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All-in-One E-Book Development in Proposing Automatic Critical Thinking Skill Assessments

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ABSTRACT

Many e-books have been developed to learn specific physics concepts with comprehensive features. This means that e-books not only contain the primary components such as animations, videos, and illustrations but also many of them are equipped with virtual experiments. However, these e-books often need more integration of the assessment process, which is an important part of the learning experience. To address this, an all-in-one e-book concept called Aneboo has been developed. Aneboo includes interactive physics illustrations, virtual laboratories, worksheets, videos, and critical thinking assessments, all built into a single media platform for learning the concept of static fluids in junior high school. Additionally, Aneboo examines its function in automatically assessing critical thinking skills. The development of Aneboo follows the Hannafin & Peck development model, which includes needs assessment, design and development, implementation, and identification of similarities between manual and automatic scoring. As a result, Aneboo has achieved a validation score ranging from 95% to 97%. Moreover, Aneboo has the potential to automatically assess critical thinking skills through the similarity check feature embedded in the media.

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INTRODUCTION

All-in-One E-Book as the Learning Media

The learning outcome of the 21st century focuses on the process of gaining information, solving contextual problems, and developing adaptability in different workplaces (Van Laar et al., 2020). According to educational experts and researchers, 21st-century learning skills encompass six competencies known as the 6C's: critical thinking, collaboration, communication, creativity, citizenship/culture, and character building (Shabrina & Astuti, 2022). Moreover, critical thinking skills play a significant role in the majority of 21st-century learning processes, particularly information processing and problem-solving, as they involve the ability to seek reasons, truth, and evidence-based on existing knowledge (Gambrill, 2018; Negoro et al., 2020; Rolfe & Freshwater, 2020). In the Indonesian curriculum, students are required to apply physics concepts effectively, and the use of critical thinking skills supports their application of these concepts in real-life situations.

Critical thinking skills consist of six fundamental abilities: clarifying, analysing, interpreting, making inferences, evaluating, and self-regulating (Lu & Nguyen, 2022; Ali-Abadi et al., 2020; Lin & Chiu, 2020). These basic skills ensure that students possess the necessary critical thinking abilities to avoid misinterpretation. These six abilities reflect students' simplest behaviours in supporting critical thinking skills, which serve as the main skill assessed in this study. For instance, if a student can formulate a research question that represents a real-life problem, they

can clarify the situation and apply problem-solving through the scientific method. When students correctly formulate such questions, their final score in critical thinking skills increases. This method is used to automate the scoring of critical thinking in this media.

One of the physics concepts that remains abstract is static fluid (Arsyad et al., 2020). For example, while the Archimedes force is easy to feel, it can be challenging to visualise for students who have yet to encounter this phenomenon before. The same difficulty arises in understanding the mechanism of the Pascal tool, where the input force is significantly less than the output force. To ensure a strong understanding of Pascal's law and decrease abstraction, illustrations must be provided to students that closely resemble real-life situations, allowing for full user control variables. Therefore, developing an e-book that gives visualisation is appropriate for this concept.

As a learning medium, interactive e-books have been widely used in the learning process (Harjono et al., 2020; Saripudin et al., 2022; Lim et al., 2021). These e-books incorporate pictures, videos, and animations, along with exercises to assess students' understanding of specific physics concepts. They serve as learning sources to enhance students' motivation during the learning process. Furthermore, the integration of virtual laboratories in interactive e-books (Ramadhani & Khusniati, 2022; Adam & Suprapto, 2019) has introduced new possibilities. With the inclusion of a virtual laboratory, e-books not only serve as learning sources but also encompass the entire learning process in many educational approaches. For instance, in guided inquiry, stages such as problem identification, formulation of hypotheses, data collection, data analysis, and conclusion can all be facilitated through an e-book when accompanied by a virtual laboratory. Students can identify problems through actual videos in the media, formulate hypotheses within the media, collect data through media resources, analyse the data based on questions in worksheets within the press, and finally, draw conclusions from the experiment process within the media.

The concept of an all-in-one media arises from the seamless integration of multiple activities within a single medium. Thus, the media developed in this study is referred to as an All-in-One E-Book or Aneboo. This media not only incorporates pictures, videos, and interactive animations but also includes apperception videos, interesting concept explanations, virtual laboratories, and student worksheets within each subchapter on static fluids. Given the comprehensive nature of this learning approach, it is crucial to ensure that the assessment process has a positive impact on students. Therefore, this media will propose an automated assessment process for critical thinking skills, emphasising its importance.

Automation in Critical Thinking Skill Assessments

Automation is a necessity in current society, serving various human needs. Including educational purposes, the automatic assessment process assists teachers in making prompt decisions regarding student engagement. This streamlines the process, making it faster, more accurate, and user-friendly. Automatic assessment has long been employed in conceptual understanding within the educational system. In certain exams, students can view their results upon clicking the finish button (Andreatos et al., 2022; Kusairi et al., 2019; Astalini et al., 2019). However, assessing other skills presents its challenges. Essay questions, particularly those about critical thinking skills, require extensive effort and a comprehensive evaluation of essential competencies. Recently, the automation of critical thinking assessment has been explored in a discussion forum (Ahmad et al., 2022; Maryuningsih, 2020). For educational purposes, prototypes have been developed to automate critical thinking assessments, with multiple vendors working towards solving this problem (Antonella et al., 2020). The design of automated critical thinking assessment is illustrated in Figure 1. The prototype consists of four modules responsible for generating automatic assessments. It begins with the authentication manager, which ensures the user is human and does not affect the server. Next, an input module is utilised to present questions and collect answers through the interface. The module contains questions related to critical thinking skills and the corresponding answer choices. Once the user enters their response, it undergoes evaluation by both manual and automatic evaluators. The manual evaluator, typically a teacher, scores each question based on predefined criteria. The results are then stored in an evaluation

database as the teachers' data answers. The automatic evaluator relies on two tools for its function. The language tool scores the language structure, while the POS Tagger assesses the similarity between the user's answer and the relevant concepts. The POS Tagger extracts all nouns and employs an algorithm to compare them with the ideas mentioned in the question. Finally, the user receives the response to their answer, after which the manual evaluator concludes the scoring process.

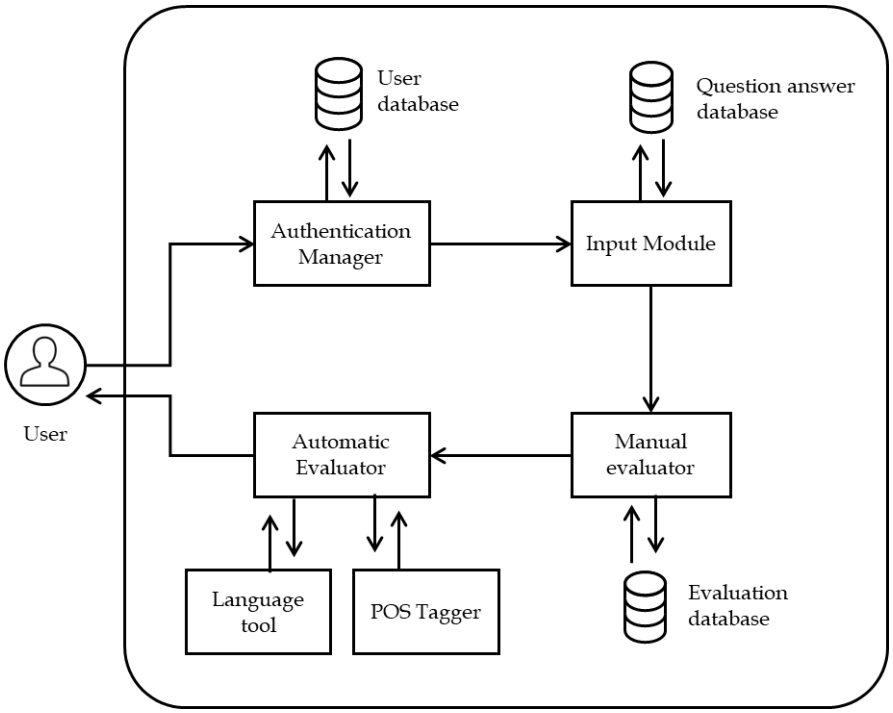


Figure 1. Four modules on automatic assessment of critical thinking

This study develops an all-in-one e-book that includes a virtual laboratory, videos, content explanations, student worksheets, exercises, and examples and integrates critical thinking skill assessment. Due to its specifications, this media is referred to as Aneboo, an acronym for the all-in-one e-book. The validity of the media is included in this study to evaluate its suitability for use. This media will be used as a comprehensive package that supports various activities in innovative learning. Students can obtain data from this media and assess their critical thinking skills. Additionally, another purpose of Aneboo's development is to explore the use of a similarity feature as an automatic tool for assessing critical thinking skills.

RESEARCH METHOD

Development Design

This research was conducted using the Hannafin & Peck development model. This instructional design consists of three main processes: the needs assessment stage, the design stage, and the development and implementation stage (Peck & Hannafin, 1993). In the final stage, experts and lecturers validate the media and make revisions if it is deemed inappropriate in terms of concept or interface design. Additionally, the other stages involve an evaluation and revision process. Moreover, this media will undergo limited testing with random students to assess the improvement in critical thinking skills, particularly in the automation feature of critical thinking assessment. These three main stages encompass the entire process of media development, as depicted in Figure 2.

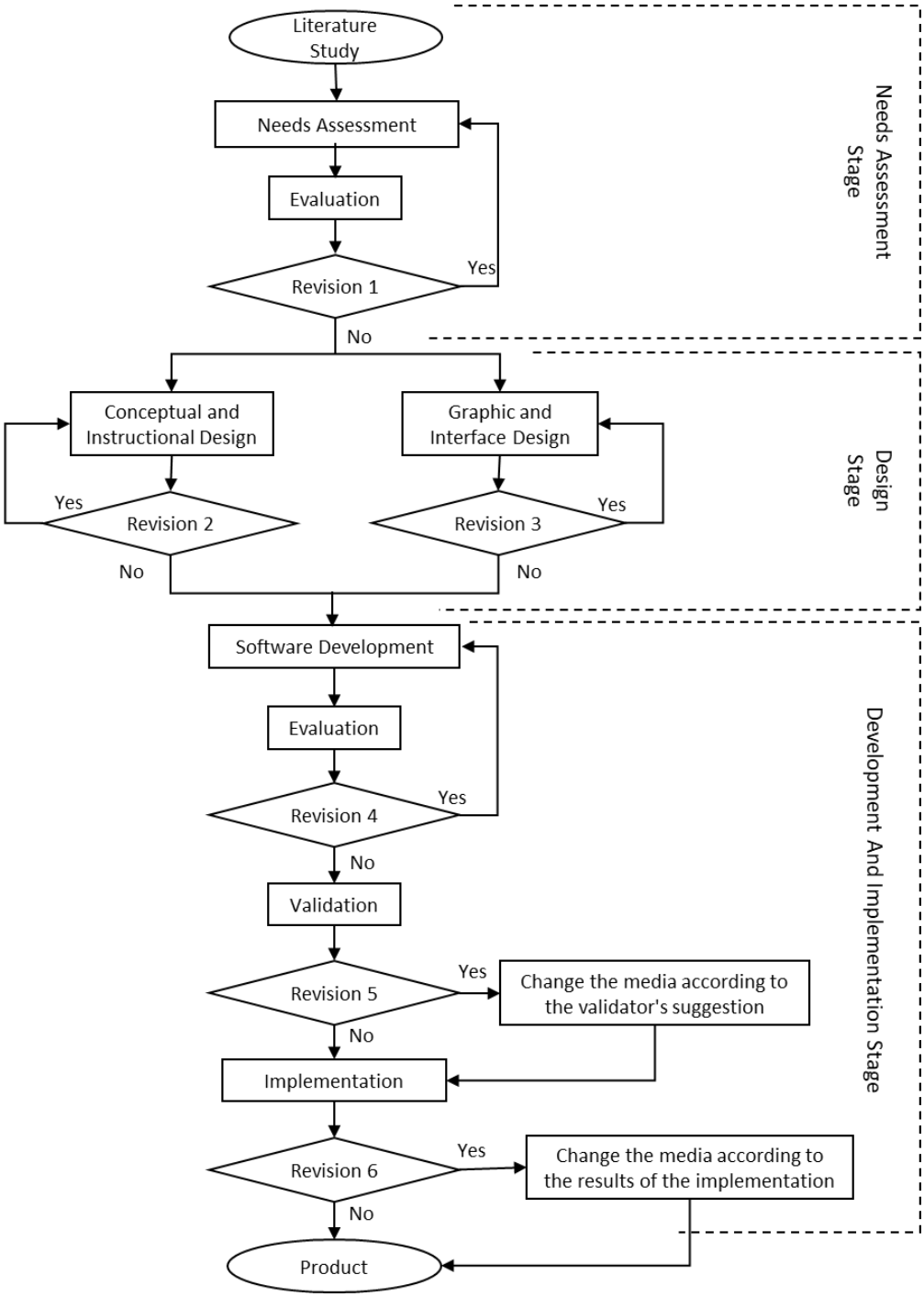


Figure 2. Development stage on Aneboo

Data Analysis

To ensure that the e-book is an effective learning medium, the validation process is conducted during the Development and Implementation stage. This process involves experts in learning media and physics and teachers who evaluate both the content and interface of the media. The validation scores are interpreted to determine the media's validity, with a score of 60% and above considered valid (Riduwan, 2016). This categorisation indicates the suitability of the media for classroom use as a learning medium. Following the validation process, the press underwent revisions and was implemented with students in the classroom. Fifteen randomly selected students from a junior high school in Batu, East Java, participated in this exclusive test. Additionally, observations and interviews were conducted as necessary to ensure that the students answered the research questions accurately.

RESULTS AND DISCUSSION

Needs Assessment Stage

At the needs assessment stage, two main processes must be carried out: literature study and needs identification. In the literature study, a review was conducted based on the conditions in the school. The e-book should be applicable in a learning environment and have a positive impact on enhancing critical thinking skills, which are essential in 21st-century learning. Moreover, the use of information technology should support students' critical thinking abilities. The key characteristic of the e-book is its utilisation of technology, a phenomenon that is prevalent in society. However, various literature sources indicate that media developers often need to pay more attention to students' thinking processes. The use of technology-based media can trigger cognitive load, especially if the content is presented randomly, forcing students to process excessive information. To address this issue, the development focuses on reducing cognitive load by creating an interface design based on previous research recommendations.

After the literature study, the needs assessment process should focus on understanding the students who will use the media, taking into account their specific conditions and cultural background. Initially, problem identification is conducted by assessing the actual learning situation in the classroom. This information is obtained through unstructured interviews with relevant teachers and comprehensive classroom observations. Through this process, it was found that the learning activities were aligned with the national curriculum, with a focus on the basic competency of explaining the concept of pressure and its application in everyday life. Additionally, other competency skills can be effectively addressed virtually through this e-book, such as presenting experimental data to investigate hydrostatic pressure at different depths and the concept of buoyancy force. Ultimately, the findings from this needs assessment are related to the minimum competency required to develop the e-book.

Design Stage

As part of the development stage of this media, the design stage encompasses both Conceptual and Interface design. The conceptual design focuses on the content of the media and how it can be effectively utilised in the learning process. The key aspects of the conceptual and instructional design are outlined below.

- The content in this media contains activities that support critical thinking skills. Therefore, the media is integrated into the critical thinking assessment, which is the main objective of the learning process in this study.
- The media includes both a hands-on aspect and a mind-on aspect, which are key features of technology-based learning media. The hands-on aspect focuses on the student's performance in the experimental process.
- The integration of e-books with virtual laboratories enhances the user experience. This media includes three virtual laboratories covering the sub-materials of hydrostatic pressure in the U-pipe, the hydraulic system for Pascal's law, and the buoyant force for Archimedes' law.
- The media provides facilities to train students' critical thinking skills.
- The learning objectives are aligned with the learning content, which includes materials on the basic concepts of pressure, hydrostatic pressure, Pascal's law, and Archimedes' law.
- The integration of the media with the assessment is seamless. Therefore, students receive feedback after they have finished answering the questions. This feedback is displayed in the e-book at the end of the assessment process.

Graphic and interface design involves the visual design of the e-book and supports the conceptual and instructional design (VanTassel & Baska, 2021). The interface design chosen is based on references from the Hannafin & Peck models and popular e-books that have been developed. The selected interface design prioritises the main content, which occupies most of the view, and includes several navigation buttons grouped by function located at the bottom of the

interface. Before that, the media should initially display general information and provide user instructions.

Development and Implementation Stage

At this stage, the conceptual and interface design is implemented into the software media. The final product has the file extension .exe for Windows and .apk for Android. Considering the widespread use of Android, it is expected that the media will reach a larger number of students. The number of Android users in Indonesia has increased due to the impact of the pandemic (Rachmawati et al., 2021). There has been a 25% increase in the use of this device compared to the previous quarter in 2020. Taking advantage of this opportunity, the media is developed as a mobile application using Adobe Animate CC with ActionScript 3.0. This program was chosen for its user-friendly nature and ability to produce media with smaller file sizes compared to other application builders. Additionally, it allows for troubleshooting specific pages within the e-book by making separations on each page.

After completing the software development step, the first version of the media is produced, which then undergoes multiple revisions in various stages. The main features of Aneboo are described in the profile below:

- Introduction video to build student motivation. At the beginning of each sub-chapter, there is a video related to the concept that showcases a real-life phenomenon. Through this video, users can observe the various parts and understand how these phenomena connect to the concept of physics. Students are encouraged to formulate questions based on the video if needed.
- Comprehensive concept explanation with interactive animations. Each sub-content of this media provides clear and easy-to-understand explanations, accompanied by interactive illustrations that enhance understanding. This is especially beneficial for abstract physics concepts, such as the force in submerged objects, the internal workings of a hydraulic pump, and the behaviour of different liquids in a U-pipe.
- Concept partitioning and keyword notes to reduce cognitive load. Given the abundance of information presented in the e-book, it is crucial to manage cognitive load. Therefore, the media development follows the recommendation of concept partitioning and provides keyword notes to help users better process and remember the information.
- Virtual laboratory support for each sub-concept. In the topic of static fluid, which includes hydrostatic pressure, Pascal's law, and Archimedes' law, the media comprises three virtual laboratories corresponding to each sub-concept. One of the virtual laboratories demonstrating Archimedes' law is shown in Figure 3.
- Student's worksheet for data collection instructions. Additionally, students can directly answer questions within the media and save their responses to an external file.
- Exercises with examples for each sub-concept. The exercises not only include calculation problems but also conceptual problems aimed at training students' critical thinking skills before the final assessment of those skills.
- A mini-game featuring Pascal's and Archimedes' laws. This mini-game is integrated into Aneboo and presents an illustrated scenario with props related to Pascal's and Archimedes' laws. If a user can locate these props, a video providing further information related to the prop will appear.
- Online and offline integration of critical thinking assessment as the main focus of student outcomes. As the primary objective of this media is to automate the assessment of critical thinking skills, this feature is highlighted on the final page of the media.

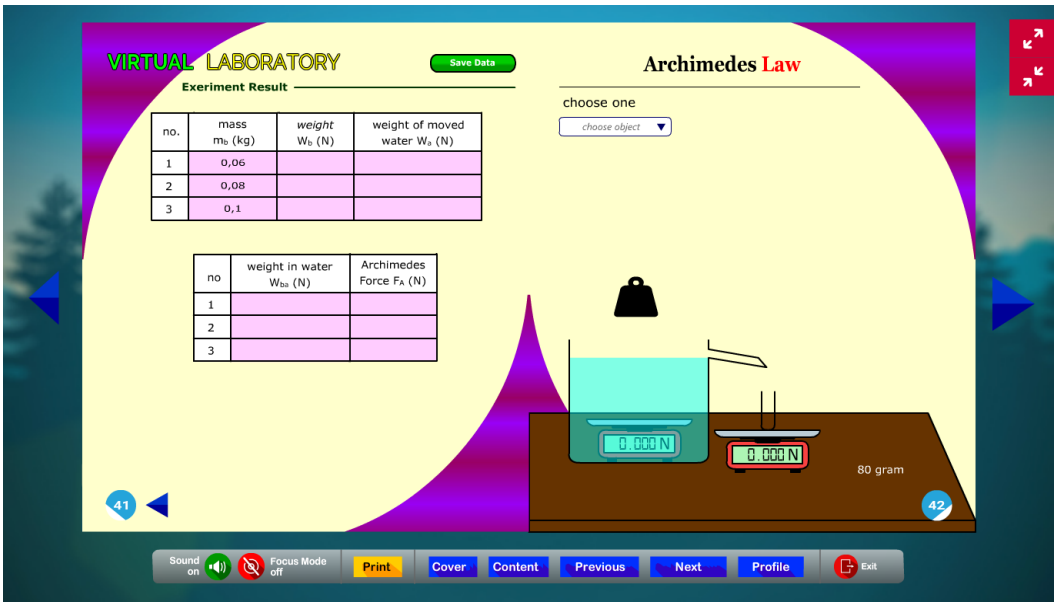


Figure 3. Media display on Buoyant Force Simulator and student's worksheet

After the software development, the media needs validation to ensure its feasibility. This validation process includes assessing both the media and content aspects, which are the main components of this media. The validation instrument consists of two categories: media and content. The media category comprises 30 statements that assess usability, effectiveness, language, sound, buttons, and user interface. Meanwhile, the content category includes 43 statements that evaluate the virtual laboratory in learning, basic competencies, indicators, experiments conducted in the virtual laboratory, concept suitability, concept compatibility, ease of understanding concepts, compatibility of images/videos/animations, competency compatibility, and worksheets. This media undergoes validation by experts and teachers who are practitioners to gain a better understanding of how to implement this media in the classroom. The validation process may lead to revisions to ensure the final version has minimal mistakes and technical issues. The percentage of the validation scores is presented in Figure 4.

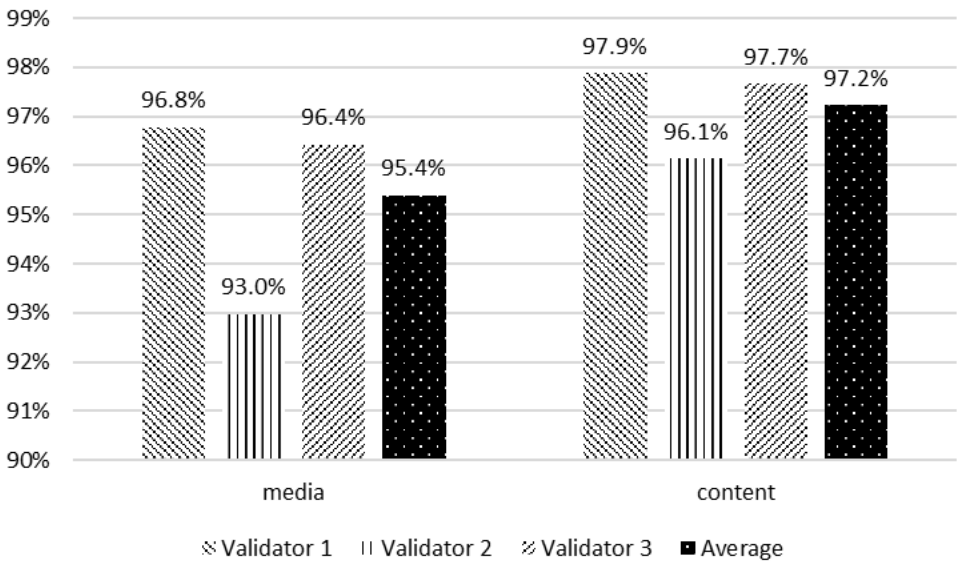


Figure 4. Percentage of validation for media and content aspects

Based on Figure 4, the validation scores for every aspect exceed 90%, indicating that all validators agreed that the all-in-one e-book falls into the very good category (Riduwan, 2016). In

other words, this media is highly valid for use in the next step of the implementation process. However, achieving this high percentage score required several revisions. Revisions are necessary as a quality control measure for research or future appropriate use (Papp, 2018). Some of the issues that were addressed include printing function errors in the previous version, the addition of narration in the apperception video, the inclusion of density explanation before Archimedes' law as a prerequisite concept, and fixing the play button error in the video from the previous version.

While the validation score yielded positive results, it is important to consider the potential negative impact of student experiences on motivation (Esra & Sevilen, 2021). The cognitive load should also be investigated when using this e-book in the learning process, as it may potentially decrease students' motivation (Yorganci, 2022; Mutlu-Bayraktar et al., 2019). The simultaneous presentation of concepts in the media can trigger cognitive load. Additionally, there are some limitations to this particular study. Firstly, this research used simple random grouping to determine the groups, which means students had to assess their learning style without assistance based on their learning preferences (Moser & Zumbach, 2018; Wanna & de Jesus Simões, 2021; Chang-Tik, 2018). Therefore, the learning media used by students in this study may not be suitable for their learning styles or needs. Secondly, further experimental settings need to be conducted to measure the effect of this media on improving critical thinking skills.

Throughout this study, several recommendations have emerged from the findings of the entire process. Firstly, this e-book can be expanded to cover other physics concepts across different school levels in Indonesia. All the concepts presented in this e-book can be developed into separate chapters tailored to the output requirements of institutions or schools. As experts suggest, this e-book can serve as an alternative way to conduct experiments without requiring laboratory props.

All-in-One E-Book for Automatic Critical Thinking Skill Assessments

As for the automatic assessment of critical thinking skills, the use of similarity has been initiated in previous research (Antonella et al., 2020). The automatic aspect is achieved through the use of a POS Tagger, which scores the relevance of students' answers to the concepts. The POS Tagger is an external website that initially extracts all nouns from the answer (Chiche & Yitagesu, 2022). This set of nouns is then compared to the concepts using an algorithm. In this media, Aneboo completes the assessment part by coding a response generator based on the student's answer. In Aneboo, the student's answer is processed by extracting all words and removing conjunctions and affixes. The extracted words are then compared to the main terms associated with each question's concept.

As a complete system, Aneboo also includes an authentication manager and input module. This ensures that the media can only be accessed by trusted users, such as teachers who have a unique code as a token. Additionally, the storage memory utilises the student's device and works offline, eliminating the need for a dedicated server to operate this automation system. The input module serves as the user interface, allowing teachers to easily edit questions without requiring coding expertise.

To evaluate the automatic assessment of critical thinking, a test was conducted with 15 randomly selected students who had undergone a learning process using the media. These students were from junior high school in Batu, East Java, and were deemed appropriate for the media's profile. The test consisted of ten questions, and the scores were converted into percentages. The teacher manually scored the answers based on the key concepts and rubric, while the automatic scoring followed the same order as the manual scores. The comparison between the manual and automatic scoring is depicted in Figure 5.

Based on the graph in Figure 5, there is a proportional relationship between the manual and automatic scores. Higher manual scores correspond to higher automatic scores, with a linear regression gradient value approximating one. This indicates that an increase in manual scores leads to a corresponding rise in automatic scores, with a data consistency of 95.44%. However,

the ranges of the two methods differ significantly, as the automatic scores tend to be lower in percentage compared to the manual scores. This discrepancy arises from the difference in scoring approaches. Automatic scoring focuses on words related to the concept, while manual scoring considers factors beyond concept appropriateness. Therefore, manual scoring is still necessary to ensure the accuracy of students' answers (Antonella et al., 2020).

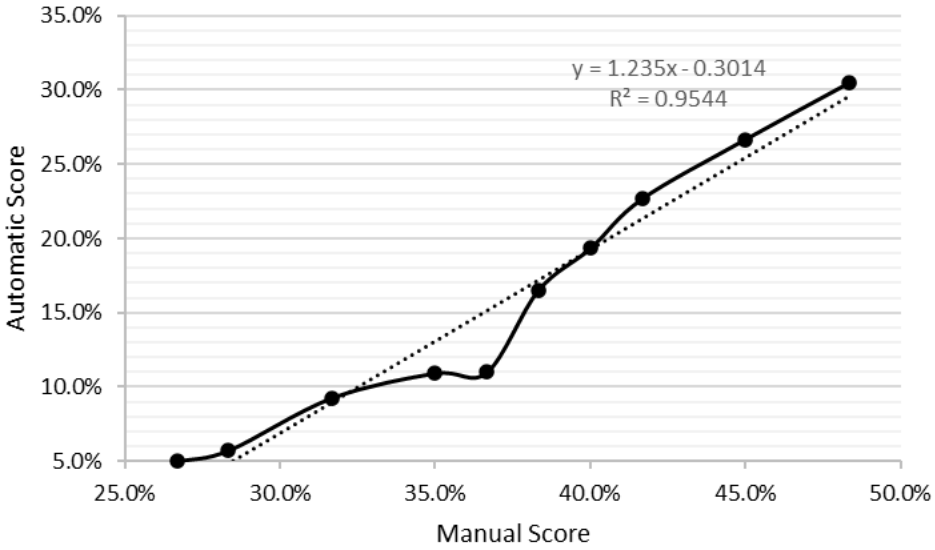


Figure 5. Percentage of validation for media and content aspects

Aneboo can be used as an automatic critical thinking assessment tool, demonstrating a linear relationship between manual and automatic scoring. This finding aligns with previous research on basic knowledge, which highlights the close similarity between manual scoring and similarity testing of answers (Trifunović et al., 2023; Thamrin et al., 2021; Süzen et al., 2020). However, further improvements are needed in its application. It requires a broader range of participants to gather more comprehensive information. Subsequently, these promising results can be utilised in the learning process to assess students' critical thinking skills. Teachers can employ it as a formative assessment tool for critical thinking and make necessary adjustments to the learning environment accordingly.

CONCLUSION

An all-in-one e-book (Aneboo) is a comprehensive media needed for the most innovative learning methods. This type of media represents an improvement over interactive e-books by incorporating virtual laboratories. The key features of this media include apperception videos, concept explanations in each section, virtual laboratories, student worksheets, exercises, and integrated assessments targeting specific skills. Furthermore, in this research, the validation process of the new era of e-books reached 96%, placing it in the "very good" category. This means that Aneboo is a valid learning medium for junior high school students, specifically for understanding static fluid concepts. Moreover, Aneboo has rapidly evolved to serve not only as a learning resource but also as an automatic critical thinking skills assessment tool. This media can be utilised to obtain faster feedback on students' critical thinking abilities. The built-in similarity function in this e-book generates patterns similar to those in manual assessments for the same questions. It can be analysed more by higher participants to assess critical thinking levels automatically.

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