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Optimising Assessment in Project-Based Learning to Improve the Quality of STEM Learning

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A B S T R A C T

Project Based Learning is a pedagogical approach that places students at the centre of learning through the completion of real projects, allowing them to integrate theory and practice effectively. This research aims to analyse how systematic and thorough evaluation or assessment can serve as a benchmark for the effectiveness of Project Based Learning-based curriculum. This research is a combination of bibliometric research and Narrative Literature Review. The natural stages of this research are Determination of Purpose and Topic of Review, Search and Selection of Literature Sources, Organisation of Findings, Analysis and Presentation of Findings. The search was conducted specifically on copus indexed articles in 2020-2024 with the help of Publish or Perish software with the keyword 'project-based learning evaluation'. Systematic and thorough evaluation or assessment can serve as a benchmark for the effectiveness of project-based learning curriculum. There are several solutions in project-based learning assessment including solutions to the need for assessment tools that are able to capture aspects of the process and results in a balanced manner, difficulty in assessing individual contributions in group projects and variations in the quality of projects produced due to differences in abilities and resources

INTRODUCTION

Education in STEM (Science, Technology, Engineering, and Mathematics) is undergoing a significant transformation to meet the demands of the Industrial Revolution 4.0 and the digital era. In this context, the importance of collaboration between secondary and higher education institutions becomes clear. According to Acker, to support the implementation of Industry 4.0, innovations in technology, including robotics technology, are required, which can be achieved through increasing student interest in STEM education and developing ICT skills (Acker et al., 2023). This is in line with Fan's view who emphasises that STEM education is critical to preparing the future workforce, given the enormous challenges faced in harnessing the full potential of Industry 4.0 (Fan & Shum, 2023).

Project-Based Learning has been a learning method that has received increasing attention in the context of STEM (Science, Technology, Engineering, and Mathematics) education. Project-Based Learning is a pedagogical approach that places students at the centre of learning through the completion of real projects, allowing them to integrate theory and practice effectively. In the era of Industrial Revolution 4.0, Project Based Learning is considered a highly relevant strategy to prepare students for real-world challenges (Hanif et al., 2019). One of the main advantages of Project Based Learning is its ability to enhance students' critical thinking skills and creativity. Hanif et al. showed that the implementation of Project Based Learning in a STEM context can have a positive influence on the development of student creativity, as this approach encourages students to think critically and creatively in solving complex problems (Hanif et al., 2019). In addition, research by Razali et al. revealed that online project-based collaborative learning can improve students' soft skills, which are crucial in today's world of work (Razali et al., 2017). This shows that Project Based Learning does not only focus on academic aspects, but also on developing essential interpersonal skills.

Project Based Learning also contributes to more meaningful learning by connecting learning experiences in school with real-life contexts. Pugh et al. emphasise the importance of integrating learning experiences inside and outside of school to create deep and meaningful learning (Pugh et al., 2023). Thus, Project Based Learning allows students to apply their acquired knowledge in relevant situations, thus increasing their motivation and engagement in the learning process. However, although Project Based Learning offers many benefits, challenges in its implementation remain. Dacumos notes that although much research has been conducted on Project Based Learning, there is still a lack of evaluation of the implementation of Project Based Learning as a pedagogical approach in STEM curricula (Dacumos, 2023). Therefore, it is important to develop a clear framework and effective evaluation strategies to ensure that Project Based Learning can be optimally implemented in the context of STEM education. Dacumos noted that although much research has been conducted on Project Based Learning, there is still a lack of evaluation of the implementation of Project Based Learning as a pedagogical approach in STEM curricula (Dacumos, 2023). Therefore, it is important to develop a clear evaluation framework and

effective strategies to ensure that Project Based Learning can be optimally implemented and deliver the expected results.

LITERATURE REVIEW

This research aims to analyse how a systematic and thorough evaluation or assessment can serve as a benchmark for the effectiveness of a Project Based Learning-based curriculum. Overall, evaluation and assessment in Project Based Learning should be conducted with a comprehensive and process-focused approach, so as to provide a better picture of students' ability to apply their knowledge in a real context. Thus, systematic and thorough evaluation can serve as a measure of the effectiveness of a Project Based Learning-based curriculum and assist in the development of relevant skills for students in this digital era. Previous relevant research has been conducted by Johan Fanani (2024) & Zaeriyah (2022) which states that PjBL can increase students' learning motivation and their critical thinking skills. In the context of the Merdeka curriculum, PjBL is integrated to support the development of students' characters and competencies in accordance with the Pancasila profile (Hutahaean et al., 2022; Permatasari et al., 2023). One important aspect in assessing the effectiveness of PjBL is the measurement of students' science process skills and scientific attitudes. Research by Agustina et al. showed that the application of PjBL in biology practicum can improve students' science process skills (Agustina et al., 2021). It is important to develop a multidimensional evaluation model for the PjBL curriculum. Hutahaean proposed the development of an evaluation model that considers various aspects, including character development, social skills, and students' academic competence (Hutahaean et al., 2022). With this approach, assessment focuses not only on academic outcomes, but also on the holistic development of students. Therefore, a systematic and thorough assessment of a PjBL-based curriculum should include the measurement of practical skills, feedback from teachers and students, and the development of a comprehensive evaluation model.

METHODOLOGY

This research is a combination of bibliometric research and Narrative Literature Review. This approach integrates two methods, namely Bibliometric Analysis by using bibliometric software to explore research trends, collaboration networks, dominant keywords, and research keyword trends related to Assessment in Project-Based Learning. Narrative Literature Review serves to compile a narrative review with a focus on the quality and contribution of the content of key publications identified through bibliometric analysis. Data collection on bibliometric analysis is carried out with several criteria including The main database used is Scopus, the search keyword used is ‘Evaluation Assessment Project Based Learning’, the filter for English-language article publications originating from 2020-2024 with document types Journal articles and conference proceedings. The data that has been collected is then equipped with its attributes and analysed with VOSviewer software. Analysis includes keywords and dominant themes using co-occurrence analysis. The output is a visualisation of research trends, and a keyword network map.

Articles with high relevance identified through bibliometric analysis will be selected based on citation count, reputable journals, and suitability to the research focus. The articles that have been selected are then subjected to an in-depth analysis process on the content of the articles, including solutions to the need for assessment tools that are able to capture process and outcome aspects in a balanced manner, the difficulty in assessing individual contributions in group projects and the variation in the quality of projects produced due to differences in abilities and resources. The stages of this research can be seen in Figure 1.

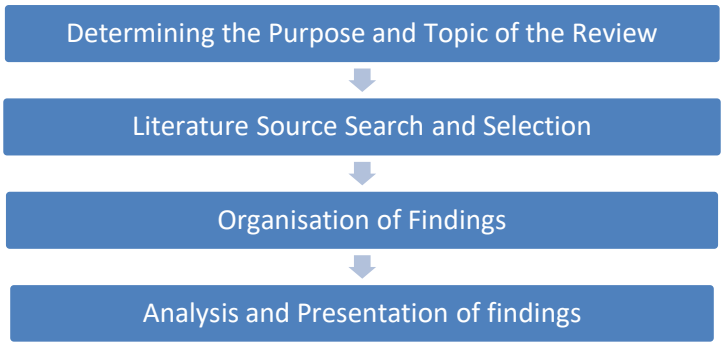

Figure 1. Research Flow

1. Determining the Purpose and Topic of the Review

The first step in a narrative literature review is to choose a clear and specific research topic. This topic will be the focus of the literature review and will determine the type of sources that need to be collected. The next step is to determine the research objectives.

2. Literature Source Search and Selection

The next stage is to search for literature from various relevant sources. The literature search included scientific journals, books, conference articles, theses, research reports, and articles from other reliable sources. The search was conducted with the help of Publish or Perish software with the keyword 'project-based learning evaluation' which is in accordance with the topic being researched. The literature collected was then selected from 2020-2024 on scopus indexed articles to find relevant and quality literature.

3. Organisation of Findings

Findings from various relevant sources must be synthesised to provide a broader picture. The organisation of findings can be done by grouping research results based on themes, main issues, or relevant topics.

4. Analysis and Presentation of findings

In the analysis section, the researcher connects the findings and shows patterns or trends that emerge in the literature with the help of VosViewer software to conduct network mapping. The mapping results from Vos Viewer were then narrated. Not only should the researcher summarise the results of previous studies, but the researcher should also analyse how these results contribute to a deeper understanding of the topic under study. The researcher needs to consider the weaknesses and limitations of each study reviewed.

RESULT AND DISCUSSION

Our results show that there is a link between evaluation and assessment with project-based learning in STEM context. Here are the findings in the form of network visualisation output from Vosviewer software.

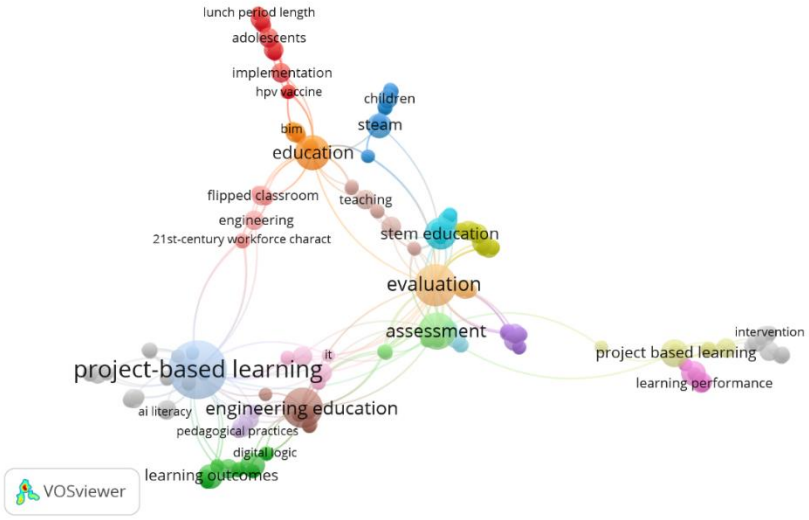

Figure 2. Network Visualization on Project Based Learning Assessment

Figure 2 shows that there is a link between evaluation and assessment with project-based learning in STEM context. This is reinforced by the finding of several keywords that are interconnected. These top sixth keywords include project-based learning with a total link strength of 59, evaluation (46), assessment (31), engineering education (31), education (25), stem education (17). These keywords, when assembled and analysed for linkage, yielded the following findings.

Tabel 1. Keyword Verification in Distance Learning Assessment

Keywords	Occurrences	Total Link Strength
project-based learning	17	59
evaluation	9	46
assessment	7	31
engineering education	8	31
education	6	25
STEM education	5	17
faculty development	3	15
project based learning	4	14
STEAM	3	13
adolescents	2	11

In engineering and STEM education related research, 'Project-Based Learning' has been recognised as a highly effective approach in developing practical and problem-solving skills among students. Project-based learning allows students to learn through hands-on experience, work on projects relevant to the real world, and apply their knowledge in a broader context. Ritonga et al., (2021) noted that Project Based Learning can improve students' critical thinking skills through their engagement in a learning process that involves clarifying the problem, assessing information needs, and developing alternative solutions. This suggests that an in-depth evaluation in Project Based Learning should include an assessment of the students' thinking process, not just the end result of the project they are working on. In-depth evaluation measures not only the knowledge that has been acquired, but also the critical thinking, collaboration, and creativity skills that are important in engineering and stem education. According to Khoiriyah et al. (2015), assessment that involves collaboration and independent learning skills can provide a more holistic picture of students' abilities in the context of Project Based Learning. This suggests that assessment tools that are able to capture the process and outcome aspects in a balanced manner are needed. The challenge can be overcome by:

1. A two-dimensional assessment rubric covering process aspects (teamwork, planning, time management) and outcome aspects (quality of final product, creativity, relevance of solution).
2. Formative and summative assessment. Formative assessments are conducted during the project process to evaluate students' progress, provide feedback, and refine their approach. Summative assessments are conducted after the project is completed to assess the quality of the final outcome.
3. Progressive checklists that can be used to guide process assessment in specific stages, such as the planning stage, implementation stage, and completion stage.
4. Reflection-based assessment which involves asking students to compile a reflective report that explains the thought process and decisions they made during the project. This provides insight into their learning process.
5. The use of assessment technology such as platforms like kahoot, padlet, or google forms can be used to create interactive and systematic process evaluation tools.

The keyword 'assessment' in the context of 'engineering education' plays an important role in facilitating project-based learning, as it gives students the opportunity to get constructive feedback. Effective assessment measures not only the end result of the project, but also the learning process that students go through, including the critical thinking skills, collaboration, and creativity that are so important in education. One approach that can be used in Project Based Learning assessment is project-based assessment, which has been shown to improve students' reasoning ability and create a positive attitude towards learning. Marmoah et al. (2022) noted that project-based assessment allows students to be actively involved in the learning process, where they can apply their knowledge and skills in a real context. However, challenges in Project Based Learning assessment remain, especially in assessing individual contributions in group projects. Sappaile et al. (2023)notes that although project-based assessment offers many benefits, there are still difficulties in identifying the contribution of each group member. One of the problems often encountered is students' dissatisfaction with group work, including difficulties in sharing tasks and interpretation of their peers' work. Pedwell et al. (2018) noted that despite efforts to design positive group interactions, problems such as uneven member contributions and uncertainty regarding the tasks to be performed persist. The solutions offered to overcome these problems include:

1. Use of peer assessment by providing students with an assessment instrument to rate their teammates' contributions based on clear criteria. This helps to capture the collective perception of individual involvement in the project.
2. Individual-specific assessment rubrics by including rubrics that evaluate each student's specific role in the group, such as responsibility, contribution of ideas, and task execution.
3. Activity logs and reflection journals by having students record their activity logs and write reflections on the tasks they have completed. This gives an idea of each individual's contribution.
4. Observation by the teacher. Teachers can make direct observations during the group work process and record individual engagement. Observation tools such as checklists can be used to ensure accuracy of judgement.
5. Use of digital platform technology for collaboration such as google workspace or trello to monitor student activity in the project. These activity logs provide objective evidence of individual contributions.

Moreover, in the context of 'STEM education', Project Based Learning allows students to engage in projects that integrate various disciplines, so that they can see how concepts from science, technology, engineering, and mathematics are interconnected and contribute to solving complex problems (English, 2016). The implementation of process-based 'assessment' allows students to focus more on self-development during the project, by assessing their ability to plan, manage, and evaluate the project. This is in line with research by Stohlmann et al., which suggests that good assessment in stem education should include aspects such as collaboration, communication, and problem solving (Stohlmann et al., 2012). Furthermore, research by Siew et al. showed that Project Based Learning that integrates concepts in stem subjects allows students to apply their knowledge and skills to solve real-world problems, which has a positive impact on their learning outcomes (Siew et al., 2015).

Challenges in stem education, particularly in the context of Project-Based Learning, often arise from variations in the quality of projects produced by students. This variation can be caused by differences in individual abilities and the resources available to each group. Möller et al. (2021) revealed that students' ability to lead and manage their own projects is an important indicator of a successful outcome. Inequalities in this ability can lead to significant differences in the quality of project outcomes produced by different groups. One of the problems often encountered is students' dissatisfaction with group work, including difficulties in task sharing and interpretation of their peers' work. The solution to this problem is:

1. Providing equal support by giving resources, such as project guides, reference materials, or access to digital tools, to all groups in order to have an equal opportunity to complete the project.
2. Differentiated instruction by providing projects that are appropriate to each student's ability level, but still challenging.
3. Flexible assessment criteria. The grading rubric should be designed to accommodate project variations without compromising objectivity. For example, assess based on student creativity and effort, not just the complexity of the final product. Assess students' ability to overcome resource limitations.
4. Directed mentoring: the teacher can act as a mentor throughout the project process, providing specialised direction to groups facing greater challenges.
5. Emphasis on the learning process by giving greater weight to process aspects (such as planning, collaboration, and iteration) than to the end result of the project to reduce resource imbalances.

The importance of the mentor's role in helping students develop the necessary skills to design and evaluate research projects (Kurtz & Kessler, 2017). Without adequate guidance, students may not have the necessary skills to manage the project effectively, which may contribute to variations in the quality of the results produced. Gibbons also pointed out that direct assessment of student work using the same rubric for formal assessment can help identify gaps in student learning and improve project quality (Gibbons, 2024). Thus, the implementation of clear and structured assessment rubrics can help reduce variations in project quality by providing better guidance for students in completing their assignments. However, this challenge is not only limited to individual abilities, but also to available resources. Variations in access to resources, be it hardware, software, or support from teachers, can affect project outcomes. Therefore, it is important to create an equal learning environment, where all students have equal access to the resources needed to complete their projects.

CONCLUSIONS AND RECOMMENDATIONS

Overall, it shows that evaluation and assessment in project-based learning play a key role in the success of learning, especially in engineering education and stem education. Systematic and thorough evaluation or assessment can serve as a benchmark for the effectiveness of project-based learning-based curriculum. Two-dimensional assessment rubrics, formative and summative assessment, progressive checklists, reflection-based assessment, the use of assessment technology can be a solution to the need for assessment tools that are able to capture the process and outcome aspects in a balanced manner. The use of peer assessment, specific assessment rubrics, activity logs and reflection journals, teacher observation, use of digital platform technology can overcome the difficulties in assessing individual contributions in group projects. Provision of equal means of support, differentiated instruction, flexible assessment criteria, directed mentoring and emphasis on the learning process by giving greater weight to the process aspect can be a solution to the variation in the quality of projects produced due to differences in ability and resources. To maximise the potential of Project Based Learning, it is suggested that educators can develop assessment tools that can measure the process and outcomes of the project fairly, incorporate elements of reflection in the evaluation to increase students' awareness of their learning process and adopt technology-based approaches to overcome the challenges of assessing group projects. With effective evaluation and assessment, project-based learning can be a catalyst to create graduates who not only have theoretical knowledge, but are also able to apply that knowledge practically in the real world. This is crucial to prepare the next generation of competent graduates in the ever-evolving era of STEM and engineering education.

FURTHER STUDY

This research still has limitations such as the lack of analysis on assessment instruments and rubrics. Bibliometrics only analyses bibliographic relationships (such as co-occurrence), but does not delve deeper into the content or quality of project-based learning assessment so further research is needed on the topic of assessment in project-based learning, to refine this research and add insight for readers.

REFERENCES

Acker, J., Rogers, I., Guerra-Zubiaga, D., Tanveer, M. H., & Moghadam, A. A. A. (2023). Low-Cost Digital Twin Approach and Tools to Support Industry and Academia: A Case Study Connecting High-Schools with High Degree Education. *Machines*, *11*(9), 860. https://doi.org/10.3390/machines11090860

Agustina, P., Saputra, A., Anif, S., Rayana, A., & Probowati, A. (2021). Analisis Keterampilan Proses Sains Dan Sikap Ilmiah Siswa Kelas Xi Ipa Sma Pada Praktikum Biologi. *Edusains*, *13*(1), 1–7. https://doi.org/10.15408/es.v13i1.11015

Dacumos, L. P. (2023). STEM education and the project-based learning: A review article. *STEM Education Review*, *1*. https://doi.org/10.54844/stemer.2023.0385

English, L. D. (2016). STEM education K-12: perspectives on integration. *International Journal of STEM Education*, *3*(1). https://doi.org/10.1186/s40594-016-0036-1

Fan, I. Y. H., & Shum, W. K. F. (2023). Knowledge Management: The Missing Bonding Discipline of STEM Education. *International Journal of Knowledge and Systems Science*, *14*(1), 1–17. https://doi.org/10.4018/IJKSS.323420

Gibbons, M. M. (2024). Developing and assessing a collaborative open-ended design project with a renewable energy focus in an introductory thermal sciences course. *International Journal of Mechanical Engineering Education*, *52*(3), 261–287. https://doi.org/10.1177/03064190231190054

Hanif, S., Wijaya, A. F. C., & Winarno, N. (2019). Enhancing Students' Creativity through STEM Project-Based Learning. *Journal of Science Learning*, *2*(2), 50. https://doi.org/10.17509/jsl.v2i2.13271

Hutahaean, B., Telaumbanua, S., & Tamba, L. (2022). Development of a Multidimensional Curriculum Evaluation Model for the Independent Curriculum in Elementary Schools. *QALAMUNA: Jurnal Pendidikan, Sosial, Dan Agama*, *14*(2), 705–724. https://doi.org/10.37680/qalamuna.v14i2.3617

Johan Fanani, A. (2024). Implementation of Project-Based Learning on Students' Critical Thinking in Mathematics Learning in The Independent Curriculum. *Noumerico: Journal of Technology in Mathematics Education*, *2*(1), 1–6. https://doi.org/10.33367/jtme.v2i1.5246

Khoiriyah, U., Roberts, C., Jorm, C., & Van Der Vleuten, C. P. M. (2015).

Enhancing students' learning in problem based learning: Validation of a self-assessment scale for active learning and critical thinking. *BMC Medical Education*, *15*(1). https://doi.org/10.1186/s12909-015-0422-2

Kurtz, C. P., & Kessler, T. A. (2017). An undergraduate collaborative team model to engage nursing students in research. *Journal of Nursing Education and Practice*, *7*(7), 112. https://doi.org/10.5430/jnep.v7n7p112

Marmoah, S.-, Istiyati, S.-, Supianto, S., Mahfud, H., & Sukarno, S. (2022). Penilaian Berbasis Proyek Di Sekolah Dasar. *Jurnal Pengabdian Masyarakat Borneo*, *6*(2), 174–181. https://doi.org/10.35334/jpmb.v6i2.2745

Möller, R., Wallberg, A., & Shoshan, M. (2021). Faculty perceptions of factors that indicate successful educational outcomes of medical students' research projects: a focus group study. *BMC Medical Education*, *21*(1). https://doi.org/10.1186/s12909-021-02954-8

Pedwell, R. K., Fraser, J. A., Wang, J. T. H., Clegg, J. K., Chartres, J. D., & Rowland, S. L. (2018). The beer and biofuels laboratory: A report on implementing and supporting a large, interdisciplinary, yeast-focused course-based undergraduate research experience. *Biochemistry and Molecular Biology Education*, *46*(3), 213–222. https://doi.org/10.1002/bmb.21111

Permatasari, P., Aldi, K., Nidiatika, A., & Maja, G. (2023). Implementation of the Independent Curriculum in Improving the Quality of Education in SMA Negri 1 Belitang III. *Scientechno: Journal of Science and Technology*, *2*(2), 125–135. https://doi.org/10.55849/scientechno.v2i2.164

Pugh, K. J., Kriescher, D. P. J., Tocco, A. J., Olson, C., Bergstrom, C. M., Younis, M., & BenSalem, M. (2023). The Seeing Science Project: Using Design-Based Research to Develop a Transformative Experience Intervention. *Journal of Science Education and Technology*, *32*(3), 338–354. https://doi.org/10.1007/s10956-023-10031-6

Razali, S. N., Noor, H. A. M., Ahmad, M. H., & Shahbodin, F. (2017). Enhanced student soft skills through integrated online project based collaborative learning. *International Journal of ADVANCED AND APPLIED SCIENCES*, *4*(3), 59–67. https://doi.org/10.21833/ijaas.2017.03.010

Ritonga, S., Areeisty, K., & Zulkarnaini, Z. (2021). Enhancing Students' Critical Thinking Skills through Problem Based Learning Integrated with Mindmapping. *Asian Journal of Science Education*, *3*(1), 63–69. https://doi.org/10.24815/ajse.v3i1.19727

Sappaile, B. I., Putro, A. N. S., Ahmad, S. N., Artayani, M., Zahir, L. A., & Andilah, S. (2023). Implementasi Model Pembelajaran Berbasis Proyek Dalam Penanaman Konsep Matematika pada Siswa Sekolah Menengah. *Innovative: Journal Of Social Science Research*, *3*(3), 8547–8557. https://doi.org/10.31004/innovative.v3i3.3155

Siew, N. M., Amir, N., & Chong, C. L. (2015). The perceptions of pre-service and in-service teachers regarding a project-based STEM approach to teaching science. *SpringerPlus*, *4*(1), 1–20. https://doi.org/10.1186/2193-1801-4-8

Stohlmann, M., Moore, T., & Roehrig, G. (2012). Considerations for Teaching Integrated STEM Education. *Journal of Pre-College Engineering Education Research*, *2*(1), 28–34. https://doi.org/10.5703/1288284314653

Zaeriyah, S. (2022). Peningkatan Motivasi Belajar Menggunakan Project Based Learning (PjBL) melalui Media Vlog Materi Senam Aerobik. *Ideguru: Jurnal Karya Ilmiah Guru*, *7*(1). https://doi.org/10.51169/ideguru.v7i1.291