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Validity of Problem-Based Learning E-Worksheets with Augmented Reality to Enhance Student Knowledge

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ABSTRACT

Implementing problem-based learning through e-worksheets integrated with augmented reality provides interactive and visual learning experiences that support students' problem-solving skills and knowledge. This study aimed to assess the validity of problem-based e-worksheets integrated with augmented reality (AR) for enhancing students' knowledge. This study adopts the Plomp development model, which consists of three stages: preliminary research, development or prototyping, and assessment. The focus of this research is limited to the development or prototyping phase, specifically the expert validation stage, while user response evaluations involving a biology teacher and students were conducted to obtain additional evidence regarding the developed product. The criteria for validity assessment by content experts included content feasibility and linguistics. The criteria for validity assessment by media experts included presentation, attractiveness, and accessibility. The content expert evaluation yielded an overall score of 42 out of 44, categorized as very valid, whereas the media expert evaluation obtained an overall score of 44 out of 52, also categorized as very valid. Furthermore, user responses from a biology teacher and students yielded overall scores of 39 out of 44 and 263 out of 288, respectively, both categorized as very good. These results indicate that the developed e-worksheets are valid and effective for learning about the human excretory system. This study contributes to the development of validated problem-based learning e-worksheets integrated with augmented reality to support innovative biology learning. Future research should investigate the effectiveness of the developed product in classroom implementation and explore its adaptation to other biology topics.

Keywords: Problem-Based Learning, E-Worksheets, Augmented Reality, Excretory System, Student Knowledge

Introduction

The Merdeka curriculum encourages students to actively construct knowledge, including conceptual and procedural knowledge, that provides a strong foundation for biology learning and helps students develop 4C skills in the 21st century. Both types of knowledge can be used to solve a problem correctly (Septiani & Paidi, 2021). Conceptual knowledge is the understanding of a field's definitions, rules, and principles, whereas procedural knowledge is the understanding of the steps or strategies used to solve problems (Fauzi, 2017).The interaction between the two types of knowledge is bidirectional (Aydin et al., 2016). These competencies are particularly important when students learn the human excretory system, which involves complex anatomical structures and physiological processes.

According to findings from an interview with a biology teacher at SMA Negeri 2 Tanah Grogot, there is a clear need to improve students' knowledge. This conclusion is based on students' mean daily test scores, which stand at 60 and have yet to meet the minimum completeness criteria score of 75. The teacher further explained that in teaching, they use learning media such as *PowerPoint*, printed worksheets, and textbooks. The absence of digital media and technological engagement in education diminishes students' motivation to learn.

In biology, comprehension and accuracy are essential. The assessment of student requirements indicated that learners struggle to comprehend biological concepts, which encompass numerous systems within the human body, such as theories and processes that are challenging to visualize (Rahmawati *et al*., 2018). For instance, students perceived the excretory system as challenging to comprehend because it is invisible to the senses. A total of 73% of students reported that the current educational media is outdated and lacks engagement. A majority of 93.9% of students expressed a desire for future biology classes to incorporate technology that enhances their understanding of the subject. Moreover, 97.4% of students expressed interest in implementing electronic worksheets that incorporate technological features like augmented reality. These findings indicate that teachers and students require learning resources that facilitate visualization, independent learning, and structured problem-solving activities.

Numerous innovations in learning media utilize technological advancements to facilitate the learning process (Van Laar et al., 2020). One innovation is electronic worksheets (E-Worksheets). E-worksheets can be accessed online through smartphones, laptops, and PCs on platforms such as Liveworksheet.com, Wizer.me, and so on (Kholifahtus et al., 2021). E-worksheets can include images, videos, and direct interaction with students through tasks, and teachers can view the results immediately (Zahroh & Yuliani, 2021). E-worksheets as a learning tool help students connect with various activities that correlate with tasks and concept formation (Noprinda & Soleh, 2019).

According to Lathifah et al. (2021), the use of E-LKPD offers several advantages, including efficiency in terms of time and location, environmental friendliness due to its digital format that eliminates the need for paper, and a more engaging appearance that can incorporate images, videos, or animations related to the material, which helps capture students' interest in learning. This finding aligns with Apriliyani & Mulyatna (2021), who found that E-LKPD can attract students' interest in learning, making them more active in the learning process and independent in building their own knowledge. Furthermore, E-LKPD enhances students' understanding of the material by being designed attractively and equipped with videos, images, or animations as supplementary resources, which can be accessed online at any time due to its digital format.

E-worksheets require a learning model that supports the achievement of learning objectives. Thus, the problem-based learning model is used. The problem-based learning (PBL) model uses real-world, relevant problems for students to solve. Students can integrate their conceptual knowledge with their procedural knowledge to solve the

problem (Aini et al., 2021). Problem-based e-worksheets can create a learning atmosphere that increases students' interest in learning because the model contains components that can increase motivation or interest in everyday life problems (Saputra et al., 2024). In this study, the researcher produced a PBL model that contrasts with the PBL model employed by the teacher. An examination of the teacher's teaching module reveals that the PBL model is confined to problem presentation and group discussions, resulting in suboptimal implementation of each syntax to facilitate students' attainment of learning objectives. Subsequently, the teacher has not yet incorporated technology or interactive media into the instruction, and the worksheets utilized are confined to printed formats. The teacher cannot offer substantial feedback following the class, resulting in inadequate reinforcement of the material assimilated by the students. Consequently, in this research, the investigator developed a PBL model enhanced by e-worksheets using augmented reality, in which each PBL syntax is effectively executed and clearly represented in the e-worksheets, making the learning experience more engaging and focused on achieving educational goals. The created e-worksheets incorporate augmented reality technology that enhances material visualization.

Integrating augmented reality into problem-based learning e-worksheets as a single digital learning resource can not only enhance student engagement but also reshape traditional education by fostering a more interactive and immersive learning environment. The excretory system material itself is closely tied to organ structure and mechanisms, such as urine formation, which the senses cannot directly observe. Augmented reality (AR) enhances learning by displaying 3D models or images, making it easier for students to visualize concepts or abstract materials and increasing their interest in the subject (Mahmudah et al., 2023).

A valid problem-based E-worksheet with augmented reality is needed to enhance students' knowledge of the excretory system material. Although previous studies have reported the effectiveness of problem-based learning, electronic worksheets, and augmented reality in biology education, few studies have developed and validated a PBL-based e-worksheet integrated with AR specifically for the human excretory system. Therefore, this study focuses on validating the developed product before broader classroom implementation. This research aimed to describe the validity of the problem-based e-worksheets with augmented reality to enhance students' knowledge.

Methods

This research is an Educational Design Research (EDR) study. Sutarti and Irawan (2017) define educational design research as research that develops and validates educational goods for use in implementing a learning process. The development model used is the *Plomp* development model, which has 3 stages: preliminary research, development or prototyping phase, and assessment phase (Plomp et al., 2013). In this article, the research stages were limited to the development phase, particularly expert validation, to determine the product's validity.

In the preliminary research stage, the researcher conducts needs analysis, curriculum analysis, concept analysis, and a literature review. Then, in the second phase, the development or prototyping phase includes the design and development steps that refer to Tessmer's formative evaluation, which consists of self-evaluation, expert review, one-to-one evaluation, small group evaluation, and field test (Tessmer, 1993). Tessmer's formative evaluation is employed in EDR research because, according to Zaini (2018), the quality of an EDR research product is determined by evaluation techniques. This development research emphasizes formative evaluation, which will serve as a control in shaping the quality of the final research product.

However, this article focuses on validity testing. Then, development continued with self-evaluation, expert review, and evaluation of user responses. The material focuses on the excretory system, especially the kidney, including the structure and function of the kidneys,

how urine is produced, what affects urine production, and issues and technologies related to the kidneys.

In this study, the participants consisted of 2 biology lecturers from Universitas Negeri Yogyakarta serving as expert validators. Next, user response evaluations were conducted with 1 biology teacher and 11th-grade students from SMAN 2 Tanah Grogot. The data collection technique employs a questionnaire designed to gather product validation data from experts and user responses. The instrument used in this study is a product validation questionnaire by experts, namely content experts and media experts. The product validation questionnaire by content experts includes two assessment aspects: content feasibility and linguistic aspects. Meanwhile, the product validation questionnaire by media experts includes three assessment aspects, namely presentation, attractiveness, and accessibility. In addition, the user response questionnaire includes content feasibility, linguistic aspects, presentation, and accessibility. The questionnaire uses a 1-4 Likert scale with 4 response options: 4 = Very Appropriate, 3 = Appropriate, 2 = Less Appropriate, and 1 = Unappropriate. The data analysis technique, in the form of product validation data analysis by validators and user responses, is tabulated for subsequent quantitative processing and descriptive analysis. This study establishes the "valid" criterion as the minimum product validity criterion. Here is the formula for quantitative analysis.

Table 1. Criteria of product validity

Formula	Criteria
$Mi + 1{,}5\ Sdi \leq X \leq Mi + 3{,}0\ Sdi$	Very valid
$Mi \leq X \leq Mi + 1{,}5\ Sdi$	Valid
$Mi - 1{,}5\ Sdi \leq X \leq Mi$	Less Valid
$Mi - 3{,}0\ Sdi \leq X \leq Mi - 1{,}5\ Sdi$	Not Valid

(Wagiran, 2014)

Description:

Mi = Ideal mean → ½ (ideal maximum score + ideal minimum score)

X = Score obtained

Sd*i* = Ideal standard deviation → ⅙ (ideal maximum score - ideal minimum score)

Maximum score = 4 →Ideal maximum score = 4 x the total statement items

Minimum score = 1 →Ideal minimum score = 1 x the total statement items

Results and Discussion

1. The Preliminary Research
   a. Needs Analysis

      The needs assessment commenced with an interview with the biology instructor. The interview results indicate that the teacher utilizes teaching materials and media such as PowerPoint, printed worksheets, and textbooks. The teacher had difficulty motivating students to learn. The examination of student needs revealed a preference for learning that entails direct participation. Students perceive that educational resource remain inadequate and fail to align with contemporary needs. Students indicated that they have never utilized augmented reality technology or any other technological engagement. The biology teacher emphasized the need to implement the latest learning media, such as AR. Students also indicated that 97.4% are interested in using e-worksheets that involve technological elements like augmented reality. According to Dewi et al. (2024), augmented reality can boost learning interest, resulting in a more meaningful learning experience while also strengthening students' cognitive abilities and knowledge of the learning material. The application of augmented reality technology, particularly in biology teaching, aims to help students better visualize abstract biological topics. 3D visualization can provide a more realistic learning experience, especially for human anatomy concepts such as the body's systems (Aripin & Suryaningsih, 2019).

b. Curriculum Analysis

The school implements the Merdeka curriculum. In Phase F, learning outcomes are categorized into components of biological understanding and science process skills. The curriculum analysis evaluates the learning targets, which are aligned with the learning outcomes.

c. Concept Analysis

The excretory system material contains complex concepts and is expressed through conceptual and procedural knowledge. Conceptual knowledge refers to students' understanding of facts, terms, and relationships among concepts in the kidney. Meanwhile, procedural knowledge relates to the stages and methods of kidney function, especially the urine formation process.

d. Literature Review

Relevant literature reviews show that previous studies have examined the use of problem-based e-worksheets with augmented reality in biology education. Therefore, the research gap is clear, underscoring the urgency of developing the product.

2. The Development or Prototyping Phase

a. Design Stage

This product was designed using Canva. The augmented reality is marker-based and was made using the *Assemblr Edu* platform. The product is uploaded to the website liveworksheet.com so it can be used online. The results of the design stage in this study are shown in Figures 1-4 below.

Figure 1. The front and back cover design

The front cover includes the university, school, and curriculum logos. Additionally, it includes the title, e-worksheets, learning topics, student identity, and the name of the e-worksheets developer.

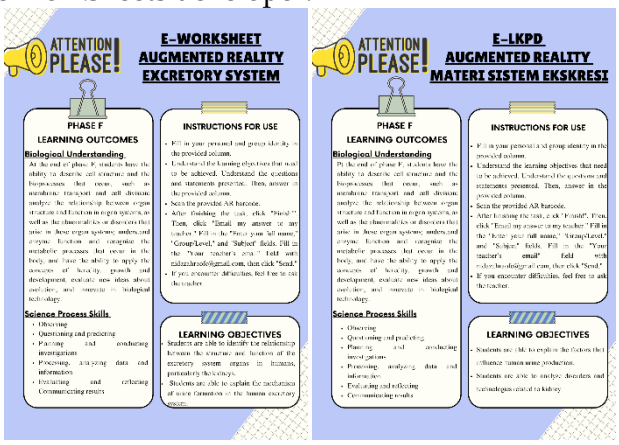

Figure 2. The design of learning outcomes, instructions for use, and learning objectives

The learning outcomes include biological understanding and science process skills. The instructions for use contain directions for using the e-worksheets. Next, the learning objectives include indicators of the learning goals that students must achieve in learning activities.

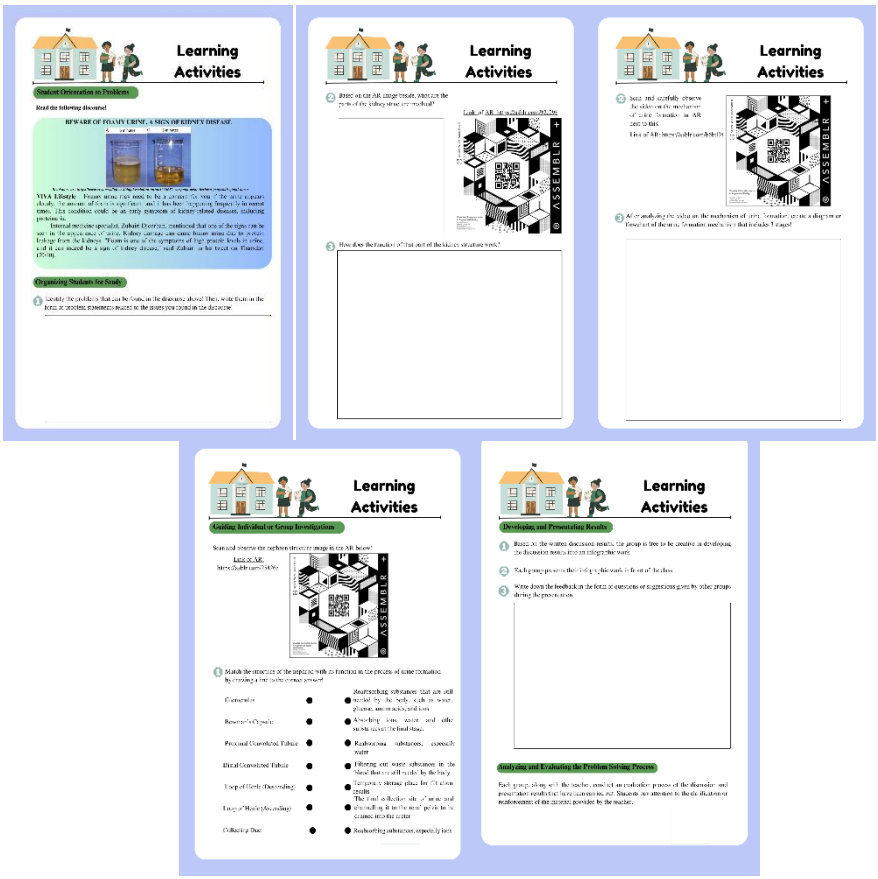

Figure 3. The design of learning activities on session 1

Learning activities include problem-based learning syntaxes, which consist of 5 steps, namely: (1) Students' orientation to the problem, (2) Organizing students for study, (3) Guiding independent or group investigation, (4) Developing and presenting results, and (5) Analyzing and evaluating the problem-solving process (Arends, 2013). The topic of session 1 is kidney structure & function and the mechanism of urine formation. The first syntax, where students read discourse about foamy urine, is an activity that leads to indicators of knowledge of principles and the generalization of conceptual knowledge, as students relate disease symptoms to kidney function. In Syntax 2, students identify problems in the discourse by formulating relevant questions. Then, students explore kidney structure through augmented reality, which can strengthen their conceptual knowledge of indicators related to theory, models, and structure.

The third syntax reinforces indicators of conceptual knowledge regarding classification and categories, as well as procedural knowledge indicators related to skills in a specific field, where students investigate the structure of nephrons and the mechanism of urine formation through augmented reality videos. The fourth syntax focuses on procedural indicators about knowledge of specific techniques and methods. Several groups conduct presentations to enhance their knowledge and discuss the topic. Finally, the fifth syntax relates to the knowledge indicator of criteria for appropriate procedures, where students, together with the teacher, evaluate the presentations and draw conclusions.

Figure 4. The design of learning activities on session 2

The second session is about factors affecting urine production, kidney-related disorders, and technologies. In the first syntax, students read a discourse on chronic kidney failure cases that helps assess their understanding of the principles and generalizations of conceptual knowledge. The second syntax involves students identifying factors that can affect urine conditions. Then, students also explore the influence of the ADH hormone on urine production through augmented reality and learn the hemodialysis work procedure by completing the provided sections. This syntax can strengthen students' conceptual knowledge about indicators related to theory, models, and structure.

The third syntax reinforces indicators of classification and categorization, as well as procedural knowledge indicators related to skills in specific fields, where students investigate the main causes and symptoms, the impact of disorders on urine production, and kidney disease treatment technologies such as kidney stones, diabetes insipidus, and kidney failure. The fourth syntax, related to procedural indicators in the form of knowledge of specific techniques and methods, involves students organizing the information, developing the infographic, and presenting their work. Several groups conducted presentations to enhance their knowledge and discuss kidney-related diseases. The fifth syntax, related to the knowledge indicator regarding criteria for appropriate procedures, involves students analyzing and evaluating the results of discussions held with the teacher.

b. Development Stage

1) Self-Evaluation

The researchers conducted a self-evaluation to independently assess areas for improvement in the product, such as structural completeness, content feasibility, component suitability, and clarity of usage instructions, before presenting it to experts for validation. This self-evaluation ultimately resulted in a problem-based e-worksheet design with augmented reality that performed better than the initial

design.

2) Expert Review and User Responses

Two lecturers from Universitas Negeri Yogyakarta conducted this assessment. The content expert evaluates the content's feasibility and linguistic aspects. Concurrently, the media expert assesses presentation, attractiveness, and accessibility. Table 1 illustrates the general requirements for product validation. Therefore, the data obtained during product validation is analyzed and converted according to Table 1. Here are the conversion tables:

Table 2. Conversion of Experts validation scores

Expert	Aspect	Formula	Criteria
Content Expert	Content Feasibility	26 ≤ X ≤ 32	Very valid
		20 ≤ X ≤ 26	Valid
		14≤ X ≤ 20	Less Valid
		8≤ X ≤ 14	Not Valid
	Linguistic	9.75 ≤ X ≤ 12	Very valid
		7.5 ≤ X ≤ 9.75	Valid
		5.25 ≤ X ≤ 7.5	Less Valid
		3≤ X ≤ 5.25	Not Valid
Media Expert	Presentation	26 ≤ X ≤ 32	Very valid
		20 ≤ X ≤ 26	Valid
		14≤ X ≤ 20	Less Valid
		8≤ X ≤ 14	Not Valid
	Attractiveness	9.75 ≤ X ≤ 12	Very valid
		7.5 ≤ X ≤ 9.75	Valid
		5.25 ≤ X ≤ 7.5	Less Valid
		3≤ X ≤ 5.25	Not Valid
	Accessibility	6.5 ≤ X ≤ 8	Very valid
		5 ≤ X ≤ 6.5	Valid
		3.5 ≤ X ≤ 5	Less Valid
		2≤ X ≤ 3.5	Not Valid

Table 3. Conversion of user response scores

Respondent	Formula	Criteria
Biology Teacher	35.75≤ X ≤ 44	Very good
	27.5≤ X ≤35.75	Good
	19.25 ≤ X ≤ 27.5	Less Good
	11≤ X ≤19.25	Not Good
Students	234 ≤ X ≤ 288	Very good
	180 ≤ X ≤ 234	Good
	126 ≤ X ≤ 180	Less Good
	72 ≤ X ≤ 126	Not Good

Table 4. Validation results by content expert

Aspect	Score Obtained	Maximum Score	Criteria
Content Feasibility	32	32	Very valid
Linguistic	10	12	Very valid
Total	42	44	Very valid

Table 4 shows that content expert validation yielded an overall score of 42 out of 44, categorized as very valid. The content feasibility aspect obtained a score of 32 (maximum score, while the linguistic aspect obtained 10 out of 12; both were categorized as very valid. The high score for the content feasibility aspect indicates that the product has successfully fulfilled the essential requirements of content validity, such as the accuracy of biological concepts and the alignment between

learning outcomes, learning objectives, and learning activities. Next, the suitability of the problem-based learning syntax and the integration of augmented reality features were evaluated. In addition, the visualization of kidney structures and urine formation was considered appropriate to support students' understanding of abstract biological concepts. Students may be more interested in reading the e-worksheets if the visual elements and colors are attractive (Lismidarni & Yohandri, 2020).

The second aspect is linguistic, and it received a very strong score. This indicates that the language used in the e-worksheets was grammatically accurate, easy to understand, and consistent with scientific writing and the spelling system. Clear, communicative language is important because it helps students understand learning materials more effectively. According to Sari et al. (2021), simple, communicative language makes it easier for students to understand the material.

The content expert suggested improving the font type and clarifying the learning goals. Therefore, the font style was revised to improve readability, and the learning objectives were refined to enhance clarity. The following are the media experts' validation results. The validation results are shown in the following table:

Table 5. Validation results by media expert

Aspect	Score Obtained	Maximum Score	Criteria
Presentation	27	32	Very valid
Attractiveness	11	12	Very valid
Accessibility	6	8	Valid
Total	44	52	Very valid

The results of media expert validation in Table 5 indicate that the product obtained an overall score of 44 out of 52, which was categorized as very valid. The media evaluation included 23 aspects, namely presentation, attractiveness, and accessibility. The presentation aspect obtained a score of 27 out of 32, and the attractiveness aspect obtained 11 out of 12, both of which fall into the very valid category. Meanwhile, the accessibility aspect obtained 6 out of 8 and was categorized as valid.

The high score for the presentation aspect indicates that the e-worksheet's visual appearance strongly supports the learning process because the selection of fonts, font size, color combinations, and the integration of augmented reality are appropriate for the learning objectives. The very well-designed visuals improve readability and help students focus on the learning content. These findings are consistent with Febrina and Qomariyah (2024), who stated that appropriate typography and visual appearance improve students' concentration during learning. Suitable font style and size enhance the overall quality of digital learning materials (Melania et al., 2021).

The second aspect, attractiveness, also received a very valid score of 11 out of 12. This indicates that integrating augmented reality features enhanced the product's visual appeal and supported the implementation of problem-based learning. Attractive learning media can increase students' interest and motivation to participate in learning activities, as reported by Elci et al (2021). The last aspect, accessibility, received a score of 6 out of 8 and is categorized as valid. It indicates the product was considered easy to access and supported by clear usage instructions. According to Ilana & Cintamulya (2022), easy-to-use learning media contribute to students' engagement and create more meaningful learning experiences.

The media expert also provided suggestions, namely adding a direct link to access the AR and replacing the video on the mechanism of urine formation with a

more detailed version. Therefore, we added a direct link to the AR page and replaced the video with a more specific one. Similar findings were reported by Zahro & Yuliani (2024), who stated that digital learning materials are considered valid when their media design, language, and visual presentation align with the learning objectives.

Table 6. User response evaluation

Respondent	Score Obtained	Maximum Score	Criteria
Biology Teacher	39	44	Very good
Students (n=6)	263	288	Very good

Following expert validation, user response evaluations were conducted involving a biology teacher and six students to complement the validation findings by obtaining users' feedback on the developed product. As shown in Table 6, the biology teacher scored 39 out of 44 and was categorized as very good in content feasibility and linguistics. Meanwhile, the students gave an overall score of 263 out of 288 and were also categorized as very good in presentation, linguistics, and accessibility. The positive user responses suggest that the e-worksheets are considered understandable, visually appealing, and easy to use during biology learning activities. According to Istiqomah & Aminatun (2025), learning tools are considered practical if user responses meet at least good criteria. Sipayung (2025) reported a similar finding: good learning media is media that is easy for students to use, employs communicative language, and features interactive content.

Valid expert ratings and user responses indicate that the developed product is not only theoretically appropriate but also positively received by its intended users, providing additional evidence of the product's quality. Based on that, these findings highlight several strengths of the developed product. First, the product integrates the e-worksheet, problem-based learning model, and augmented reality as a single digital learning tool, allowing students to engage in problem-solving while visualizing abstract concepts about the human excretory system using augmented reality. Second, the e-worksheets are clearly organized around the learning objectives and guide students through each stage of the problem-based learning process, making learning easier. Third, the use of QR code-based augmented reality objects increases students' engagement and has the potential to support independent learning by providing easy access to interactive visualizations using smartphones.

Although the developed product demonstrated several strengths, some limitations should be acknowledged when interpreting the findings. The developed product was specifically designed for one topic and has not yet been adapted for other biology topics. The user response evaluation was also limited to one biology teacher and six students, restricting the generalizability of the findings. Furthermore, this study focused primarily on expert validation and user response evaluation, while the effectiveness of the developed E-Worksheet in improving students' knowledge was beyond its scope. Therefore, future research is recommended to evaluate its effectiveness in broader classrooms and to adapt the product for other biology topics.

Conclusion

Based on the results of this study, it can be concluded that the problem-based e-worksheets with augmented reality are very valid for enhancing students' knowledge. The product received a score of 42 from the content expert and 44 from the media expert, both categorized as very valid. In contrast, user response evaluations received scores of 39 from the biology teacher and 263 from the students, both categorized as very good. Future research is recommended to evaluate its effectiveness through broader classroom implementation involving more diverse participants and to adapt the product for other biology topics.

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Generative AI Disclosure

The use of artificial intelligence in this manuscript is limited to language, translation, and editing to improve readability, without affecting the scientific substance, data analysis, or research interpretation.

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