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ARTICLE

Opening New Horizons in Chemistry Learning: A Literature Review of Development Project-Based Learning Student Worksheet

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ABSTRACT
This study addresses the crucial need for well-structured resources in project-based learning (PBL) for chemistry education, focusing on the development and utilization of project-based learning student worksheets. Despite the recognized benefits of PBL, many chemistry classrooms lack adequate support, hindering effective implementation. By systematically analyzing existing research, this study aims to identify best practices, innovative approaches, and common challenges associated with PBL student worksheets. The research's urgency lies in enhancing student engagement, fostering critical thinking skills, and improving learning outcomes in chemistry education. Ultimately, this study aims to inform educators, curriculum developers, and policymakers to enhance the integration of PBL strategies in chemistry teaching.

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1. Introduction

In recent years, educational paradigms have increasingly emphasized active and experiential learning methodologies [1,2]. Among these, project-based learning (PBL) has garnered significant attention due to its potential to engage students deeply and enhance their understanding of complex subjects, particularly in the sciences [3]. Chemistry education, often perceived as challenging due to its abstract concepts and extensive theoretical content, stands to benefit immensely from the integration of PBL strategies [4,5]. These strategies facilitate a hands-on, inquiry-based learning environment that fosters critical thinking, problem-solving, and the application of knowledge to real-world scenarios [6,7].

Active learning strategies, such as project-based learning (PjBL), are emerging as one of the most relevant and studied strategies for improving learning in chemistry education [8,9,10]. This approach not only offers a constructivist approach by involving students in practical problem solving, but also provides them with the opportunity to develop technical and theoretical skills in depth [11, 12,13]. Rooted in the educational concept promoted by John Dewey more than a hundred years ago, PjBL has been widely applied in chemistry education since the 1970s [14,15,16]. This method encourages team collaboration, cross-disciplinary knowledge mobilization, and the creation of final products that are relevant to real professional contexts [17,18,19]. Thus, PjBL not only prepares students for future industrial challenges, but also enhances higher-level cognitive skills, such as metacognition and problem solving, making it a vital and effective learning strategy in chemistry education [20,21,22].

Despite the proven advantages of PBL, its implementation in chemistry education is fraught with challenges [23,24]. Educators frequently encounter obstacles such as a lack of resources, insufficient training, and the absence of well-structured materials to support PBL activities [25,26]. One critical component missing from many chemistry classrooms is the project-based learning student worksheet [27]. These worksheets are essential tools that guide students through project phases, provide scaffolding for complex tasks, and ensure alignment with curriculum objectives [28,29,30,31,32]. The scarcity of such resources highlights the need for targeted development efforts to create effective PBL worksheets tailored for chemistry education [33,34].

This literature review aims to address the gap in available resources by systematically examining the development of project-based learning student worksheets specifically designed for chemistry education. By analyzing existing research and development projects, this review seeks to uncover best practices, innovative approaches, and the common challenges associated with creating and implementing these educational tools. The insights gained from this review will inform educators, curriculum developers, and policymakers about the effective integration of PBL in chemistry teaching, ultimately enhancing student engagement and learning outcomes.

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The primary objectives of this review encompass a comprehensive exploration of project-based learning (PBL) student worksheets within the domain of chemistry education. Firstly, the review endeavors to identify and emphasize the advantages inherent in employing PBL worksheets, aiming to elucidate their role in enhancing the learning experience for chemistry students. Secondly, it seeks to delve into the challenges and impediments faced in both the development and implementation phases of these worksheets, shedding light on areas that require attention and improvement. Additionally, the review undertakes an analysis of the distribution of existing studies on PBL worksheets in chemistry, leveraging databases like the Web of Science to discern trends and gaps in research. Lastly, the review aims to provide actionable recommendations for the effective creation of PBL worksheets, offering insights into best practices while also outlining avenues for future investigation in this dynamic field.

This literature review seeks to explore the following research questions: 1) What are the advantages of using project-based learning student worksheets in chemistry education, as reported in the literature? 2) What challenges are associated with the development and implementation of these worksheets in the educational setting?

2. Experimental

This research uses a literature review method related to project-based learning in chemistry education. A literature review is an analysis of scientific references on a particular subject [35]. This provides an outline of current understanding, so that relevant research hypotheses, approaches, and gaps can be established [36,37]. A literature review includes selecting, assessing, and studying publications related to a research problem such as books, articles, and journals [38,39]. A literature review is a perfect way to present previous literature [40,41]. This can be a compilation of research results related to the researcher's topic and reveal gaps that have not been addressed and make it one of the researcher's priorities for future research [42,43]. The current research uses a qualitative approach to collect data.

This literature review aims to provide an overview of current understanding, so as to identify gaps in previous research. This process involves the selection, appraisal and study of articles relevant to the research topic. This enabled the collection of research results related to this topic and uncovered unaddressed gaps to be the focus of future research. The study consisted of three systematic stages: planning, conducting, and final evaluation. Each stage is described in more detail in figure 2.

2.1 Planning Process

The use of project-based learning in education is increasing, especially in chemistry [44]. Research on the development and application of project-based teaching materials has been conducted, so it is important to conduct a literature review to find out the development and application of these in chemistry education, including the types of teaching materials, educational aspects that have been applied, advantages, and challenges faced [45,46]. In this planning stage, the activities undertaken include:

2.1.1 Determination of Inclusion and Exclusion Criteria

In this stage, inclusion criteria are established to define the desired sample based on the research objectives, while exclusion criteria are set to exclude samples that meet the inclusion criteria but are not relevant to the study [47]. Inclusion criteria include articles published in English within the last five years (2019-2024), with full-text availability, and are relevant to the research focus. Exclusion criteria involve removing duplicate articles, articles not aligned with the research question or category, articles not relevan to the topic, articles not available and payment.

Inclusion Criteria	Exclusion Criteria
• Articles published in English • Years between 2019-2024 • Full-text availability and open access • Relevant to the research focus	• Removing duplicate articles • Articles not aligned with the research question or category • Articles not relevant to the topic • Articles not available and payment

Figure 1 Inclusion and exclusion criteria

2.1.2 Sources of Information

A variety of information sources are utilized to gain a global perspective, including Scopus, Springer, MDPI, Taylor & Francis, and Elsevier databases.

2.1.3 Search Stages

To identify literature related to project-based learning in chemistry education across all databases, several keyword combinations are used. The keywords include "project-based learning", “chemistry education", "project-based learning in education", “education”, "project-based learning in chemistry education”.

2.2 Conducting Stage

2.2.1 Search Syntax

Searches are conducted based on titles, abstracts, and keywords, utilizing specific search words combined with Boolean operators (AND, OR) to refine the search results and ensure relevance to the research objectives [48].

2.2.2 *Data Extraction*

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Data extraction is performed using structured forms, with Microsoft Word chosen for its ability to create tables facilitating data extraction and synthesis. A descriptive summary of the results addressing the research objectives and questions is generated, and a draft chart template is developed for efficient coding of extracted data.

2.3 Final Stage/Evaluation

In this stage, the results obtained from the search process are presented. A literature search is conducted on journal articles related to the use of project-based learning in chemistry education. Several recognized article databases are selected and used for the search. Only the most relevant articles are selected after careful review, and quality evaluation is applied to ensure the selected articles are appropriate for the study. A total of 35 articles are identified as the final dataset for this study.

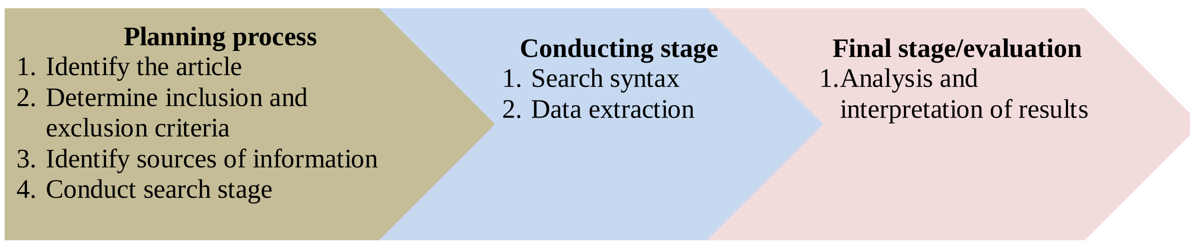

Figure 2 Research Process adopted from Okonkwo & Ade-Ibijola (2021) [49]

3. Results and discussion

3.1 Results

This literature review research aims to find research on project based learning in chemistry education; The following subsections provide detailed information about the review results.

3.1.1 The advantages of using project-based learning student worksheets in chemistry education

1. Advantages for Students

Integrating project-based learning worksheets into chemistry education has been shown to significantly enhance student engagement and motivation. According to Almulla (2020), PBL encourages students to actively participate in their learning process, making it easier for them to achieve their educational goals [50]. Teachers aim to use PBL to motivate students to learn and to make classroom participation more meaningful and positive [51,52,53]. Unlike traditional learning methods where the teacher is the central figure, PBL places students at the center, requiring them to engage in hands-on activities, respond to real-world problems, and conduct content assessments [54,55,56].

Umar & Ko (2022) found that the use of PBL elements in education improved student engagement both in conventional classrooms and online learning environments [57]. The essence of PBL lies in its ability to make learning activities more enjoyable and relevant, thereby increasing students' intrinsic motivation to participate [58,59]. This method fosters a supportive and positive educational culture, which is crucial for creative teaching and learning [60,61]. PBL's intrinsic engagement promotes active student participation in the learning process, supporting constructive learning, problem-based learning, and experiential learning [62].

The primary objectives of PBL are to enhance specific skills, set purposeful learning goals, engage students, maximize learning outcomes, and foster positive changes in attitudes and interactions [63,64]. Effective PBL design includes dynamic activities, social participation, freedom of choice, and opportunities for safe failure, which are key to increasing student involvement and performance [65,66]. Additionally, PBL provides students with immediate feedback on their progress, which can boost self-esteem and motivation [67,68]. Researchers have recognized PBL as an effective way to improve student learning through various approaches [69,70,71]. For example, Irawati (2022) noted that PBL significantly boosted students' learning outcomes in a Merdeka curriculum, and Li & Tu (2024) suggested that well-designed PBL could inspire students to participate more actively in online discussions, providing flexibility and deeper reflection [72,73].

2. *Advantages for Teachers*

Project-based learning (PBL) student worksheets offer numerous benefits to teachers in the realm of chemistry education. These worksheets serve as valuable resources for enhancing various pedagogical skills and improving classroom dynamics. The structured yet flexible nature of PBL worksheets enables educators to foster essential skills such as decision-making, cooperation, and communication among their students [74,75]. By integrating real-world problems into the curriculum through PBL, teachers can create a more engaging and motivating learning environment [76,77,78]. One significant advantage of using PBL student worksheets is the enhancement of teaching efficiency and effectiveness. These worksheets provide a clear framework for lesson planning, ensuring that all necessary topics and concepts are covered systematically [79,80]. This structured approach allows teachers to align their lessons with curriculum standards while still offering flexibility to adapt to the needs and interests of their students [81,82]. Moreover, the hands-on, inquiry-based nature of PBL encourages active learning, which can lead to better retention and understanding of complex chemistry concepts [83].

3.1.2 The challenges are associated with the development and implementation of these worksheets in the educational setting

The development and implementation of project-based learning (PBL) worksheets in educational settings present several challenges. One significant hurdle

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is the considerable time and effort required for creating high-quality PBL materials that effectively integrate hands-on activities and curriculum objectives [84]. This process demands meticulous planning and resources from educators, including ensuring alignment with educational standards and learning outcomes, which adds complexity to the development phase [85,86].

Resistance to the adoption of PBL by both educators and students is another notable challenge. Some teachers may lack the necessary training or support to effectively integrate PBL into their teaching methods [87,88]. Additionally, students accustomed to more traditional learning approaches may initially struggle with the shift to a more active and self-directed learning paradigm, requiring time and guidance to adapt [89,90,91].

Resource constraints and logistical challenges also hinder the implementation of PBL worksheets. Access to laboratory equipment, materials, and technology varies across educational institutions, limiting the scope and effectiveness of PBL activities [92,93,94]. Moreover, large class sizes and time constraints within the curriculum can pose logistical hurdles for conducting hands-on experiments and collaborative projects [95,96].

Assessing student learning and performance within the context of PBL presents additional challenges. Traditional assessment methods may not accurately capture the complex skills and competencies developed through project-based [97,98,99,100]. Educators must devise alternative assessment strategies, such as rubrics and peer evaluations, to effectively measure student progress [101,102]. Overall, addressing these challenges requires dedicated effort, collaboration, and a commitment to student-centered pedagogy to fully realize the potential benefits of PBL in educational settings.

3.2 Discussion

The findings from the literature on project-based learning (PBL) in chemistry education suggest that it offers numerous advantages but also presents challenges during development and implementation. Research consistently highlights the efficacy of PBL worksheets in enhancing student engagement, motivation, and critical thinking skills [103,104,105]. By involving students in hands-on projects that address real-world problems, PBL fosters a deeper understanding of complex chemical concepts and promotes collaboration and communication skills [106,107]. However, creating high-quality PBL materials demands significant time and effort from educators, including careful alignment with curriculum objectives and educational standards [108,109]. Resistance to the adoption of PBL by both educators and students can also pose challenges, requiring additional support and training to effectively integrate PBL into the curriculum [110].

Moreover, resource constraints and logistical challenges hinder the implementation of PBL in chemistry education. Limited access to laboratory equipment, materials, and technology can restrict the scope and effectiveness of PBL activities [111,112,113]. Large class sizes and time constraints within the curriculum further complicate the execution of hands-on experiments and collaborative projects [114,115]. Assessing student learning and performance within the context of PBL also presents challenges, as traditional assessment methods may not adequately capture the complex skills and competencies developed through project-based learning [116,117]. Educators must devise alternative assessment strategies to accurately measure student progress and achievement [118,119].

Despite these challenges, the potential benefits of PBL in chemistry education make it a valuable pedagogical approach worth pursuing. To overcome the hurdles, educators and institutions must invest in professional development, ensuring teachers are equipped with the skills and knowledge needed to effectively implement PBL strategies [120,121,122]. Additionally, securing funding and resources to provide the necessary laboratory equipment and materials is crucial for facilitating hands-on activities [123,124,125,126]. Collaboration among educators to share best practices and successful PBL models can also help mitigate logistical challenges and improve implementation [127,128]. By addressing these issues, PBL can be more widely adopted, ultimately enhancing student learning experiences and outcomes in chemistry education [129,130,131].

4. Conclusion

In this study, we explored the benefits and challenges of using project-based learning worksheets in chemistry education. We found that utilizing these worksheets can enhance student motivation and engagement, facilitate the development of critical skills, and support a deeper understanding of chemistry concepts through real-life applications. However, we also identified several challenges, including time and resource constraints, teacher and student readiness, and the complexity of evaluating learning outcomes. By providing recommendations for the effective development and implementation of project-based learning worksheets, we aim to guide educators, curriculum developers, and policymakers in integrating this approach effectively in chemistry teaching, with the goal of enhancing student engagement and learning outcomes.

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