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Analysis of the Validity and Readability of E-Supplement Based on Problem Based Learning Assissted Augmented Reality to Improving Students' Critical Thinking Skills

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Abstract

This study aims to analyze the validity and readability of Problem Based Learning (PBL)-based e-supplements assisted by Augmented Reality in improving students' critical thinking skills. Learning by utilizing teaching materials in the form of e-supplements integrated with PBL and Augmented Reality learning models is expected to provide a significant contribution to improving students' critical thinking skills, as well as providing new insights in developing effective digital teaching materials. This study usedthe research and development (R&D) method but only up to the small-scale trial stage. The subjects of this study were grade XI students of SMA N 6 Surakarta. The data instruments used in this study were media and material validation questionnaires and readability questionnaires. The product validity criteria are seen from the assessment of media and material expert validators, while the readability criteria are seen from the results of student response questionnaires. The results of the study showed that the validity of the product was declared very valid with an average of 94.5% for media experts and 93.7% for material experts. The readability value was considered very good with an average of 89.8%. Based on the research results obtained, it can be concluded that PBL-based e-supplement assisted by Augmented Reality is feasible and has the potential to improve students' critical thinking skills.

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INTRODUCTION

The industrial revolution 4.0 has had an impact on human life in various fields, including in the world of education. Preparing students to face the Industrial Revolution 4.0 Era is not easy. Teachers need learning strategies that can facilitate students to develop. Learning strategies affect the mindset and what students will produce in the future. The selection of learning strategies plays an important role in preparing students to face the Industrial Revolution 4.0 Era. Learning is said to be successful if students have the ability to think at a high level (critical) (Hasan et al., 2019). Critical thinking skills have been recognized as one of the important indicators that show the quality of student learning. (Wayudi, 2020). Through critical thinking, students have the ability to reason, understand and make complex decisions, understand the relationships between systems, organize, express, analyze and solve problems (Gazali & Dasna, 2023).

Critical thinking skills have a very important role in equipping students to be able to handle social, scientific and practical problems effectively in the future (Mahrunnisya, 2023). Critical thinking skills are crucial for students to survive and thrive in the rapidly changing future work environment (Koszalka et al., 2021). These 21st century skills mean the basic skills that must be obtained and mastered by students for a successful career in life, namely mastery of learning and innovation (critical, creativity, problem solving, collaboration, communication), life and career skills (responsibility, social, tolerance, productivity, adaptation) and skills in using media, information and technology.

In relation to students' critical thinking skills, what needs to be considered is how to create a learning process that directs students to carry out learning activities. To be able to learn well, a good process and motivation are also needed. Therefore, learning that can foster learning motivation is very necessary. According to research by Yan et al., (2025), learning motivation can be defined as internal and external drives that drive students to engage in learning activities, maintain effort, and achieve academic goals. However, the facts on the ground show that students' critical thinking skills were low. This is evidenced by the results of the average percentage value of students' critical thinking skills in high school of 56.28%. The results of the interview showed that biology subjects have dense and rote material, one of which is the human digestive system. This is in line with research conducted by Stefvannof et al., (2024) that the material on the human digestive system is material that has detailed properties and physiological processes involved, so that students feel bored and lack motivation to learn. The application of learning media used in delivering human digestive system material that is less varied can cause low student learning motivation (Hidayati et al., 2022).

Based on the factual information obtained, efforts to improve the quality of learning are very necessary. One effort that can be made is to develop interesting learning media innovations so that it can increase students' learning motivation and critical thinking. Biology learning requires direct experience for students to build their own experiences. Direct experience can be realized with the existence of learning media that contains guidance in carrying out learning activities and problem solving, as well as containing interesting illustrations.The innovation of developing electronic teaching materials or e-supplements was chosen because it can increase the effectiveness of learning (Alfiana & Iswari, 2022).

E-supplements have the potential to enrich conventional learning materials with interactive and interesting digital content (Hwang et al., 2020). Problem Based Learning (PBL) is a learning model that focuses on solving real problems. This method has been proven effective in improving students' critical thinking skills (Hamamous & Benjelloun, 2023). The integration of PBL in e-supplements can provide relevant context and stimulate students to think deeply. Augmented Reality (AR) is a technology that allows the integration of virtual objects into real environments in real time. The use of AR in education has shown the potential to increase student motivation and engagement in the learning process of the human digestive system (Akcayır & Akcayır, 2017).

E-supplements that combine PBL and AR have the potential to create a challenging and engaging learning environment, thereby increasing students' motivation to learn the digestive system material. The development of e-supplements that combine PBL and AR requires a careful instructional design approach. The principles of multimedia learning design need to be considered to ensure the effectiveness of the teaching materials (Halim et al., 2024). In addition, formative and summative evaluations need to be carried out to ensure that the developed e-supplements can achieve the desired learning objectives.To obtain good learning media that is in accordance with the learning objectives to be achieved in learning, the learning media must be evaluated to meas-

ure its quality, one of which is by conducting a validation test until the media is declared valid for use (Agis et al., 2021). The validity test of the material and media is also considered from student responses through small-scale trials through readability trials. Readability testing is important to be done on a text in a teaching material. By testing the level of readability, it will be useful to know to what extent the teaching material can be understood, comprehended, and is suitable for students (Nugrahani et al., 2024). Based on the background described above, it is necessary to develop teaching materials in the form of PBL-based e-supplements supported by Augmented Reality. Previous research has revealed the potential of PBL and Augmented Reality, but these studies have not been conducted in an integrated manner. The purpose of this study is to analyze the validity and readability of e-supplements in improving students' critical thinking skills.

METHOD

The validity test of e-supplement consists of media experts and material experts, namely two expert lecturers and two biology teachers. The product readability test was carried out by 20 grade XI students. The score results obtained from the validation and readability instruments are calculated using the following equation.

$$P = \frac{obtained\ score}{maximum\ score} \text{ x } 100\%$$

(Sugiyono, 2017)

The results of the media and material validation were then interpreted using the score interpretation in Table 1.

Table 1. Validity Criteria

Percentage	Criteria
81.25% < P ≤ 100%	Very valid
62.5% < P ≤ 81.25%	Valid
43.75% < P ≤ 62.5%	Quite valid
25% < P ≤ 43.75%	Not valid

(Akbar, 2013)

A product is declared feasible to use if it obtains a validity percentage of more than 62.5%, which is in the valid criteria (Akbar, 2013). Apart from being declared valid based on media and material validators, e-supplements also need to undergo a readability test to determine their level of readability. The results of the readability test were then interpreted using the score interpretation in Table 2.

Table 2. Readability Criteria

Percentage	Criteria
81.25% < P ≤ 100%	Very good
62.5% < P ≤ 81.25%	Good
43.75% < P ≤ 62.5%	Quite good
25% < P ≤ 43.75%	Not good

(Akbar, 2013)

A product is declared feasible to use if it achieves a readability percentage of more than 62.5%, which is in the good criteria (Akbar, 2013).

RESULT AND DISCUSSION

The validity of the e-supplement teaching materials was carried out by lecturers of FMIPA Semarang State University and high school biology teachers. The components of the validity of the e-supplement teaching materials include graphics, electronic media, content, presentation, and language. The aspects of graphics and electronic media are included in the media validation assessment, while the content, presentation, and language are included in the material validation assessment. The results of the media validity can be seen in Table 3.

Table 3. Media Validity

Assessment Aspect	Average (%)	Criteria
Graphics	97.3	Very valid
Electronic media	91.7	Very valid
Average	94.5	Very valid

Based on Table 3, it can be seen that the assessment results by the media validator obtained an overall average of 94.5% with a very valid category for use. The media validity test on the graphic aspect shows that the product developed has good quality in the visual appearance presented. The percentage value obtained in the graphic aspect is 97.3% which shows that the e-supplement has a good presentation, starting from the size, cover appearance, and content appearance. The size of the e-supplement teaching materials refers to the physical dimensions of this electronic teaching material. The size fit is very important to ensure comfort in using this product. In line with this, the e-supplement teaching materials can be displayed optimally on various electronic device screens such as computers, tablets, and smartphones.

The cover appearance of the e-supplement teaching materials plays an important role in attracting students' interest. This is in line with re-

search conducted by Putra & Hadiyanto (2022) which states that students tend to like attractive colors so that they can be an attraction for students to open their schemata towards teaching materials, and arouse students' curiosity about the contents of the teaching materials. Cover components that need to be considered include the appearance of layout elements, colors, illustrations, and typography. The cover of the e-supplement teaching materials contains elements of color, illustration, and typography that are displayed harmoniously and related to each other. The illustrations chosen on the e-supplement cover represent the contents in it, namely regarding the human digestive system.

Consistency of layout and layout elements in the contents of the e-supplement are harmonious. The e-supplement teaching materials are arranged by considering the placement of layout elements on the side of the e-supplement teaching materials, such as titles, subtitles, learning objectives, learning activities, material descriptions, and illustrations consistently based on patterns. The overall layout of the e-supplement content is in accordance with the needs of delivering the material and has been presented systematically and consistently. The placement of illustrations is consistent with the appropriate image captions to clarify the presentation of the material, both in form and size. The selection of images in teaching materials and the layout of images or text should be considered so that these teaching materials are of very good quality and worthy of implementation (Arini & Sudatha, 2022).

The typography of the content in the e-supplement teaching materials is presented simply so that it is easy to understand in using the e-supplement teaching materials. This includes writing subtitles, placing page numbers, and placing illustrations along with image captions. The writing of subtitles is adjusted to the hierarchy of the presentation of teaching materials. The placement of page numbers is adjusted to the pattern and layout. Illustrations and image captions are able to clarify the presentation of the material, both in form, proportional size, and attractive colors. Image captions are placed close to the illustrations with a different model than the text font, so that they can clarify students' understanding in interpreting the illustration images.

The results of the validation of the electronic media aspect show that the e-supplement of teaching materials can be operated well. The electronic media aspect gets a percentage of 91.7% with a very valid category which shows that the e-supplement of teaching materials is not only visually effective, but also functional. This is supported by the fact that the e-supplement of teaching materials is easy to operate, especially the navigation button feature. In compiling electronic teaching materials, one thing that needs to be considered is the ease of operating the navigation buttons (Farhana et al., 2021) Navigation buttons have an important role and are one of the main characteristics of interactive electronic learning media. The e-supplement of teaching materials that are developed can be accessed repeatedly with various electronic devices. The advantage of using digital or information technology-based teaching materials is easy access anytime and anywhere (Trinaldi et al., 2022).

The media contained in the e-supplement of teaching materials such as images, audio, and video can be displayed clearly so that they can help clarify the delivery of material in the e-supplement of teaching materials. E-supplement teaching materials have high accessibility, so they are easy to use. Digital teaching materials should have an easy way to access them because there is a link address that makes it easy for students to open digital teaching materials (Nisa et al., 2024). The developed e-supplement of teaching materials contains the syntax of the PBL learning model and is equipped with illustrations of human digestive organs in the form of Augmented Reality that can be accessed through a QR code scan. The appearance of the e-supplement of teaching materials is presented in Figure 1.

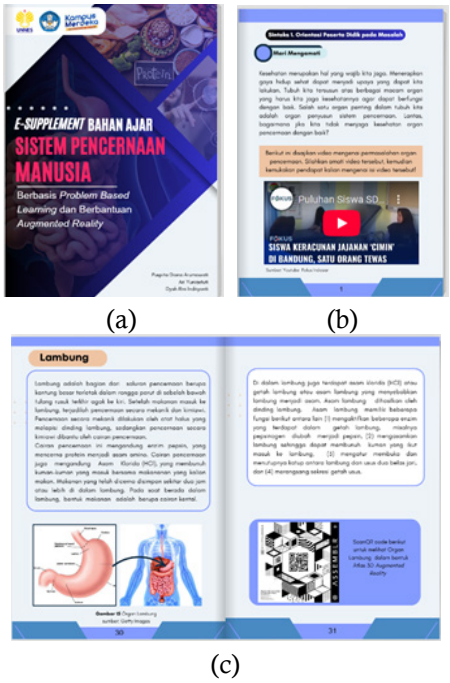

Figure 1. (a) front cover; (b) PBL sintaks; (c) material page and Augmented Reality QR code

The e-supplement teaching material products that have been developed are then validated by material experts. The results of the material validation assessment can be seen in Table 4.

Table 4. Material Validity

Assesments Aspect	Average (%)	Criteria
Content	96	Very valid
Presentation	92	Very valid
Linguistics	93	Very valid
Average	93.7	Very valid

Based on Table 4., it can be seen that the assessment results by the material validator obtained an overall average of 93.7% with a very valid category for use. The validity test of the material on the content aspect shows that the e-supplement teaching materials has accurate material, the material is in accordance with the development of science and technology, can encourage students' curiosity, and presents examples of problems that are relevant to everyday life. The content aspect gets a percentage of 96% with a very valid category. The completeness of the content components in the preparation of learning media must be considered in order to meet the standards and produce better products that are worthy of being implemented in the learning process (Sarip et al., 2022).

The results of the validity of the material on the presentation aspect show that the e-supplement teaching materials developed already contain material on the human digestive system phase F. The presentation aspect gets a percentage of 91% with a very valid category.This shows that the e-supplement teaching materials developed have a consistent presentation system and contextual presentation of problems, so that they can attract students' interest. The examples used are cases that occur in the surrounding environment (conceptual), because students will find it easier to understand the material if the examples used are in the real world compared to abstract examples (Nazara et al., 2022).

This e-supplement teaching material contains Problem Based Learning (PBL) syntax that can develop students' critical thinking skills. The integration of PBL in learning is recognized as an effective pedagogical approach that encourages students to actively participate in their learning by solving real-world problems (Munarun, 2025).

The presentation of e-supplement material containing PBL syntax is packaged interactively and participatively. This can be seen from the use of convergent media, namely combining audio and visuals. The presentation of illustrations of e-supplement teaching materials is equipped with Augmented Reality in the form of human digestive system organs that can be accessed by scanning a QR code or with the link provided. This organ illustration was developed with the AssemblrEdu application. The results of the validity of the material in the linguistic aspect show that the e-supplement teaching material is compiled using easy-to-understand language. The linguistic aspect gets a percentage of 93% with a very valid category. This shows that the e-supplement teaching material contains sentences that are straightforward and communicative so that they are easy for students to understand. The use of communicative language and in accordance with the correct rules aims to ensure that the meaning contained in the writing can be conveyed to the reader (Asri & Dwiningsih, 2022). The sentences used in teaching materials should be effective sentences and the language used should not only refer to language standards, but also refer to language communicativeness (Rahmayantis et al., 2024).

After conducting the validity test, this study also tested the e-supplement on a small scale which aims to determine the readability of the e-supplement that has been made before being implemented in a large-scale trial. The small-scale trial was conducted on 20 grade XI students. Data on the results of small-scale student responses can be seen in Table 5.

Table 5. The Result of Readability Test

Assessment Aspect	Average (%)	Criteria
Instructional Media	88.7	Verry good
Material	89.7	Verry good
Benefit	91.3	Verry good
Average	89.8	Verry good

Based on Table 5, it can be seen that students' responses to the e-supplement of teaching materials showed positive results or good criteria based on the three indicators by obtaining an overall average assessment of 90.6%. Trialing teaching materials on students can help researchers determine which parts need to be revised, so that teaching materials can be produced that are easy for students to understand (Annisa et al., 2020). With the readability test, researchers can get an idea of how the teaching materials are used in learning by students. In line with Zainurrahman et al., (2024) that the readability of a teaching material affects the success of students in understanding the material at an optimal reading speed. If

the text presented has a low level of readability or is difficult to understand, students tend to read slowly and repeatedly in order to understand the contents of the material well.The results of the study showed positive responses to all aspects of the assessment, including learning media, materials, and benefits. Students feel helped by the e-supplement of teaching materials because they are easy to access, have an attractive appearance, the material presented contains problems. The problems presented are also relevant and in accordance with those found around students.

Most students stated that with PBL, it can stimulate students to learn to solve the problems that have been provided. PBL learning can improve students' problem solving abilities (Ningsih et al., 2023). This is because the problems presented can be found in the surrounding environment. The addition of the Augmented Reality feature which

can display illustrations of human digestive organs in 3D also increases students' motivation to learn. This is in line with the research results obtained by Ziden et al., (2022) that learning using Augmented Reality can increase students' learning motivation. Students are very enthusiastic about accessing the Augmented Reality feature which can be accessed by scanning the QR code or via the link provided. With the percentage of student responses obtained in the very good category, the e-supplement teaching materials developed can be used in large-scale tests.

CONCLUSION

Based on the research results, the e-supplement of teaching materials based on PBL assisted by Augmented Reality that was developed was declared very valid based on the validity test of media experts with an average percentage of 94.4% and material experts of 93.7%. The results of the readability test obtained an average percentage of 89.8% with a very good criteria. Based on the research results obtained, it can be concluded that the e-supplement based on PBL assisted by Augmented Reality is feasible and has the potential to improve students' critical thinking skills.

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