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Development of an Augmented Reality-Enhanced Interactive E-Module on the Polyhedron Topic to Maximize Learning Styles

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ABSTRACT

When studying polyhedron, learning sources that are predominantly verbalistic can lead to difficulties in understanding the concept. Learners have diverse learning preferences for absorbing and processing information. Therefore, learning media is required to provide multimodal learning representations that encompass text, audio, video, animations, images, and augmented reality to support students' diverse learning preferences. This study employs a research and development (R&D) design based on the Richey and Klein model, which is limited to the development and evaluation phases without field testing. Throughout the development process, the e-module prototype was subjected to a rigorous validation process involving three content specialists and three media experts. The main validation results indicated that every element produced in the polyhedron e-module was highly valid, achieving an average suitability rating of 93.5% from content experts and a highly suitable level from media experts. The results show how integrated multimedia and augmented reality components map to visual, auditory, and kinesthetic modalities. These findings imply that the validated e-module has the potential to support student engagement and spatial comprehension of geometric concepts, offering valuable guidance for enhancing digital educational resources in STEM instruction.

Keywords: augmented reality, flipbook, interactive e-module, learning style, research and development.

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Introduction

The transformation of life in the era of the 4.0 industrial revolution compels humans adapt to the use of technology. This era has a significant impact across various fields in enhancing the quality of human resources, including education (Riyanto et al., 2020). Education contributes to maximizing human potential in terms of physical, mental, and character aspects (Muhsyanur et al., 2021). The role of technology leads to a paradigm shift in interactive and flexible teaching, enabling students to acquire knowledge easily and effectively (Lawrence & Tar, 2018; Raja & Nagasubramani, 2018). Innovations that teachers can implement in technology-integrated learning activities include instructional media (Murtikusuma et al., 2019). The selection of instructional media should be based on students' needs, allowing teachers to make informed decisions. Consistent with research (Baya'a et al., 2019), it is recommended that teachers consider technological characteristics and factors to enhance the effectiveness of teaching practices.

Mathematics is one of the disciplines that encourages humans to think critically, logically, and systematically to address real-world problems. Students who grasp mathematical concepts well can apply their learning experiences to simple real-life activities(Saha et al., 2020). Geometry is one of the branches that requires students to communicate, express, and analyze geometric objects (Serin, 2018). Geometry instruction cannot rely solely on lectures(Wardani et al., 2019), but requires media to visualize realistic three-dimensional geometric objects (Safaati & Yunianta, 2022). If this action is neglected, students will face difficulties in understanding concepts and solving problems in the context of polyhedron (Hasibuan, 2018), (Fanoni & Suryowati, 2022), (Safitri, 2017). Thus, students studying geometry require a learning resource medium that can accommodate their learning needs. Developing technology that aligns with students' preferences in learning could contribute to overcoming learning problems(Riyanto et al., 2020).

Semi-structured interviews with mathematics teachers at SMP Negeri 152 Jakarta (a public junior high school in Indonesia) revealed that instructional resources remain predominantly traditional, relying heavily on printed books, teacher-centered lectures, and static visuals, while lacking interactive components such as multimedia or augmented reality (Hasibuan, 2018; Mulia, 2019). This conventional approach poses difficulties in catering to diverse learning styles, particularly in helping students grasp polyhedron concepts. This aligns with the research (Indraningtias & Wijaya, 2017)indicating that many schools in Indonesia overlook students' needs, and the presented instructions remaining standardized. Books with the same instructions, known as a "one style for all" approach, fail to accommodate students' learning styles hindering optimal performance (Ditasona, 2017; El-Sabagh, 2021). Each perspective of information presented by the teacher when explaining geometric shapes evokes different imagination for students. Students encounter difficulties in providing definitions for geometric objects if the textbook used only focuses on explaining area measurement formulas(Tossavainen et al., 2017). Learning media should be designed to encompass instructional materials for each learning style preference. Ditasona (2017) states that the paradigm teachers need to change is not how to teach, but how to provide the best way for students to learn. Furthermore, the teaching provided to students must adhere to differentiated instruction. Tomlinson (Tomlinson, 2017) categorizes two ways of thinking in differentiated learning: (1) Focusing on what the learners need to know; (2) Giving learners access to the content. Learning media featuring interactive elements such as animations, audio, video, and images complete students' learning needs(Wahidah et al., 2020). The use of learning media that supports these features through an e-module oriented towards learning styles, with the teacher playing the role of both instructor and facilitator (Suyatna, 2020).

The e-module is an interactive multimedia-based teaching material that can be used independently and flexibly by students (Ayu Made Manu Okta Priantini & Luh Gede Karang Widiastuti, 2021; Lumbantoruan & Ditasona, 2024). Furthermore, its use follows a learning pattern, enabling students to learn individually. The e-module has interface criteria that suggest multimedia presentation should include animations, images, verbal elements, video, audio, etc. (Alessi & Trollip, 2001). An interactive e-module includes features oriented toward learning styles. Learning style is defined as students' preference or approach in learning according to their characteristics to master the material (Fleming & Baume, 2006; Strauss, 2013). Each person has different learning preferences to learn (Felder & Brent, 2005). In this research, learning styles adopt the classification of Deporter and Henarcki categorized into three types: visual, auditory, and kinesthetic (DePorter & Hernacki, 2007). E-module oriented toward students' learning styles not only focuses on a single learning style, but also accommodates all students' learning styles (Mulia, 2019). E-modules oriented toward learning styles emphasize diverse features and structured component studies to support students' diverse learning preferences (Fatmianeri et al., 2021). One of the characteristics of e-modules is user friendly, where each material provides the best opportunity based on students' learning styles (Kosasih, 2021).

One of the software programs that can be used to develop an interactive e-module is Flip PDF Professional. The development of an e-module using Flip PDF Professional on polyhedron material can assist students in comprehending mathematical concepts and increasing their learning interest (Elvadiningsih & Jazwinarti, 2021). Moreover, Flip PDF Professional is a user-friendly interactive media design tool that does not require HTML programming skills, making it accessible for novice developers (Seruni et al., 2019). In addition to flipbook-based interactivity, augmented reality can be integrated into an e-module to strengthen students' spatial visualization. Augmented reality enables the integration of real and virtual objects, images, and information in three-dimensional spatial structures, thereby helping students understand the components and characteristics of geometric objects more concretely (Dinayusadewi & Agustika, 2020; Majeed & ALRikabi, 2022; Simbolon et al., 2025). Previous studies have developed learning-style-oriented e-modules and reported that such products were valid, practical, and effective for learning (Fajarwati, 2022; Fatmianeri et al., 2021; Mertayasa, 2019; Murtadho et al., 2022). However, these studies have generally focused on e-module development or learning-style accommodation without explicitly integrating augmented reality as a spatial visualization feature for polyhedron learning. Likewise, prior AR-based geometry studies have mainly emphasized visualization and conceptual understanding, but have not specifically mapped e-module features to visual, auditory, and kinesthetic learning preferences within a single interactive flipbook-based learning package. Therefore, this study contributes new value by developing and validating an augmented reality-enhanced interactive e-module on polyhedron that combines text, images, audio, video, animation, project activities, and AR features to support students' diverse learning preferences in a more integrated manner.

Through the phenomenon of challenges and potentials discussed earlier, this study aims to develop and validate an augmented reality-enhanced interactive e-module on polyhedron topics that supports students' diverse learning. The developed e-module will incorporate diverse features using Flip PDF Professional, ensuring information delivery caters to various learning preferences. Embedded features encompass text, audio, video, animations, images, andaugmented reality. Thus, the purpose of this research is to develop a valid and practically suitable AR-enhanced interactive polyhedron e-module that supports students' diverse learning preferences.

Methods

This study employed a research and development (R&D) approach, in which the researcher developed and validated an educational product (Sugiyono, 2017). The development procedure was adapted from the Richey and Klein model, which consists of three main stages: research, development, and evaluation (Richey & Klein, 2014). In this study, the implemented stages included the research stage, the development stage, and the evaluation stage. The research stage focused on identifying problems, learning needs, students' learning preferences, curriculum requirements, and relevant literature. The development stage focused on designing and producing the augmented reality-enhanced interactive e-module on the polyhedron topic. The evaluation stage was limited to expert validation of the developed prototype. Field testing and effectiveness testing with students were not conducted because this study was designed as a limited development study that focused on product design and expert-based feasibility assessment before classroom implementation. Therefore, the effectiveness of the e-module in improving students' learning outcomes should be examined in future studies. The developed e-module prototype was assessed through expert judgment involving six validators in total, consisting of three content experts and three media experts from schools and universities in Indonesia. The content experts evaluated the accuracy, relevance, depth, curriculum alignment, language, and instructional suitability of the polyhedron material. The media experts evaluated the presentation strategy, interface design, multimedia components, usability, and the integration of augmented reality as part of the interactive e-module. The validators were selected purposively based on predetermined eligibility criteria and their relevance to the aspects being evaluated. Content experts a bachelor's degree have a minimum of five years of teaching mathematic experience. Meanwhile, media experts a postgraduate degree and experience in the field of instructional media.

Method of Data Collection Tool in Research and Development Phase

The research instruments used to identify the potentials and problems at the research site consisted of an interview guideline and student questionnaires. The interview guideline was developed by the authors to obtain in-depth information from the mathematics teacher regarding the learning process, students' difficulties in learning polyhedron, the instructional media commonly used, the availability of technological facilities, and the need for an interactive e-module. Examples of interview questions included: "What difficulties do students commonly experience when learning polyhedron?", "What learning resources or media are usually used in teaching this topic?", and "What types of digital learning features are needed to support students' understanding of three-dimensional geometric objects?" The interview was conducted with one mathematics teacher at SMP Negeri 152 Jakarta. The teacher was selected using purposive sampling because the teacher directly taught the polyhedron topic, understood students' learning difficulties, and was familiar with the instructional media and classroom conditions related to the preliminary needs analysis. The student questionnaire consisted of two parts. The first part was used to analyze students' problems and learning needs in polyhedron learning, including their difficulties in understanding concepts, their responses to existing learning resources, and their need for multimedia-based learning support. The second part was used to identify students' learning preferences. The questionnaire items were developed based on the objectives of the preliminary needs analysis and relevant literature on learning needs and learning preferences. The instruments were reviewed by the researchers before data collection to ensure that the items were aligned with the focus of the study. The questionnaire was administered to 36 students in Grade VIII at SMP Negeri 152 Jakarta, consisting of students who had studied or were studying the polyhedron topic. The student participants were selected from the class involved in the preliminary study because they represented the intended users of the developed e-module. The data obtained from the interview and questionnaires were used as the basis for designing the augmented reality-enhanced interactive e-module. After the prototype had been developed using Flip PDF Professional, the e-module was assessed using open- and closed-ended validation questionnaires completed by content and media expert validators. The closed-ended items were used to obtain quantitative feasibility scores, while the open-ended items were used to collect suggestions, comments, and recommendations for revising the prototype. Figure 1 presents the stages of the research procedure adapted from the Richey and Klein model (Richey & Klein, 2014; Sugiyono, 2017).

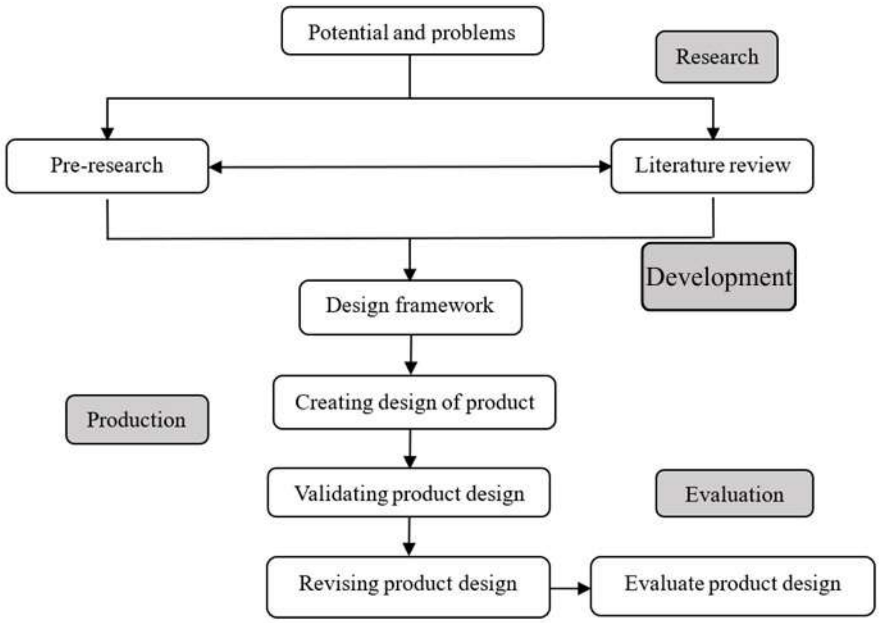

***Figure 1**. Research phase referring to the Richey and Klein model*

Through product assessment, expert validators in both content and media will provide suggestions for improving the e-module's shortcomings, leading to revisions. The researcher also identifies the curriculum, along with its underlying competencies and instructional objectives, utilized in the school.

Data Analysis Technique

The assessment strategy conducted by content and media expert validators involved completing questionnaires using a Likert scale. The Likert scale entails differentiated responses in the form of a scale or numerical values (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree)(Cohen et al., 2018). The obtained scores are used to determine the level of feasibility through a mathematical equation (1).

$$K = \frac{F}{N \times I \times R} \qquad (1)$$

In Equation (1), K represents the feasibility percentage, F represents the total obtained score from all validators, N represents the highest score for each item on the Likert scale, I represents the total number of questionnaire items being assessed, and R represents the number of validators involved in the assessment. When calculating the feasibility percentage for each e-module element, F was obtained by summing the scores given by all validators for all items included in that element. The total score was then divided by the maximum possible score, namely the highest Likert score multiplied by the number of items and the number of validators, and then multiplied by 100%. Therefore, the percentage represents the proportion of the obtained score compared with the maximum possible score. The same calculation procedure was applied separately to the content validation and media validation instruments. For content validation, the calculation was based on the scores provided by the content expert validators, whereas for media validation, the calculation was based on the scores provided by the media expert validators. The resulting percentages were interpreted using the following criteria: 0%–20% = highly inappropriate, requiring major improvement; 21%–40% = not suitable, requiring further improvement; 41%–60% = sufficiently appropriate, requiring revision; 61%–80% = appropriate, requiring minor revision; and 81%–100% = highly suitable, requiring no revision).

The data analysis techniques employed in this study consisted of quantitative and qualitative analysis. Quantitative analysis was used to calculate the feasibility scores obtained from the closed-ended validation questionnaires completed by the content and media expert validators. The scores for each e-module element were converted into percentages and interpreted according to the predetermined feasibility criteria. Qualitative analysis was conducted on the open-ended responses provided by the validators, including suggestions, comments, criticisms, and recommendations for improving the e-module prototype. The qualitative data were analyzed descriptively through several steps. First, all open-ended responses were read carefully to identify important points related to the quality of the e-module. Second, similar comments were coded and grouped into several categories, such as content accuracy, depth of material, language clarity, instructional presentation, media design, interactivity, augmented reality integration, and support for students' diverse learning preferences. Third, the categorized comments were summarized thematically to identify the main strengths and weaknesses of the prototype. Finally, the results of the qualitative analysis were used as the basis for revising the e-module before determining its final feasibility. Thus, the qualitative findings complemented the quantitative validation scores by providing more detailed explanations of the aspects that needed improvement.

Results and Discussion

Preliminary Needs Analysis

Throughout the research phase, the researcher focused on identifying problems and potentials at one of the junior high schools in Indonesia as part of the preliminary study. The researcher visited a school in Jakarta to conduct a preliminary study aimed at identifying existing problems and potentials. Data obtained from an interview with a mathematics teacher revealed that student motivation regarding the polyhedron topic remains constrained. Specifically, within this teacher's classroom context, only 10 out of 36 students were able to complete the assigned geometric tasks. Furthermore, the teacher emphasized that students' fundamental understanding is still incomplete, such as the inability to differentiate between volume and surface area. In response to this classroom phenomenon, the teacher implemented a learning model, namely project-based learning, which emphasizes students' learning of concepts related to polyhedron through the use of simple teaching aids. While these preliminary findings provide valuable initial insights, the authors acknowledge that these data are limited to a single-teacher perspective and a specific classroom context, and are not intended to represent a generalized representation of all schools.

Additionally, the researcher administered a needs analysis questionnaire to all 36 students in the class to identify mathematical problems encountered during classroom learning. The questionnaire items specifically asked students about their conceptual hurdles, such as: "Do you experience difficulties in visualizing and differentiating the surface area and volume formula of polyhedrons?" The results revealed that 58.3% of the participants 21 out of 36 students answered affirmatively, confirming that they faced major difficulties, specifically in understanding the concept of polyhedron. This difficulty stemmed from the lack of meaningful comprehension in the process of understanding the material.

The media used as learning resources for polyhedron consist of teaching aids provided by the school and instructional books from the government. The provided teaching aids include models like cube nets, rectangular prism models, and other geometric objects. However, based on interview findings, these teaching aids fail to motivate students to learn due to their unattractive designs. Additionally, the instructional flow of these teaching aids does not effectively aid students in comprehending the concepts of polyhedron. Based on a document analysis of the government textbooks and reinforced by teacher interviews, the instructional books still adhere to a "one style for all" approach as they present uniform instructions for all readers. The majority of the information in the books is presented verbally. The explanations provided in the instructional material and practical activities remain abstract. Consequently, this situation poses disadvantages for students, as the learning process does not cater to their individual needs and learning styles, resulting in incomplete comprehension of the subject matter..

The teacher also implements instructional videos as a learning medium in teaching three-dimensional flat shapes. Students are motivated when studying and easily comprehend mathematical concepts when connected with animated visuals. However, a challenge faced by the teacher is the availability of projectors in school that, on average, do not operate at their maximum capacity. When videos are connected to the projectors, the display is often unclear. School policies also do not allow students to bring digital devices, except when there is an agreement between the teacher and students. As a result, teachers can only provide videos and instruct students to watch them at their respective homes. The challenge is that teachers are not fully aware of the students' responses as there is limited supervision of the students.

Through the identification of problems and potentials in teaching of the topic polyhedron, the creation of a flipbook-oriented e-module tailored to learning styles is proposed. In the initial stage, the researcher identified students' learning styles through an online assessment platform available via the link *https://akupintar.id/tes-gaya-belajar*. This platform utilizes a standardized questionnaire adapted from DePorter and Hernacki's learning style frameworks, ensuring reliability and valid psychometric mapping through automated dichotomous scoring procedures suitable for educational field diagnostics. Out of 34 student respondents in the classroom who completed the test, the percentages for each category revealed that 15 individuals (44.1%) had a kinesthetic learning style dominance, 12 (35.3%) had a typical visual style, and 7 (20.6%) had an auditory learning style. These metrics serve strictly as a descriptive baseline to map immediate classroom preferences rather than an absolute classification of the students' permanent psychological traits. As a result, e-module features were developed, such as incorporating audio, video, animations, augmented reality, and project activities to support students' diverse learning preferences. Students have experience learning through e-modules during online instruction. However, they encounter external challenges, specifically the limited capacity of their mobile devices. To address this, the researcher arranges access to the e-module using a .html link format. By presenting the link, students are not required to download specific applications and can access the content through a browser.

The presentation of flipbook-based e-modules desired by teachers and students involved incorporating interactive videos, audio, and animations. Therefore, students find it easier and more motivating to comprehend the concepts of polyhedron, making learning more meaningful. The development of the e-module aligns with the curriculum implemented in Indonesia, namely the 2013 curriculum. In other words, the development of e-modules adjusts to the basic competencies and instructional objectives outlined in the curriculum guidelines. The researcher utilized Flip PDF Professional software for creating e-modules due to its compatibility with students' feature requirements. Additionally, the researcher introduced an enhancement by incorporating augmented reality (AR) features integrated via QR code markers. The AR system was developed using the MyWebAR cloud platform, rendering three-dimensional geometric models of polyhedrons such as cubes, cuboids, prisms, and pyramids directly within a web browser. This marker-based mechanism eliminates the need for downloading dedicated mobile applications. To run the AR feature smoothly, the minimum device requirements involve a smartphone equipped with a functional built-in camera, an active internet connection, and a web browser supporting WebGL (such as Google Chrome or Safari).

Based on this comprehensive analysis of identified problems and localized classroom potentials, the required components and multimedia layout for the interactive package were firmly established. To demonstrate how these diagnostic parameters were translated into the actual digital platform, the systematic design framework and the resulting prototype interfaces are presented in the following section.. Through this e-module, students can learn according to their needs and harness their potential in the global era by utilizing technology-based learning media (Wangid et al., 2021).

Development Phase

In line with the development stage in the Richey and Klein model (Richey & Klein, 2014), the e-module was developed from findings in the research phase. The e-module features are specifically designed to provide multimodal representations, including text, audio, video, animation, images, and augmented reality, to support students' diverse learning preferences. It includes a cover (created via Canva, see Figure 2), concept map, content, audio/video, augmented reality, and exercises, leading to expert assessment for refinement.

Figure 2*. E-module cover design*

The researcher utilized various elements and images provided in the Canva software to design the e-module interface more engagingly. The design concept adopts simple ideas and avoids overly vibrant color intensity. Users can leverage the flipbook by navigating page by page, simulating the experience of virtually flipping through a book, resulting in an attractive and dynamic display (Hidayatulloh et al., 2019). Furthermore, accessing the e-module is possible through tablets, computers, smartphones, and laptops. Additionally, a concept map was crafted by the researcher depicted in Figure 3, to inform students about the topics covered within e-module.

Figure 3*. E-module Main Map Design and Learning Guide*

The researcher utilized the shape features available in Microsoft Word 2019 to insert text into the selected shapes. The arrangement of the concept map follows indicators based on fundamental competencies and instructional objectives specified in the polyhedron material. The researcher also created a learning guide page aimed at providing instructions on how to effectively use the e-module, in order to prevent confusion for students when they utilize the features within the e-module. Furthermore, the researcher devised an introduction (see Figure 4) as an apperception within the polyhedron content.

***Figure 4**. E-module introduction material design*

The researcher conducted a study on the introductory material, highlighting the significance for students to delve into the concept of polyhedron. The arrangement of the introduction also established the fundamental connection between spatial structures and the calculations of surface area and volume. Mathematical concepts need to hold relevance to real-world scenarios in students' daily lives (Cogan et al., 2018). To facilitate this, visual aids were utilized as they tend to be more engaging than verbal explanations (Raja & Nagasubramani, 2018). Students with visual learning effectively absorb and process information without any disadvantage.

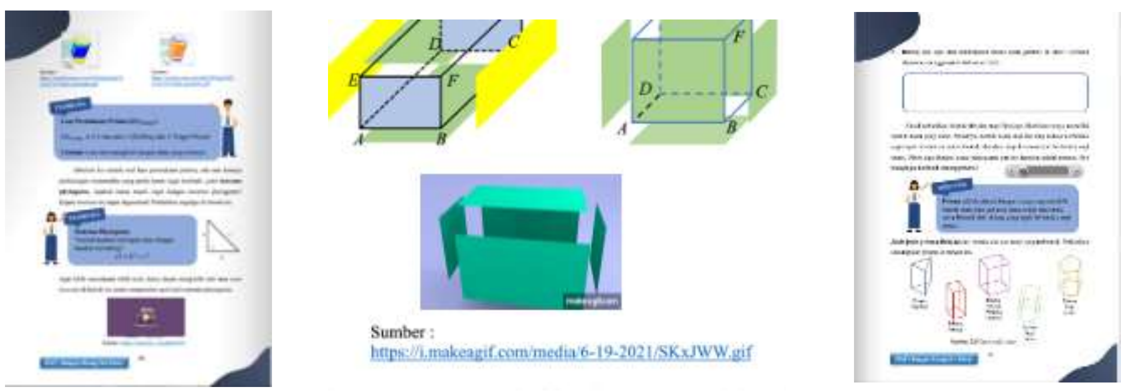

***Figure 5.** E-module features design (video, audio, and animation)*

Several pages within the e-module are enhanced with audio features, featuring the researcher's voice through sound recording. The researcher utilized the Adobe Podcast BETA to refine the audio quality, ensuring clear audibility for students. Students have the flexibility to adjust the playback of explanations by navigating the audio timeline. The audio component aims to support learning for auditory students, enabling them to absorb content through auditory channels(Rahman & Ahmar, 2016). The e-module also incorporates relevant videos sourced from YouTube, specifically chosen to align with the content on cubic spatial shapes. Videos presenting dynamic combinations of visuals (image transitions and text overlays) are strategically aligned with the learning preferences of visual and auditory learners alike (Kurniawan, 2017).

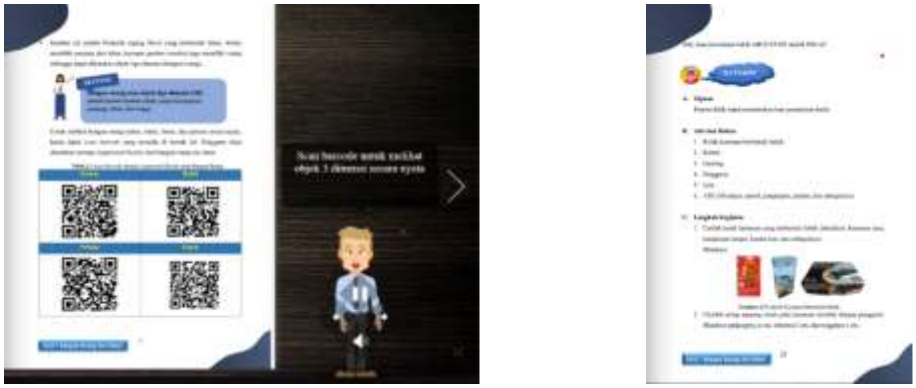

Figure 6. *E-module features design (Augmented Reality and Project Activity)*

The e-module is presented in the form of a set of accessible barcodes for accessing Augmented Reality (AR). It was created by the researchers using the MyWebAR website. When students scan the barcode with their smartphone camera, they are directed to a web-based AR interface and must click the 'Launch' button to initiate the AR experience. Upon activation, the screen displays dynamic, three-dimensional geometric objects (such as interactive models of cubes, cuboids, prisms, or pyramids) overlaid onto the real-world background. Students can rotate, pinch-to-zoom, and examine the spatial attributes, vertices, faces, and nets of these virtual polyhedrons through touch controls on their device. Augmented Reality is a dynamic strategy for capturing learners' attention during the ongoing learning process (Antonioli et al., 2016). Augmented reality technology is capable of virtually visualizing geometric objects. The material on polyhedron also aims to provide students with the opportunity to compare the characteristics of various geometric objects, encompassing their features (İbili et al., 2020).

Validation Results

After the product has been developed, it must be validated by expert assessors in both content and media through prepared questionnaires. The primary goal of the e-module, which is intended for field use, is to determine the suitability of the e-module. Refer to Table 1 for the interpretation of the assessment of each e-module element by expert content validators.

Table 1. *Validation Results of the Polyhedron E-Module by Content Experts*

No	E-Module Elements	Mean Element Score		
		Validator 1	Validator 2	Validator 3
1	Alignment with Subject Matter Standards	5	5	4.5
	Percentage		96.6%	

2	Depth of Polyhedron Material	4.83	5	4.5
	Percentage		95.5%	
3	Development of Life Skills	4.71	4.71	4.42
	Percentage		92.38%	
4	E-Module Features for Learning Styles	4.14	5	4.28
	Percentage		89.52%	
5	Alignment with Student Development	5	5	4
	Percentage		93.3%	
6	Appropriate and Correct Language Usage	5	4.66	3.83
	Percentage		90%	
7	Dialogic and Interactive Nature	5	5	5
	Percentage		100%	
8	Suitability of Problem-Based Learning Model	4.4	5	4.4
	Percentage		92%	

The validation of content, conducted by three content specialists, resulted in an average suitability rating of 93.5% for every component, as shown in Table 1. Such a strong outcome stemmed from successive refinements driven by expert recommendations, with a special emphasis on bolstering the e-module's accommodations for visual, auditory, and kinesthetic learning preferences. Based on the evaluation results from the first to the third content validators, a quantitative score of 96.6% was obtained for the alignment with the subject matter standards element, indicating a highly suitable level. Next, the evaluation outcome for the depth of polyhedron material element yielded 95.5%, also signifying a high level of suitability. Furthermore, the percentage result for the development of the life skills element was 92.38%, indicating a very suitable level. The subsequent element referring to e-module features for learning styles achieved a score of 89.52%, demonstrating high suitability. Although this represents a highly suitable level, it was the lowest score among the content validation elements. Based on the expert feedback, this lower initial score occurred because the initial prototype lacked sufficient hands-on physical tasks to fully engage kinesthetic learners, focusing heavily on visual and auditory features instead. To improve this aspect, revisions were promptly made by expanding both individual and group manipulative activities such as constructing physical cubes, prisms, and pyramids using real-world materials thereby creating a more balanced approach across all three learning preferences. Moving forward, the evaluation result for the alignment with the student development element reached 93.3%, indicating a very suitable level. The next element of appropriate and correct language usage scored 90%, signifying high suitability. A quantitative score of 100% was obtained for the dialogic and interactive nature element, demonstrating a highly suitable level. Lastly, the cumulative result for the suitability of the problem-based learning model element reached 92%, which signifies a very suitable level.

Discussion

The first validator's assessment of the prototype highlighted its ability to address different learning preferences: visuals that supported comprehension for visual learners, integrated videos and narration that benefitted auditory learners, and project-based or collaborative exercises that involved kinesthetic learners. This feedback confirmed the design's overall strength and indicated only minimal revision needs at the early stage.

The assessment by the second content validator following the revisions indicates that the e-module has undergone changes. Based on this input, revisions were carried out by embedding animated graphics and narrated audio explanations. When evaluated by the second validator, the updated version was confirmed to have improved significantly: animations strengthened the visual dimension, narration allowed auditory reinforcement, and real-world contextual activities supported kinesthetic engagement. These refinements positioned the e-module as more inclusive, ensuring consistently high validation results.

The third validator similarly acknowledged the adequacy of visuals (with clear illustrative images) and auditory features (well-developed videos), but identified shortcomings in kinesthetic aspects due to limited practical exercises. Recommendations were made to expand both individual and group activities to include manipulative tasks with three-dimensional shapes—for example, constructing prisms and pyramids using physical materials. These inputs were adopted through the addition of interactive simulations and virtual hands-on tasks, effectively resolving the weaknesses. After these improvements, the e-module demonstrated stronger balance across all three learning styles, which was reflected in the 89.52% score on the learning styles criterion as well as its overall high validation outcome.

Table 2. *Accumulated average scores of each element by media expert assessors along with their percentages.*

No	E-Module Elements	Average Element Score		
		Validator 1	Validator 2	Validator 3
1	Presentation Strategy	5	5	5
	Percentage		100%	
2	Learning Presentation	5	5	5
	Percentage		100%	
3	E-Module Appeal	5	4	5
	Percentage		93.33%	
4	E-Module Size	5	4.125	5
	Percentage		94.16%	
5	E-Module Content Design	5	4.4	5
	Percentage		96%	

The results of the analysis from the first to the third media validators indicate that the elements achieving 100% in the e-module are content presentation and learning presentation. These percentages indicate that the two elements meet the criteria for being highly suitable. The subsequent element that pertains to the e-module appeal element obtained a score of 93.33%, signifying high suitability. Next, a quantitative score of 94.16% was obtained for the e-module size element, indicating a high level of suitability. Lastly, the cumulative result for the suitability level of the e-module content design element reached 89.33%, which signifies a highly suitable level.

According to the first media validator, the e-module successfully addresses diverse learning preferences by incorporating multiple sensory inputs. The integration of spatial geometry images and AR barcodes supports visual-spatial needs, clear narrated explanations accommodate auditory preferences, and structured activities engage kinesthetic learners through practical application. In interpreting this feedback, the e-module's design aligns with Mayer's cognitive theory of multimedia learning, which emphasizes that combining text, visual elements, and auditory narration reduces cognitive overload and facilitates complex spatial processing (Alessi & Trollip, 2001). Furthermore, utilizing interactive AR features provides spatial-visual supports crucial for abstract topics like polyhedrons, helping students visualize 3D geometric structures more concretely without over-relying on purely verbal instructions (Antonioli et al., 2016).

The second media validator affirmed the e-module’s suitability for visual and auditory learners, identifying images, animations, and audio elements as key strengths. However, the validator recommended expanding the audio explanations to provide more comprehensive verbal guidance. For kinesthetic learners, the inclusion of structured practical exercises was deemed appropriate to support material comprehension. This feedback emphasizes the value of incorporating varied learning channels to bridge sensory modalities, prompting a deeper refinement of the narrative components. Based on these suggestions, the audio descriptions were amplified to enhance instructional thoroughness. Ultimately, the validator concluded that with these minor adjustments, the interactive e-module has the potential to support diverse learning preferences within adaptive digital environments.

Lastly, the third media validator critiqued the visual elements for lacking dynamic illustrations, such as moving or shifting forms, rendering it less suitable for visual learners who benefit from motion to grasp geometric transformations. Auditory support was praised for its descriptive narrated content, but kinesthetic accommodation was deemed inadequate due to the absence of motion-reliant activities that aid phenomenon recall through physical interaction. Consequently, the validator determined that the polyhedron e-module does not fully support students' diverse learning preferences in its current state. Interpreting these findings, the identified gaps reveal scopes for the e-module to more accurately replicate practical 3D shape interactions. This critique resonates with differentiated instruction approaches, which stress that tangible kinesthetic experiences are essential for diverse learners in STEM subjects like geometry (Tomlinson, 2017). Addressing these shortcomings by integrating fluid animated transitions and simulation features would strengthen the e-module's compatibility with learner variations (Felder & Brent, 2005). The media validators' opinions overall reveal a robust foundation for multimodal support in the e-module, pointing to targeted enhancements that could achieve near-perfect suitability. However, the authors acknowledge a critical limitation of this study: the developed e-module was strictly evaluated through expert validation stages without undergoing empirical field testing with students. Consequently, while the product demonstrates strong conceptual and media readiness based on specialist judgment, its actual effectiveness on student learning outcomes and classroom academic achievement remains to be measured in future field implementation.

Conclusion

This study aimed to develop and validate a flipbook-based interactive e-module for teaching polyhedron that accommodates students' diverse learning styles—visual, auditory, and kinesthetic. Through a structured development process using the Richey and Klein model, the resulting e-module was evaluated by content and media experts. The findings indicated that the module is valid and highly suitable in terms of content relevance, instructional design, and media presentation. Key features such as animations, audio narration, videos, augmented reality, and project-based activities effectively supported differentiated learning preferences, enhancing students' conceptual understanding and engagement. However, while the module addressed visual and auditory learners well, suggestions were made to strengthen kinesthetic elements through more hands-on tasks.

Based on the findings, it is recommended that future development of e-learning modules further emphasize kinesthetic interactivity by integrating physical manipulation tasks or hybrid learning approaches involving real-world objects. Schools and educators are encouraged to adopt this type of differentiated instructional media to improve mathematics learning outcomes, especially in geometry. Additionally, field testing with broader student samples is suggested to assess learning effectiveness and student achievement. This will provide further empirical evidence for the practical impact of technology-integrated modules tailored to learning styles.

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