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ARTICLE

Chemistry Learning Innovation in the Digital Era: A Literature Review of Development an E-LKPD with Problem-Based Learning and STEM Approach

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ABSTRACT
The rapid advancement of digital technology has changed educational practices, requiring innovative approaches to improve learning outcomes. This literature review explores the development of electronic Student Worksheets (E-LKPD) utilizing Problem-Based Learning (PBL) which is integrated with the Science, Technology, Engineering, and Mathematics (STEM) approach in the context of chemistry education. By using the literature study research method, it was found that the use of E-LKPD can improve critical thinking, problem solving skills and interdisciplinary knowledge among students. The integration of PBL and STEM in E-LKPD is highlighted as a promising strategy to make chemistry learning more interesting and relevant to real-world applications. Key challenges, such as technological barriers and teacher readiness, as well as solutions to these challenges, are also discussed, for future research and implementation practice. This review aims to provide comprehensive insights to educators, researchers, and policymakers on the use of digital tools to innovate chemistry education in the digital era.

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1. Introduction

Chemistry learning in the digital era has been revolutionized by electronic-based learning, offering unprecedented access to resources and interactive tools [1][2]. Virtual laboratories, simulation software, and online platforms provide students with hands-on experiences and real-time feedback, allowing them to explore complex chemical reactions and concepts without the constraints of physical lab space and materials [3][4][5]. These tools facilitate personalized learning, enabling students to progress at their own pace and revisit challenging topics as needed [6]. Additionally, incorporating multimedia resources, such as instructional videos and interactive quizzes, improves comprehension and retention of material, leading to a deeper understanding of chemistry [7]. This transition to digital learning equips students for the contemporary, technologically advanced scientific research environment and enhances the availability of high-quality educational resources [8].

Electronic-based student worksheets have emerged as a pivotal component of modern chemistry education, offering a dynamic and interactive alternative [9][10]. These digital worksheets often incorporate multimedia elements such as videos, animations, and interactive simulations, which provide students with a richer learning experience [11][12]. For instance, students can watch a video demonstration of a chemical reaction and immediately apply their understanding by completing related tasks on the worksheet [13][14]. This integration of multimedia content helps to clarify complex concepts and makes abstract ideas more tangible [15]. Additionally, electronic worksheets can offer instant feedback and hints, guiding students through problems and ensuring they grasp the underlying principles before moving on [16][17].

Moreover, electronic-based worksheets enhance collaborative learning and accessibility [18][19][20]. Through cloud-based platforms, students can work together in real-time, sharing ideas and solutions even when they are not physically in the same location [21]. This capability fosters a collaborative learning environment, encouraging peer-to-peer interaction and discussion [22][23]. Teachers can also easily track student progress, identify areas where individuals may be struggling, and provide timely support [24][25]. The accessibility of electronic worksheets ensures that all students, regardless of their physical location or resources, can benefit from high-quality educational materials. This inclusive approach not only supports diverse learning needs but also promotes equity in education, preparing all students to succeed in the digital and scientific landscapes of the future [26][27].

One learning model that is effective and can be applied to electronic worksheets is the problem based learning model [28][29][30]. This model involves presenting students with detailed, real-world scenarios or case studies that require critical analysis and problem-solving [31][32]. In an electronic format, these case studies can be interactive, incorporating multimedia elements such as videos, simulations, and virtual labs to enhance engagement [33]. Students work through the case by researching information, analyzing data, and proposing solutions, often collaborating with peers through integrated communication tools [34]. This model not only helps students apply theoretical knowledge to practical problems but also develops essential skills such as critical thinking, teamwork, and digital literacy [35]. The electronic nature of the worksheets allows for real-time feedback and adaptive learning paths, ensuring that students receive personalized support and can refine their problem-solving strategies effectively [36].

Apart from learning models, an approach is needed that can support learning. The approach that can be used in learning chemistry is STEM, this approach is applied to electronic student worksheets (E-LKPD) which integrate Science, Technology, Engineering and Mathematics into one unified learning experience [37]. By presenting interdisciplinary problems, such as designing an experiment, students apply knowledge from across STEM fields to develop solutions [38]. Digital formats enhance this experience with interactive simulations and collaborative tools, making complex concepts more accessible and engaging [39]. This method not only demonstrates the interconnectedness of STEM disciplines but also builds important technical and problem-solving skills, preparing students for future challenges [40].

This research emphasizes the development of strength-based electronic student worksheets (E-LKPD) utilizing a Problem-Based Learning (PBL) framework with a STEM approach, aiming to enhance student engagement and learning outcomes [41][42]. By focusing on leveraging students' existing strengths and interests, these digital worksheets are designed to present real-world problems that align with individual abilities and aspirations, thereby fostering a more personalized and motivating learning experience [43]. Integrating STEM disciplines, the worksheets challenge students to apply their knowledge in science, technology, engineering, and mathematics to solve complex, interdisciplinary issues [44][45]. This approach not only deepens their understanding of the subject matter but also enhances critical thinking, problem-solving, and collaboration skills [46]. Through interactive features and instant feedback mechanisms, the E-LKPD supports adaptive learning and encourages students to build on their strengths, ultimately leading to a more effective and engaging educational process [47].

The aim of this review is to provide a thorough analysis of the selected topic, investigating the main aspects, theories, and offering readers an in-depth understanding. By focusing on the title taken, this review aims to collect and organize information from various studies to determine the positive and negative impacts as well as the solutions offered from the application of E-LKPD based on problem-based learning with a STEM approach in chemistry subjects. In addition to summarizing the existing literature, this review also provides a useful and up-to-date source of information for researchers. Overall, the aim and scope of this review is to provide valuable insights and inform future research directions.

2. Experimental

This research uses a literature review method that focuses on problem-based learning (PBL) in the context of a STEM (Science, Technology, Engineering, and Mathematics) approach [48]. By collecting, analyzing existing studies and publications. This method enables a comprehensive understanding of how PBL can be applied effectively to improve STEM learning outcomes, foster critical thinking, problem-solving skills, and interdisciplinary knowledge [49]. Through this literature review, this research seeks to provide valuable insights and recommendations for educators and researchers to optimize STEM education through innovative PBL strategies.

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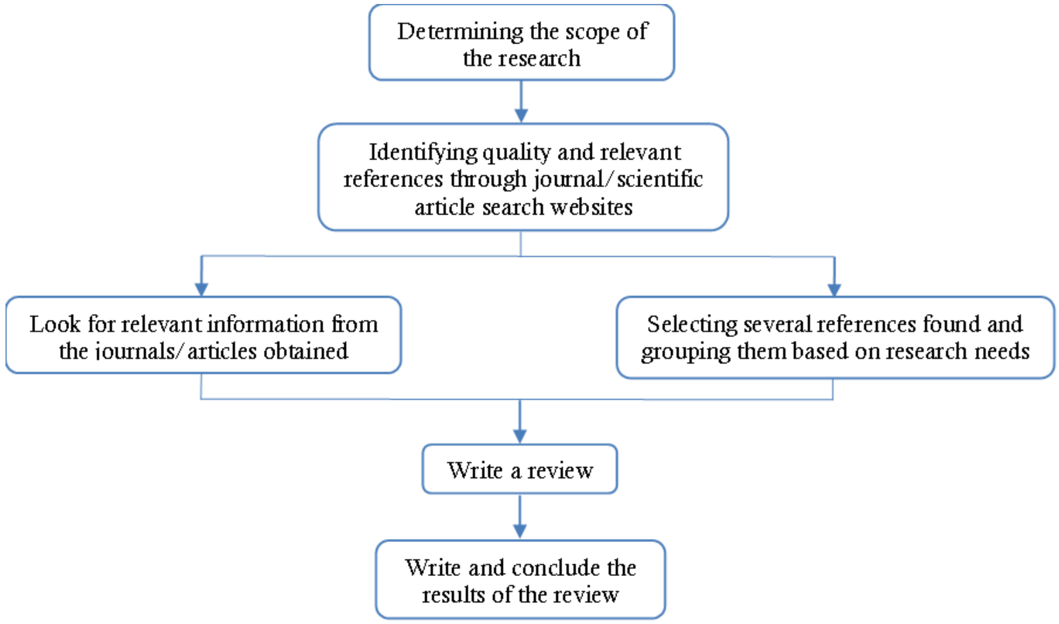

Figure 1. Literature Review Stages

Literature Study (Literature Review) is a type of research that involves deepening, examining, reviewing and identifying knowledge from previous research [50]. This research was carried out by searching for sources from websites that are commonly used to find scientific journals/articles such as Google Scholar, ScienceDirect, BERA, and others [51]. The following are the stages of literature study in this research: (1) determining the scope of the research, (2) identifying quality and relevant references through journal/scientific article search websites, (3) look for relevant information from the journals/articles obtained, (4) selecting several references found and grouping them based on research needs, (5) write a review, and (6) write and conclude the results of the review [52].

3. Results and discussion

Integrating digital tools into chemistry learning has significantly increased student engagement and understanding [53]. Electronic worksheets, with their interactive elements and multimedia features, provide a more dynamic and personalized learning experience than traditional methods [54]. These digital resources support differentiated instruction by meeting diverse learning needs and allowing students to learn at their own pace [55]. This review also discusses the challenges associated with implementing electronic worksheets, such as the need for a robust technological infrastructure and comprehensive teacher training [56][57]. The findings suggest that electronic worksheets offer major benefits, including increased student motivation, deeper understanding of complex concepts, and better preparation for future scientific endeavors [58]. Effective integration of electronic worksheets in chemistry learning requires addressing these challenges through targeted investments in technology and ongoing professional development for educators [59][60].

Electronic student worksheets (E-LKPD) are student worksheets in digital format that allow interactivity and access via electronic devices [61][62]. E-LKPD can significantly increase student engagement and motivation, especially because of its interactive and multimedia features [63][64]. This digital format allows for a more dynamic and flexible learning experience compared to traditional paper-based worksheets [65]. Additionally, the review identified that E-LKPD supports differentiated teaching, meets diverse learning needs and enables personalized learning pathways [66]. However, challenges such as the need for adequate technological infrastructure and teacher training were also discussed [67]. This study shows that successful E-LKPD integration requires addressing these challenges through appropriate resource allocation and professional development programs for educators. Overall, E-LKPD provides a promising opportunity to enrich the learning process, careful planning and support are essential to maximize its potential benefits.

The Problem Based Learning (PBL) model significantly enhances students' critical thinking and problem-solving abilities by engaging them with real-world problems, which fosters a deeper understanding and retention of course material [68][69]. The interactive and student-centered nature of PBL promotes active learning and engagement, requiring comprehensive educator training and a collaborative learning environment to be effective [70][71][72]. Successful implementation include presenting well-structured and relevant problems, along with skilled facilitation that guides learners without offering immediate solutions [73]. Although transitioning to PBL can be challenging for both students and teachers, the benefits, such as improved lifelong learning skills and the application of knowledge in real-world contexts, make it a valuable educational approach that can improve educational outcomes and better equip students for future challenges [74][75].

STEM (Science, Technology, Engineering, and Mathematics) approach reveals substantial benefits for student learning and engagement [76][77]. The results indicate that integrating STEM into the curriculum enhances students' problem-solving skills, critical thinking, and creativity [78][79]. By exposing students to interdisciplinary projects and real-world applications, the STEM approach fosters a deeper understanding of core concepts and encourages innovation [80][81]. Additionally, the review highlights improved academic performance and increased interest in STEM-related fields among students who participate in STEM programs, suggesting that early exposure can influence career choices and future educational pursuits [82][83][84].

The discussion further examines the challenges and considerations in implementing the STEM approach [85]. One significant challenge is the need for adequate resources and professional development for educators to effectively teach STEM subjects [86][87][88]. The review emphasizes the importance of teacher training programs that equip educators with the skills to design and facilitate integrated STEM lessons [89][90]. Furthermore, the necessity of creating an inclusive learning environment that supports diverse student populations, ensuring equal access to STEM opportunities [91][92]. Despite these challenges, STEM approach is a powerful educational strategy that prepares students for the demands of the modern workforce and promotes lifelong learning and curiosity [93].

Combining the problem-based learning (PBL) model with the STEM (Science, Technology, Engineering, and Mathematics) approach provides many benefits for student learning [94][95]. The results showed that this integrated educational strategy significantly improved critical thinking, problem-solving skills, and creativity [96]. Students who engage in PBL in a STEM context are more likely to apply theoretical knowledge to real-world problems, fostering a deeper understanding of complex concepts and interdisciplinary relationships [97]. This combination also promotes greater

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engagement and motivation, as students perceive the learning process to be more relevant and stimulating [98]. Additionally, the review shows that students are developing critical 21st century skills, such as collaboration, communication and innovation, better preparing them for future academic and career challenges [99].

This discussion outlines the practical implications and challenges of implementing PBL within a STEM framework. One of the main advantages is the alignment of PBL with the experiential and inquiry-based nature of STEM education, which naturally lends itself to collaborative, hands-on projects [100]. However, the review also noted several challenges, such as the need for significant teacher training and resource allocation to effectively manage and facilitate blended learning environments [101][102]. Educators must be adept at designing interdisciplinary problems that are challenging enough but accessible to students of various abilities [103]. In the learning process, it is important to create a learning environment that supports and encourages students to experiment and take risks [104]. Therefore, integrating PBL with STEM provides an effective method for enhancing student engagement and learning outcomes, equipping students with the skills and knowledge necessary to succeed in a rapidly evolving world [105].

The application of Electronic Student Worksheets (E-LKPD) with a problem-based learning model (PBL) and a STEM (Science, Technology, Engineering, and Mathematics) approach shows significant positive results on student learning and engagement [106]. Integrating E-LKPD with PBL and STEM can improve critical thinking and problem solving skills, including in chemistry learning [107][108]. The use of PBL encourages students to tackle real-world chemistry problems, encouraging critical thinking and problem-solving skills, while the STEM approach integrates interdisciplinary knowledge, making the learning process more holistic and relevant [109][110][111]. The interactive, multimedia-rich features of E-LKPD make learning more engaging and accessible, while the PBL framework encourages students to address real-world problems using interdisciplinary STEM knowledge [112][113]. This combined approach not only improves academic performance but also fosters a deeper understanding of the subject matter, as students can apply theoretical concepts to practical scenarios effectively [114][115].

There are benefits and challenges in implementing E-LKPD with a PBL and STEM approach [116]. One important advantage is increasing student motivation and active participation, because E-LKPD provides an interactive platform that supports various learning styles and needs [117][118]. In addition, the integration of PBL with STEM in a digital E-LKPD format allows for a more personalized and adaptive learning experience [119]. In this implementation, adequate technological infrastructure, teacher training and support are needed to utilize digital tools effectively [120]. Teachers must be skilled in digital literacy and facilitating PBL-STEM activities to maximize the benefits of E-LKPD. The application of E-LKPD by combining PBL and STEM offers a powerful educational strategy to improve student learning outcomes, equipping them with important skills for the future [121].

Several challenges were found that hamper the effectiveness of implementing E-LKPD with the problem-based learning (PBL) model and STEM (Science, Technology, Engineering, and Mathematics) approach [122]. One significant challenge is the lack of adequate technological

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infrastructure in many educational institutions, which limits access to digital devices and internet connectivity required for E-LKPD [123]. Additionally, there are often gaps in teachers' digital literacy and their ability to seamlessly integrate technology with PBL and STEM methodologies [124]. These issues can result in inconsistent application of the E-LKPD framework, thereby reducing its potential benefits for student learning and engagement. Additionally, students from disadvantaged backgrounds may face additional barriers, exacerbating educational disparities [125].

There are several solutions to overcome this weakness. To address technology infrastructure challenges, the review recommends increased investment in digital resources and infrastructure by educational institutions and governments, to ensure that all students have equitable access to the tools required for E-LKPD [126]. To improve teachers' digital literacy and instructional skills, comprehensive professional development programs should be implemented, with a focus on technological proficiency and effective pedagogical strategies for integrating PBL and STEM [127]. Additionally, creating a supportive community of practice among educators can facilitate the sharing of best practices and collaborative problem solving [128]. To address educational disparities, targeted support and resources must be provided to disadvantaged students, such as device subsidies and internet access, as well as tailored teaching strategies to meet diverse learning needs [129]. By overcoming these weaknesses with targeted solutions, the implementation of E-LKPD using the PBL model and STEM approach can be significantly improved and maximize educational benefits [130].

The development of Electronic Student Worksheets (E-LKPD) based on Problem Based Learning (PBL) with a STEM approach provides significant insight and detailed discussion, especially relevant to chemistry learning [131]. This study outlines a systematic process for integrating PBL into E-LKPD, with a strong focus on developing real-world problem-solving skills in a chemistry context [132]. During the design phase, careful planning ensures that chemistry content aligns with STEM principles, seamlessly combining scientific, technological, engineering, and mathematical concepts [133]. The testing phase revealed that students engaged more deeply with the chemistry material, demonstrating improved critical thinking and problem solving abilities. The interactive nature of E-LKPD combined with the PBL framework creates a more engaging and effective learning experience, making complex chemistry topics more accessible and stimulating for students [134].

Student responses to E-LKPD were very positive [135]. Many students appreciate the interactive elements and the real-world relevance of the problems presented [136]. They reported that the PBL approach made STEM concepts more relevant and easier to understand [137]. In addition, the use of E-LKPD provides flexibility in learning, allowing students to progress at their own pace [138]. However, some students face challenges with the digital format, highlighting the need for additional support and resources to ensure equitable access [139]. Overall, it was found that PBL-based E-LKPD with a STEM approach significantly improved student engagement and learning outcomes, although continuous improvement and support were essential to maximize its effectiveness [140].

4. Conclusion

Based on the results and discussions that have been described shows that the use of E-LKPD based on problem based learning with a STEM approach significantly increases student engagement,

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critical thinking and problem solving skills in chemistry learning. The perfect combination of real-world problem-solving tasks with interdisciplinary STEM concepts provides a comprehensive and in-depth learning experience. Although there are challenges such as the need for inadequate technological infrastructure and a lack of professional development for educators. however, these challenges can be overcome through targeted training and resource allocation, implementation of E-LKPD can result in more effective and meaningful chemistry learning experiences, as well as better preparation of students for future science and technology endeavors.

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