Eric database. These articles were reviewed one by one in detail. A qualitative thematic review was used in this study. All articles were downloaded and read by the researchers. Each researcher studied together to determine themes. The themes were decided as "studies on the effectiveness of PjBL" and "studies on the process of PjBL".

The findings of past review studies about PjBL in science and STEAM education were analysed and compared in-depth to ensure the reliability of this review. Thus, the investigation of the past review studies in-depth also helped to better understanding of the research scope and provide reliability of this current review.

Studies on the Effectiveness of PjBL

There are several descriptive studies on the effectiveness of PjBL in the literature. For example, Intykbekov (2017) revealed that PJBL is an effective teaching approach that can increase student engagement and help them gain a deeper understanding of course content through self-directed learning. Kılınç (2010) stated that the project-based learning environment caused positive changes in student teachers' behaviors regarding environmental protection likewise. The paper concluded with a discussion about the relationships between environmental education and science, socio-cultural issues and educational implications. Similarly, Han (2017) showed that students with positive attitudes toward PjBL components (i.e., skill-based learning, self-directed learning, hands-on activities) were more likely to imitate in addition to collaborative learning. According to McKibben & Murphy (2021), it was recommended that teachers and curriculum designers deliberately consider the importance of authenticity when designing project-based learning opportunities for students because the effect of project authenticity has an impact on learning.

Rusmini et al. (2021) stated that the low ability of students in science process skills although students gave a positive response to project implementation during a pandemic. An effort is needed to train science process skills to prospective chemistry teachers in order to produce teachers who have good science process skills. In another similar study, Lukitasari et al. (2021), project-based learning (PJBL) allows students to develop their metacognitive skills developed through e-portfolio based documents that students carry out while completing all project assignments. On the other hand, Sulisworo and Santyasa (2018) used project-based learning as a learning strategy. The final product was online learning design for physics. Another similar result showed that altogether students experience positive learning through online learning. Ralph's study (2016) suggested that there was a positive relation between content knowledge learning and PjBL in collaborative settings. As a result, students' learning performance increased students' response to good learning, and the learning atmosphere appeared to be very interesting. Therefore, it can be concluded that if the E-Learning activity supported by PjBL is implemented through the Lesson Study activity, the quality of learning can be improved in the discipline of instructional planning in physics according to Widyaningsih and Yusuf (2020).

Research conducted by Cook and Weaver (2015) has shown that in-service programs have had a positive but limited effect on teachers' learning experiences. This study highlights the need for professional development to increase teachers' content knowledge and pedagogical understanding and to encourage collaboration between teachers and professional development providers, especially when they are in a classroom setting.

The results of Torío's study (2019) also demonstrate a high level of student satisfaction and performance throughout the course. The competences that the teachers qualitatively assessed based on the competences that the students themselves acquired during the course and on the basis of formative and summative assessments are significantly higher than those available in courses similar to traditional pedagogical methods. Moreover, Putra et al. (2021) demonstrated that project-based learning could be used to develop spatial thinking and geography skills as a 21st century learning objective. Similarly, Parnis and Hendry (2021) developed a geography project integrated with STEM approaches in both the skills and concepts as developed and explored by students.

Suryandari (2021) concluded that creative thinking skills were found to be enhanced in terms of flexibility, refinement, freedom and originality. The SRBP model has a positive effect on improving creative thinking skills. In addition, Baran et al. (2021) stated that students' 21st century skills, such as the degree to which they use autonomy and collaboration skills, as well as their sensitivity to the environment, have improved significantly. Students also reported that these activities had a positive impact on many 21st century skills such as communication and collaboration, problem solving, creativity, critical thinking, responsibility, environmental management and information technology literacy.

Some of the studies related to project-based learning in STEAM education can be concluded as follows:

Huysken et al. (2019) demonstrated that collaborative, project-based learning models are effective in improving student engagement and learning in science, technology, engineering and mathematics (STEM) disciplines. Similarly, Siew and Ambo (2018) showed that PjBL-STEM is a reliable, valid, appropriate and effective teaching and learning module to enable scientific creativity in fifth graders. In addition, Hanif et al. (2019) concluded that project-based STEM learning has a positive impact on student creativity and project-based STEM learning can be used as an alternative educational strategy in universities. Furthermore, the results showed that PJBL pedagogical design has the potential to improve teaching strategies and replace traditional teacher-led art classrooms. This approach guides teachers to deliver authentic art lessons while focusing on the artistic process to create STEAM projects that benefit students, while actively collaborating to achieve desired artistic content and explore challenges and challenges specific learning activities according to Hawari and Noor (2020).

Li et al. (2020) showed that the pilot improved the participants' laboratory skills, scientific presentation skills and experimental design skills. These analyzes indicated that the small-scale practice in this study was effective for students and that the method could be widely disseminated.

Giang (2021) showed that there are five factors that have a significant impact on project-based learning. (1) Teachers must divide the class into groups to effectively implement the project. (2) The subject should be interesting and encourage students to evaluate, explore and produce STEM products. (3) Students should have a positive attitude and not be afraid to face difficulties and challenges while performing STEM tasks. (4) Students must know how to introduce STEM products. (5) Students must have school and parent support in completing STEM tasks.

The study conducted by Kartini et al. (2021) recommends STEM Project-Based Learning as a way to improve students' problem-solving skills since they can integrate their knowledge and apply it to solve a real-world challenge. In conclusion, Domenici (2022) examined how effective the preservice teacher training methodology was based on the motivation and interest of participants towards the course's content, as well as the final evaluation of students regarding their training experiences and, more specifically, their appreciation for STEAM project-based learning activities. Consequently, Samsudin et al. (2020) showed that STEM PjBL improves students' sense of self-efficacy in solving physics problems.

Rahmawati et al. (2021) showed that students could explain using simple sentences and prior knowledge while integrating complex stories using STEM-PJBL. In addition, this approach gives students the opportunity to develop their critical thinking, creativity and argumentation skills through problem solving and project development. Siew and Ambo (2020) demonstrated that fifth grade students who studied in the STEM-PjBCL method performed better in the PjBL and CV methods in terms of fluency, originality, elaboration, topic summary and resistance to premature closure. However, PjBL fifth graders do not perform significantly better than their CV counterparts on the five subscales of scientific creativity. A large effect size was obtained comparing STEM-PjBCL with PjBL and the CV method.

Studies on the Process of PjBL

It was found that pupils were able to document their design process according to the Creative Design Process by Doppelt (2005). In conclusion, teachers who know the creative thinking scale become better tutors. In another study, it was found four strengths (discussions, groups, instructor support, and knowledge and experience); six weaknesses (absences, collaboration, communication, dominant member, motivation, and procrastination), four opportunities (Canvas and Google Docs, community members and family, out-of-class communication and discussion and websites) and two threats (animosity and personal issues/ignoring the group) according to Patrick et al. (2020).

Novak and Wisdom (2018) provides some insight into how teacher education programs can use 3D printing technology as a way to prepare future teachers to implement the skills and technical standards recently adopted in K-12 science. Similarly, Muzana et al. (2021) found that there was a significant difference in the mean score of ICT proficiency and problem-solving ability according to the difference between the two teaching methods. It is concluded that the implementation of e-STEM project-based and problem-solving learning models in science education has a significant impact on improving ICT skills and problem-solving skills. In addition, During the COVID-19 pandemic, ICTs and their use in STEM education have acquired significant momentum (Usak et al., 2020). Instructors were provided with unique opportunities and online tools to transform certain course material into distant learning. During the pandemic process, traditional face-to-face data collection and content analysis methods have also undergone fundamental changes and shifted online (Cumhur et al., 2021). Many academic studies have been conducted, articles have been published and projects have been produced on developing novel data collection and content analysis paradigms that educators can use (Zakeri et al., 2023).

PjBL implementation in to science and STEAM education has been widely studied in the literature. For example, Chen et al. (2021) highlights the diversity of PjBL implementation at the course level, interdisciplinary level, curriculum level, and project level. At these four levels, similar problems are reported at the individual level for teachers and students, but also at the institutional and cultural level. Secondly, Tsybulsky and Oz (2019) showed that the practice of implementing PjBL during the educational experience is an important step in leading science student teachers to experience success and satisfaction and to develop student-centered, inquiry-based learning and positive attitudes toward a variety of principles and issues. Afterwards, Jirana et al. (2020) concluded the influence of PjBL model implementation for critical thinking skills and creativity stimulation of students as a prospective biology teacher with significantly. Additionally, applying PjBL to thermal engineering research, a project-based learning model, was developed for the research master's program "Building Energy Efficiency" by Arce, Cacabelos et al. (2013). Similarly, the results in the study of Haatainen and Aksela (2021) stated that although PjBL is useful for teachers, they need support to implement it. In PJBL, science teachers' pedagogical competence can be facilitated through collaborative learning where students, teachers, and other participants learn from each other. Finally, Imaduddin et al. (2021) determined how to implement STEAM PJbL in chemistry education on the topic of colloidal systems with a heterogeneous group of students in terms of habits, hobbies, goals and gender. The study also elucidated the relationship between students' attitudes towards STEAM PjBL and their attitudes and understandings.

CONCLUSION AND RECOMMENDATION

This review study examined previous research on the PjBL in science and STEAM education and these studies included effectiveness of PjBL and process on PjBL in science and STEAM education. It can be concluded that PjBL caused positive effect on teaching, learning, motivation and engagement based on the literature review above. Furthermore, PjBL can improve skill-based learning, creativity and attitudes toward PjBL in science and STEAM education. Thus, PjBL can make students more participated in classroom environment according to the studies in the literature.

The results showed that on average PjBL can be categorized as a learning model that can improve student learning outcomes in science learning and train students in problem solving and critical thinking. The review reveals that PjBL has an influence on student learning, especially in science and STEAM education. From this article, it can be concluded and can be recommended three recommendations related to the essential success of PjBL in schools.

STEAM project-based learning can be used as alternative teaching strategies in all levels of science education.

Based on the literature above, PjBL can help students guide through major and job selection by integrating PjBL into STEAM and science classrooms.

It appears that students believed they would be able to apply the skills they learned from PjBL in future classroom and career settings, based on literature findings.

This study was limited to only Eric database. In reference to the limitations of this work, more academic databases and search engines should be explored such as, Scopus, Web of Science and Google Scholar. This is done to provide a more extensive and detailed background search of the relevant literature related to PjBL in science and STEAM education. This study was also limited to 36 articles to review. On the other hand, more articles could be investigated and reviewed systematically to answer the research questions designed.

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