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Development of Interactive E-Quiz with Articulate Storyline: Transformation of Plane and Space Geometry Assessment in Higher Education

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Abstract
This research overcomes the problem of traditional assessments in Plane and Spatial Geometry courses which are often unable to measure students' mathematical spatial abilities effectively. Thus, the aim of this research is to develop and evaluate a computer-based assessment instrument using Articulate Storyline which is designed to improve the quality and efficiency of evaluation in this course. The research methodology follows the ADDIE development model, starting with an analysis of the needs of 2nd semester students of the Mathematics Department, FMIPA, Medan State University (UNIMED), followed by design, development, implementation and evaluation. The research results show that this instrument has a high level of validity and reliability, with the majority of students showing good skills in using digital devices and supporting network access. This instrument also received positive responses from students and lecturers, demonstrating its effectiveness in increasing engagement and understanding of the material. In conclusion, this computer-based instrument succeeded in improving the quality of evaluation, although this research was limited to several chapters and one institution. It is recommended that future research expand the scope of materials and implementation contexts to test the generalizability of results as well as overcome network access barriers, opening opportunities for further innovation in academic assessment.

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INTRODUCTION

Geometry is a branch of classical mathematics that plays a fundamental role in modern mathematics education (Baah-Duodu et al. 2020; Galili 2018). A deep understanding of geometry is essential for developing critical and spatial thinking skills, which are essential in solving a variety

of mathematical and scientific problems (Aini et al. 2020; Casey and Fell 2018; İbili et al. 2020). Additionally, geometry serves as a foundation for other disciplines, including physics, engineering, architecture, and graphic design, where spatial and geometric concepts are widely used (Bellone, Mussio, and Porporato 2019). Effective geometry education can strengthen students' analytical skills and improve their ability to analyze and interpret visual-based data and information (Mukuka and Jogymol Kalariparampil Alex 2023; Wahab et al. 2018). Therefore, geometry not only teaches basic mathematical skills but also prepares students to face future cognitive challenges that require logical thinking and sophisticated visualization (İbili et al. 2020).

Despite its importance, teaching plane and space geometry faces a number of significant pedagogical challenges (Rashevska et al. 2020; Tachie 2020). One of the main challenges is the complexity of geometric concepts which are often abstract, making them difficult for students to understand. Difficulty in understanding and visualizing three-dimensional shapes can hinder students in bridging theory and practical application (Rahmawati, Dianhar, and Arifin 2021). Traditional teaching methods are often inadequate in providing the tools and visual representations necessary to understand these concepts in depth (Abdulrahaman et al. 2020). Additionally, limitations in the use of interactive educational technology can limit teachers' ability to develop meaningful learning experiences for students (Anderson and Rivera-Vargas 2020; Kostiainen et al. 2018; Major and Watson 2018). Therefore, there is an urgent need to design more innovative and interactive teaching methods and assessment instruments that can improve students' understanding and engagement in geometry learning.

In the current digital and computerized era, technology has been significantly integrated into the learning process, providing a major positive impact on education (Lawrence and Tar 2018). Technology in education is known as an approach Technological Pedagogical Content Knowledge (TPACK), which includes the integration of technology in assessment known as Computer Based Test (CBT) (Paje, Rogayan, and Dantic 2021; Singh, Sharma, and Paliwal 2020; Wang and Lu 2021). With the CBT method, test instruments are no longer given in hardcopy form but in various multimedia forms such as web-based applications (Chun et al. 2023; Danladi and Dodo 2019). CBT provides advantages in terms of cheating prevention, transparency of results, and support for paperless learning systems, which makes it an essential requirement in exam administration (Bhatia and Joshi 2023) . However, although CBT has been proven effective in various disciplines, many mathematics education lecturers, such as at Medan State University, have not fully utilized this technology. Especially in Plane and Space Geometry courses, assessments are often carried out using conventional methods, such as sending questions in Word or PDF format, which requires students to write answers manually before uploading them again. This process is not only time consuming but also prone to errors and less efficient.

Even though Computer-Based Testing (CBT) has been proven effective, most mathematics education lecturers at Medan State University have not adopted CBT-based assessment. Based on interviews conducted by researchers with mathematics education lecturers, only a small percentage use CBT instruments, and there are no lecturers who use CBT assessments, especially for the Plane and Space Geometry course which aims to assess students' mathematical spatial abilities. So far, assessments have been carried out by sending test instruments in Word or PDF format via the Online Learning System (SIPDA) or WhatsApp, and students are asked to answer by writing the

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answers on paper, photographing them, then sending them back via SIPDA or WhatsApp. Initial research results are presented as follows:

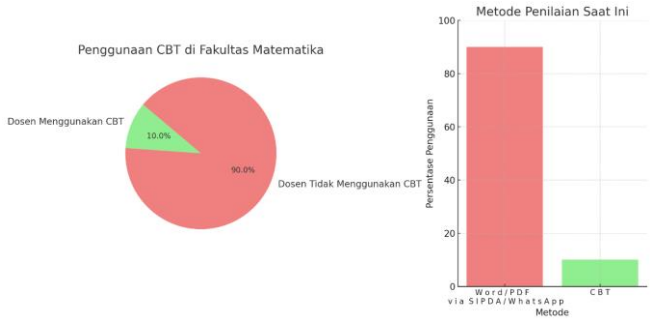

Fig 1. Use of CBT in the Faculty of Mathematics

The data above shows that the adoption of Computer-Based Testing (CBT) is still very limited, with only 10% of lecturers utilizing this instrument. Meanwhile, 90% of lecturers still rely on traditional assessment methods, where test instruments are sent in Word or PDF format via platforms such as the Online Learning System (SIPDA) or WhatsApp. Students are asked to write their answers on paper, take photos of their work, and send them back via the same media. The pie graph shows the dominance of traditional methods in the use of assessment by lecturers, while the bar graph emphasizes this preference by highlighting the percentage of use of Word/PDF-based assessment methods compared to CBT. This explanation reflects the urgent need for the integration of more interactive and effective assessment technologies, especially for courses such as Plane and Spatial Geometry, which require a more in-depth evaluation of students' mathematical spatial abilities. The use of Articulate Storyline, as a CBT tool, can offer innovative solutions to improve the quality and efficiency of assessments, considering that the available technological facilities and network accessibility are adequate. Thus, efforts to increase CBT adoption are important to ensure that assessment not only keeps pace with developments in educational technology but also meets higher academic needs.

To overcome the problem of lack of adoption of CBT-based assessment among mathematics education lecturers, E-Quiz with Articulate Storyline can be used. Articulate Storyline offers a comprehensive solution in the form of an interactive and accessible assessment instrument, designed to increase engagement and evaluation effectiveness in Plane and Space Geometry courses (Addriani et al. 2023; Daryanes et al. 2023). This e-Quiz allows lecturers to create tests that not only include text and images but also include multimedia elements such as video, animation and audio, thereby facilitating a more comprehensive assessment of students' mathematical spatial abilities (Chan et al. 2023). With the ability to be accessed via various devices, including laptops, tablets and smartphones, this E-Quiz offers flexibility and convenience for students in taking assessments in a digital environment that suits modern learning needs.

In the existing literature, there are a number of studies that explore the role of technology in increasing educational effectiveness, especially in mathematics and geometry learning. For example, a study by Arifin & Suprapto (2022) highlights that the use of digital assessment tools in mathematics education can significantly improve student learning outcomes. Other research by Su et. al (2022) reveals that interactive learning systems increase student engagement and understanding in geometry. However, much of this research focuses on technology use in general,

without delving deeper into the use of specific tools such as Articulate Storyline for assessment in the context of plane and space geometry learning.

Although there are similarities in the literature emphasizing the effectiveness of digital technology, this study differs in that it targets the use of the Articulate Storyline as an innovative assessment instrument. Most previous studies, such as those by Castro1 (2019), highlight different applications and platforms or focus on enhancing learning through digital tools in general. This research, in contrast, focuses on the development of an e-quiz with Articulate Storyline, exploring its impact on students' understanding and engagement in a plane and space geometry course, which is an area that has not been explored much in previous research. By examining the effectiveness of e-quiz developed through Articulate Storyline, this research seeks to provide new insights into how this technology can be used to improve the quality of assessment and learning. It is hoped that the results of this research can serve as a guide for educators and educational technology developers in implementing technology-based assessment solutions in the wider educational environment.

METHODS

Research Design

The research method used was the development of the ADDIE (Analysis, Design, Develop, Implement, and Evaluate) model developed by Reiser and Mollenda. In the ADDIE development design model there are five stages, namely as follows:

1) Analysis Stage

At this stage, a comprehensive learning process needs analysis is carried out to ensure that the product being developed can meet the desired target needs. This analysis focuses on learning needs and relevant materials, with the aim of designing assessment instruments that are appropriate to the academic context. In this process, a survey was conducted on second semester students majoring in Mathematics, FMIPA, Medan State University (UNIMED) who were taking the Geometry of Planes and Space lectures. This survey aims to identify students' learning needs, difficulties and preferences, as well as to collect empirical data that will be used as a basis for developing more effective and efficient learning products.

2) Planning Level

At this stage, researchers took several crucial steps designed to support the development of assessment instruments in the Plane and Space Geometry course. First, the researcher partitioned the amount of course material to ensure that the content delivered was structured and in accordance with learning needs. Second, the researcher designed an assessment instrument rubric designed to comprehensively measure various aspects of student understanding. Third, the assessment instruments are prepared in digital formats, such as Word documents and PDFs, to ensure accessibility and ease of use. Fourth, interactive assessment features were developed using Articulate Storyline software, which allows for more dynamic and interesting delivery of material and evaluation. Finally, the researcher designed an instrument in the form of a questionnaire aimed at lecturers and students to collect feedback, as well as a validation sheet involving material experts and media experts, and a readability questionnaire to assess the clarity and acceptability of the material prepared.

3) Development Stage

The next stage in the research process is the development of an e-quiz for the Plane and Space Geometry course. At this stage, the previously designed assessment rubric is implemented, and assessment features are further developed using Articulate Storyline software to develop assessment instruments that suit the curriculum needs of the course. Once development is complete, the assessment instrument is exported to a variety of output formats, including HTML5, to ensure compatibility with a wide range of devices. At this stage, additional research instruments in the form of questionnaires to assess practicality and effectiveness were also developed.

Next, product review is carried out through testing the validity and reliability of the quality of the question items. This testing consists of two methods: logical trials and empirical trials. Logical trials were carried out by five lecturers who taught the Plane and Space Geometry course, which aimed to assess the suitability of the content and structure of the assessment to the learning objectives. Meanwhile, the empirical trial involved 30 students who had completed the course, to evaluate the effectiveness and acceptability of the product in the end user context.

The next stage involved testing the instruments produced from the Articulate Storyline software, which was carried out by three material expert lecturers and two media experts. This test aims to assess quality from the perspective of content and media design. The results of this validation process provide valuable input for further improvement and development, resulting in a final product that is of higher quality and meets high academic standards.

4) Implementation Stage

After the product development stage is complete, the next step is to implement the product through trials carried out on two scales, namely small scale and large scale. Small scale trials conducted to test the readability and initial understanding of the product by involving 10 students as research subjects. This stage aims to identify initial problems and obtain input that can be used to improve the product before further implementation. Large scale implementation then carried out involving 30 students who took the Plane and Space Geometry course. This stage is designed to test the practicality and effectiveness of the product more widely. Practicality is evaluated based on responses from students and lecturers, while product effectiveness is measured through analysis of the results of validity, reliability and differentiability of questions. This testing aims to ensure that the product being developed can not only be used easily by users, but can also achieve the desired learning objectives effectively.

5) Evaluation Stage

After the implementation phase has been completed, the results obtained from all instrument implementation activities are collected and analyzed. These results become an important basis for the product evaluation stage. Evaluation is carried out by collecting data from various sources, including interviews with students, student response questionnaires, as well as observation notes collected during implementation in the field. Based on a comprehensive analysis of this data, final revisions were made to the assessment instrument to ensure that the final product met all established feasibility aspects. Products that have been revised and adapted based on the results of this evaluation are then identified as products that meet the appropriateness standards for use in the targeted educational context.

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All research stages are presented in figure 1.

Fig 2. Research Stages

Research subject

Participants in this research included 2nd semester students of the Mathematics Department, FMIPA, Medan State University (UNIMED), lecturers teaching Field and Space Geometry courses, as well as relevant material and media experts. The selection of students as participants was based on the fact that they were the end users of the assessment instruments being developed, so that their involvement of 10 people for small-scale trials and 30 people for large-scale trials could provide empirical data related to needs, learning preferences, and readability levels. instrument. Meanwhile, lecturers and experts were selected because they have in-depth understanding and experience in teaching the subject, which is necessary to assess the validity and reliability of the content and structure of the instrument. Five lecturers were involved in logical testing, while three material expert lecturers and two media experts participated in the validation process to ensure that the assessment instruments met applicable academic and curriculum standards. These experts provided valuable feedback and recommendations in testing the validity and reliability of the instrument through Product Moment correlation analysis and measuring internal consistency with Cronbach's Alpha coefficient. The selection of participants was based on the research objective of producing an assessment instrument that is not only effective and efficient, but also innovative and appropriate to the higher education context. Through this collaborative approach, this research aims to provide relevant solutions for teaching Plane and Space Geometry courses at the tertiary level.

Research instruments, Data Collection Techniques, Data Analysis Techniques

The data obtained needs to be arranged systematically and processed carefully in order to produce appropriate conclusions that can be described scientifically. Validity and reliability analysis is carried out by measuring factor validity, namely by connecting or correlating the factor score (the

sum of all items in one factor) with the total factor score (the total number of factors). To measure item validity, analysis is carried out by correlating the item score with the total score of all existing items. Instrument validity testing was carried out using correlation analysis Product Moment with the help of software SPSS (Statistical Package for the Social Sciences) version 20. The criteria used in this validity test are as follows:

1) If rcount > table then the instrument is declared valid.
2) If rcount > rtable then the instrument is declared invalid

After the research instrument has passed the validity test stage, the next step is to carry out a reliability test. Reliability testing aims to assess the consistency of measurement results when carried out repeatedly on the same variables using similar measuring instruments (Sofyan, 2014). In this research, the reliability of the instrument was assessed using the Cronbach's Alpha coefficient with the help of SPSS version 20 software. The Cronbach's Alpha method was used because it is able to provide a reliable estimate regarding the internal consistency of the research instrument. The criteria for reliability testing with Cronbach's Alpha are as follows:

1) The instrument is said to be reliable if the Cronbach's Alpha value is > 0.60.
2) The instrument can be said to be unreliable when the value of Cronbach's Alpha < 0.60

Meanwhile, the practicality and feasibility questionnaire scale for material and media experts is as shown in table 1.1 below

Table 1. Feasibility Scale

Category	Score
Not eligible (TL)	1
Not Eligible (KL)	2
Worth it	3
Very Worth It	4

Next, the average scores obtained from experts and the response scores of students and lecturers were analyzed with the value criteria in table 1.2 below.

Table 2. Eligibility Criteria

Rate - rate	Eligibility Criteria	Information
$3{,}26 \leq \bar{x} \leq 4{,}00$	Very Worth It	Very Worth Using
$2{,}51 \leq \bar{x} < 3{,}25$	Worth it	Not Revised
$1{,}76 \leq \bar{x} < 2{,}50$	Not Worth It	Partial revision and retesting of material
$1{,}00 \leq \bar{x} < 1{,}75$	Not feasible	Total Revision

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RESULT

Results of Needs Analysis for Development of Assessment Instruments

Based on the results of the analysis of the initial abilities of students in the second semester of the Mathematics Department, FMIPA, Medan State University (UNIMED), it was found that all students (100%) had digital learning support facilities, such as laptops and gadgets, which are important prerequisites for implementing technology-based learning. From the survey, 20 students showed high ability to utilize features on digital devices, while 8 students were in the medium ability category, and only 2 students were in the low category. This shows that the majority of students have fairly good skills in using digital devices, which is a strong basis for implementing computer-based assessments. Apart from that, network accessibility is also an important supporting factor. Based on the survey, 95% of students reported ease in accessing the internet network, indicating that the network infrastructure provided by the university really supports network-based learning and assessment activities. In contrast, only 5% of students experienced difficulty in accessing the network, indicating that the majority of students are ready to engage in learning and assessment activities that use digital technology. The analysis results are presented in the graph below

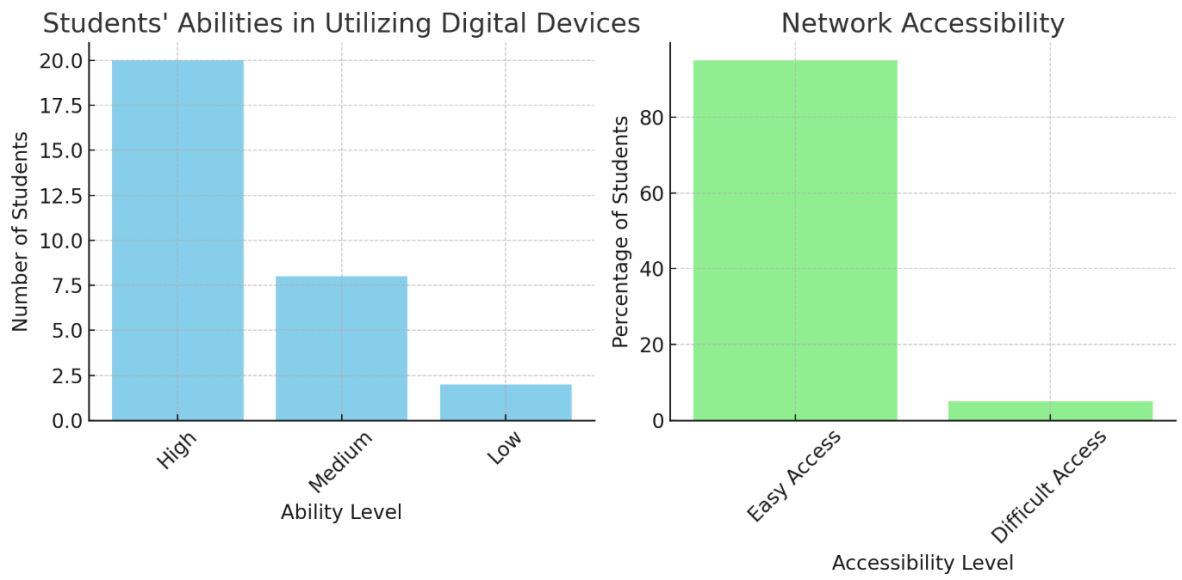

Fig 3. Results of Needs Analysis for Development of Assessment Instruments

With adequate infrastructure and student capabilities, it is hoped that the development of computer-based assessment instruments (CBT) using Articulate Storyline can be carried out effectively. This instrument is designed to measure students' mathematical spatial abilities in the Plane and Space Geometry course, with the aim of providing a more interactive and comprehensive evaluation. The use of technology in this assessment not only aims to increase student involvement in the learning process but also to improve the quality of academic assessments. Therefore, student readiness and adequate supporting infrastructure are crucial factors in the successful implementation of this assessment instrument. Thus, this research shows that the development of technology-based assessment instruments has great potential to improve the effectiveness and

quality of evaluation processes in higher education, especially in the context of Plane and Space Geometry courses.

Design and Development of the E-Quiz instrument

This research focuses on developing an HTML5-based assessment instrument which aims to measure students' mathematical spatial abilities in the Plane and Space Geometry course. This instrument is designed systematically and includes six chapters of material, with each chapter containing ten questions developed to test various aspects of student understanding. However, in this research, instrument development was limited to chapter three. This assessment instrument is equipped with a 1-2 minute video tutorial, which is designed to provide structured guidance in answering questions. The video tutorial displays high-quality visuals and clear audio dubbing, so that it can facilitate student understanding effectively. Each chapter comes with a unique password to ensure security and personalize access, and after problem solving, assessment results are displayed live, allowing for in-depth evaluation of student understanding. The use of Articulate Storyline in the development of this instrument allows the integration of interactive and evaluative features, resulting in an assessment tool that is not only comprehensive, but also meets modern pedagogical standards. The following are several displays of the e-quiz that has been developed as an assessment instrument.

Fig 4. Initial appearance of the product

Figure 4 shows the initial interface of the Articulate Storyline-based e-Quiz product designed for the Plane and Space Geometry course. This interface serves as an entry gate for users before starting training or evaluation. In this view, users are instructed to enter a password as an initial authentication step, which aims to ensure that only registered users can access the quiz content. Visual elements such as character icons and colorful graphic designs are utilized to create an engaging and friendly user experience. The 'Start' button functions as the main controller to start the

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quiz session after successful authentication. This interface design is designed not only to meet functionality requirements but also to increase student involvement and motivation in interactive geometry learning.

Fig 5. Main Menu Display

Figure 5 depicts the main menu display of the e-Quiz application which is designed to support learning in the Plane and Space Geometry course. This interface provides easy navigation for users by presenting a structured and easy to access menu. Personalization elements, such as the user's name and institution, are placed at the top of the screen, indicating that the application supports individual user data management. These personalization features not only increase user engagement but also add a more personalized element of interaction. The main menu presents six geometry learning modules covering various important topics, viz Basic Concepts and Systems of Geometry, Triangles, Quadrilaterals, Straight Lines and Circles, Polygons, and Flat and Curved Shapes. Each module is accessed via an “Open” button, which allows users to explore the learning content according to their needs. The use of consistent colors and attractive graphic design serves to enhance the visual appeal of the application, as well as helping to clearly differentiate each module. This intuitive interface design is designed to increase learning effectiveness and efficiency by allowing users to access learning materials quickly and directly. By utilizing Articulate Storyline, this application provides an interactive and responsive learning environment, which is expected to increase student motivation and involvement in learning complex geometric concepts.

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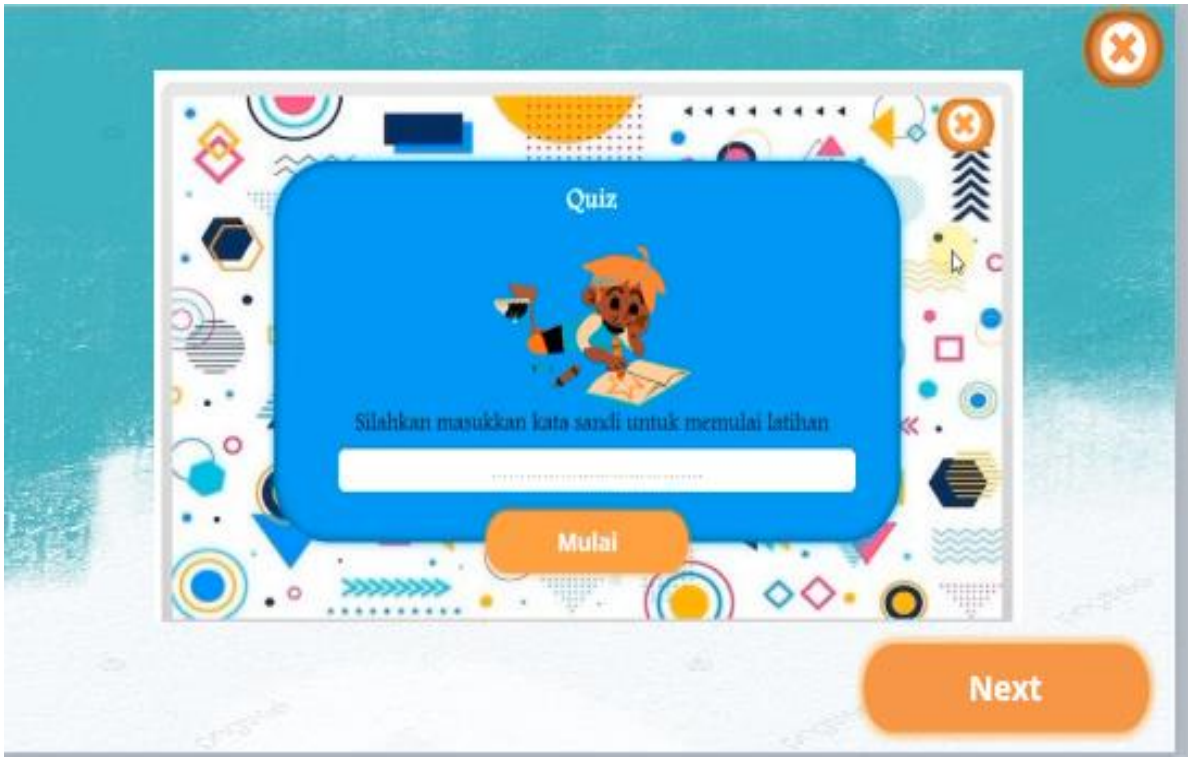

Fig 6. Tutorial video display for working on questions

Figure 6 shows the interface of the video tutorial in the e-Quiz application which is designed to provide guidance to users in completing geometry practice questions. This interface functions as a learning support feature that helps students understand how to use the application and effective problem solving strategies. In these video tutorials, users are asked to enter a password to access the material, emphasizing security and personalization of user access. The visual design uses cheerful and educational graphic elements, aimed at attracting attention and increasing user engagement. The "Start" and "Next" buttons signal navigation within the tutorial, allowing users to move forward through the various stages of learning smoothly. The function of this tutorial video is very important to provide a more detailed and interactive explanation of problem solving techniques, which is expected to improve a better understanding of geometric concepts and facilitate a more adaptive and personalized learning experience.

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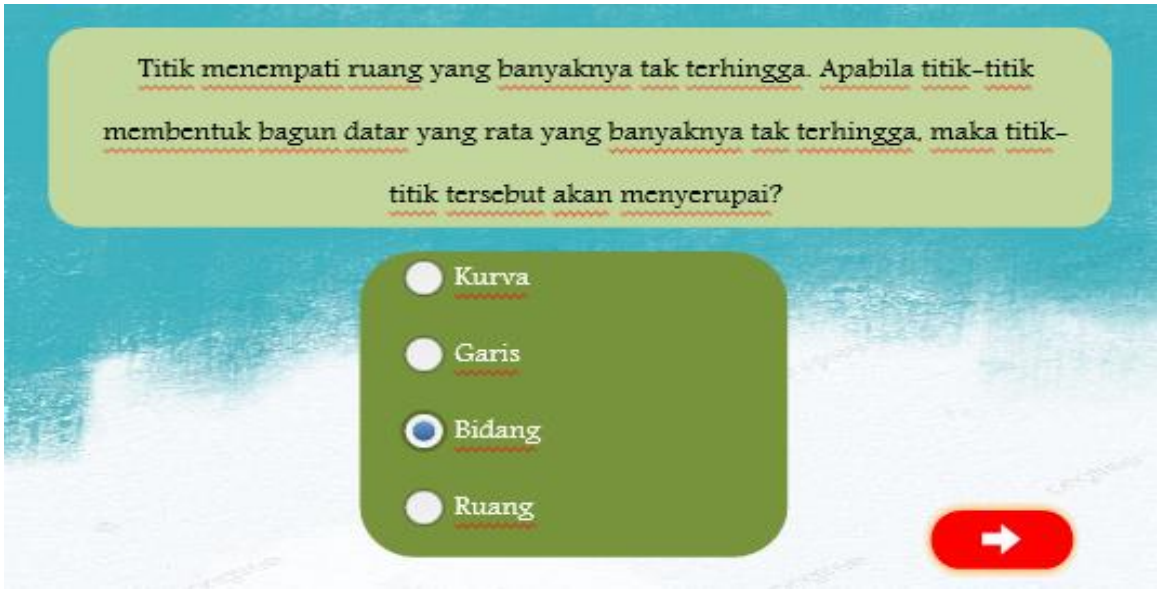

Fig 7. Display of one form of question

Figure 7 depicts one type of multiple choice question in the e-Quiz application designed for the Plane and Space Geometry course. This question tests students' understanding of basic geometric concepts by asking about geometric shapes resulting from an infinite number of points in space. The multiple choice format was chosen because it can measure students' analytical and reasoning abilities in determining the correct answer from the options provided, namely Curve, Line, Plane, and Space. The correct answer is "Plane," indicating that students must understand the basic properties of geometric elements to answer this question.

The question interface is designed with an attractive background and clear answer choices to facilitate user interaction. The use of navigation buttons, such as the red arrow button, allows students to easily move on to the next question after answering. The design of these questions focuses not only on testing knowledge but also on improving user experience through simple but effective visual interactions. In addition, the visual presentation of questions aims to increase student engagement, ensuring that learning remains interesting and challenging.

Instrument Validation Test

To review the feasibility of this E-quiz instrument, an expert validation test was carried out consisting of 2 media experts and 3 material experts along with research data obtained by the researcher.

Table 3. Expert Eligibility Score

CHAPTER	Materials Expert	Criteria	Members of the Media
I	3,2	Worth it	3,12
II	3,1	Worth it	3,03
III	3,02	Worth it	

Table 3 displays the results of the feasibility assessment of the Articulate Storyline-based e-Quiz which was evaluated by two material experts and two media experts. This assessment was

carried out to assess the quality of the content and media presentation of the e-Quiz designed for the Plane and Space Geometry course. The evaluation includes three chapters of material, where each chapter gets a score indicating its suitability for use in learning. Chapter I received a score of 3.2 from material experts and 3.12 from media experts, both indicating that the content and media presented worthy. For Chapter II, the scores obtained were 3.1 from material experts and 3.03 from media experts, with the same results, namely worthy. Meanwhile, Chapter III received a score of 3.02 from material experts and the media expert's assessment stated its feasibility even though the specific score was not listed in the table. This score shows that all the material in the e-Quiz meets the eligibility criteria based on predetermined evaluation standards, which consider aspects of content quality and effectiveness of media presentation. These results indicate that e-Quiz is considered capable of supporting the geometry learning process in an effective and interactive way, providing validation that this application is suitable for use in an educational context. However, there are several inputs from validators to improve the instrument. Below is a revised instrument based on input from validators.

Table 4. Revision Results

Before Revision	**After Revision**
Change the background color on all media displays to make it more attractive, don't make it too busy and choose colors that are pleasing to the eye. 	Display after changing background color on all media displays. 
Before entering the question login, you should be given a tutorial on how to do the questions because in the questions there are different types of questions in each chapter. 	The display after being given a video tutorial on how to do the questions before logging in to the questions. 

Table 4 displays the results of revisions to the e-Quiz application interface design designed to improve user experience and learning effectiveness. This revision includes two main aspects: changes to the background color and the addition of video tutorials. Before the revision, the app's interface used an overly busy color palette, which had the potential to distract users and reduce readability. Therefore, an update was made to the background colors by choosing a calmer and

more harmonious palette, which is expected to improve visual comfort and help users focus more on the learning content. In addition, the previous application did not provide guidance on how to do the questions before logging in, which could confuse students, especially when they had to face different types of questions in each chapter. To overcome this, video tutorials were added after the revision to provide clear and detailed guidance on how to work on the questions, explain the variety of question types available, and provide the necessary context for users to understand the working process. With these changes, the e-Quiz application not only becomes more aesthetically attractive but also more functional in supporting learning, providing a better and deeper user experience. Overall, this revision focuses on improving the visual quality and instructional support, which is expected to increase the effectiveness of the application as a learning aid in the context of geometry education.

The results of the product revision were then carried out by a readability test. This test was given to 10 students to assess whether each question item developed could be read well. The following is the readability score for each question in the CHAPTER.

Table 5. Readability Value Of Question Items

Student	**Readability Criteria (CHAPTER)**		
	I	**II**	**III**
1	Good	Good	Good
2	Good	Good	Good
3	Good	Good	Good
4	Good	Good	Good
5	Good	Good	Good
6	Good	Good	Good
7	Good	Good	Good
8	Good	Good	Good
9	Good	Good	Good
10	Good	Good	Good

Based on the table above, it is known that the E-Quiz assessment instrument produces good readability scores. This can indicate that the author has succeeded in presenting the material clearly and structured, so as not to cause confusion or difficulties for the reader. These consistently positive readability evaluations provide constructive feedback for the author, as they demonstrate that the writing style and presentation of the material meet good standards in terms of readability. However, for a more in-depth analysis, it is also necessary to pay attention to other factors such as clarity of content, grammar and logical flow of each chapter. Good readability will improve the quality and impact of scientific documents, as well as make it easier to disseminate the knowledge contained therein.

Instrument Validity and Reliability test results

Next, a validity and reliability test was carried out for each question item in each chapter which is depicted in the graph below.

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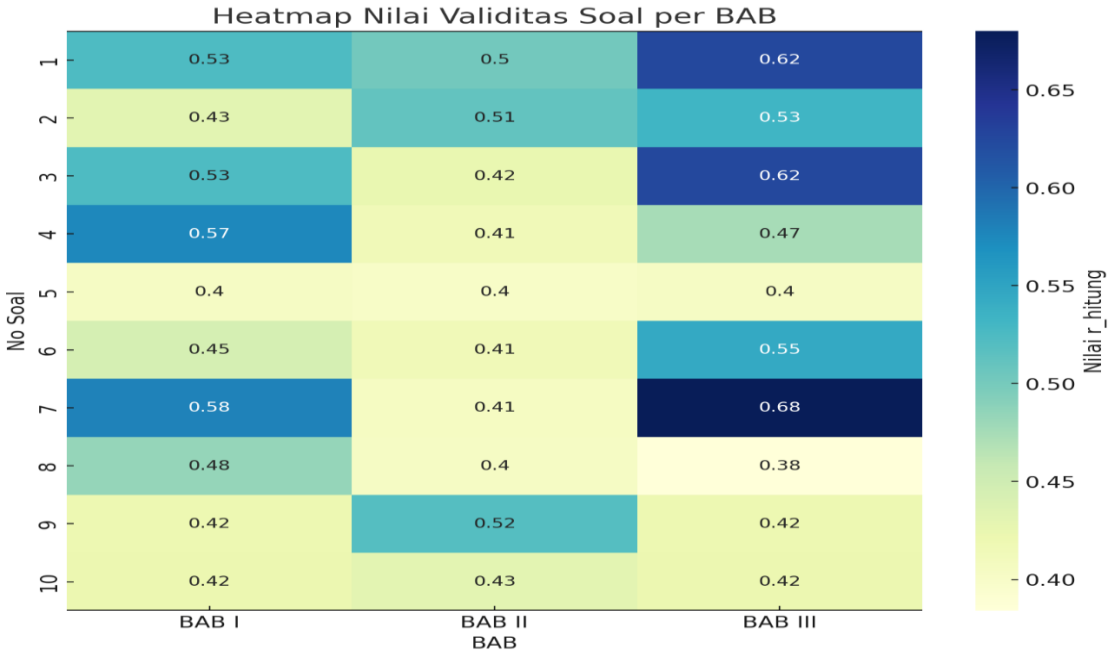

Fig 8. Validity test results

Based on this heatmap, it is known that overall, all questions from BAB I, BAB II, and BAB III have validity that meets the requirements, with a value of rcount_{count}rcount exceeding the minimum limit of r tabel r_{tabel} rtabel of 0.361. This shows that each question is quite capable of measuring the concept or competency intended in each chapter. However, there is variation in the level of validity between the questions, which is illustrated by the different colors on the heatmap. Some questions, such as numbers 4 and 7 in CHAPTER I and number 7 in CHAPTER III, show very high validity values, which means that these questions are very effective and reliable in assessment. On the other hand, questions such as number 5 in CHAPTER II and number 8 in CHAPTER III have relatively lower validity values, even though they still meet the minimum validity criteria. This may indicate that there is room for improvement or refinement of the questions to better align with the learning objectives. In addition, this heatmap provides insight into the consistency of the assessment instruments used in each chapter, which generally shows that these instruments are quite good and can provide valid assessment results. Therefore, this instrument can be used with confidence in the context of educational evaluation, although revision or refinement of questions with lower validity could be considered to further improve the quality of the assessment.

Furthermore, the reliability values of the assessment instruments for each chapter are presented in the diagram below

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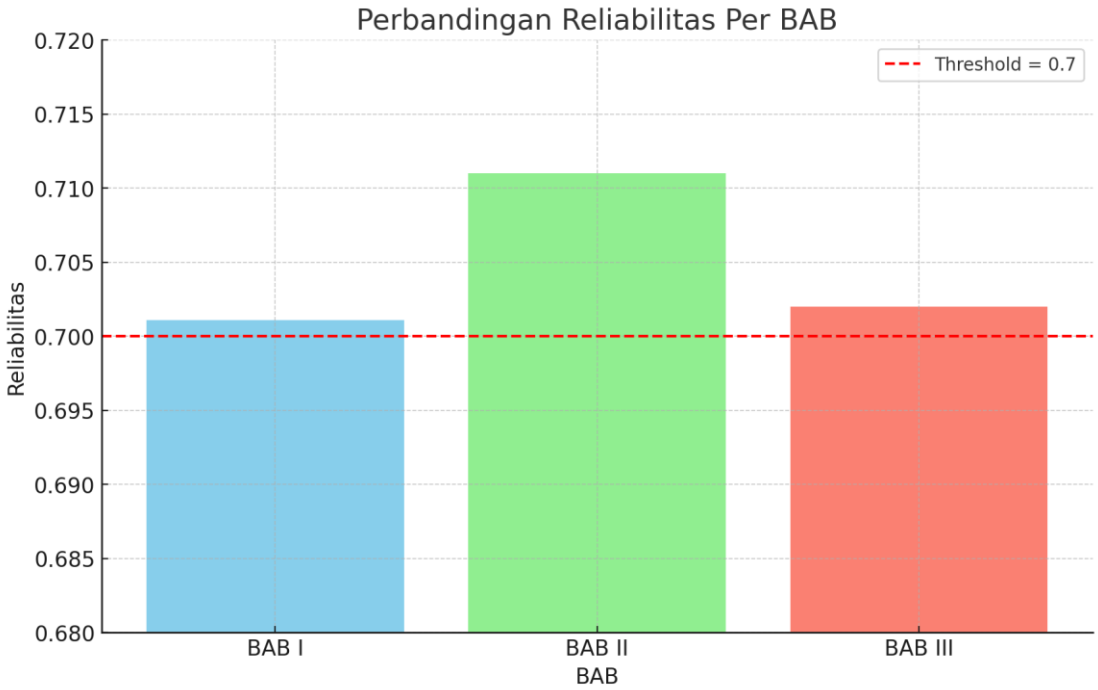

Fig 9. Reliability test results

In this graph, each bar represents a reliability value for a chapter, and the values are displayed numerically above each bar. The dotted red line shows the minimum accepted reliability threshold value, namely 0.7, which serves as a reference for determining whether the instrument has sufficient consistency.

CHAPTER I shows a reliability value of 0.7011, which is slightly above the threshold, indicating that this assessment instrument has met the minimum requirements for consistency but still has room for further improvement in order to increase its reliability. CHAPTER II has the highest reliability value of 0.711, indicating that the assessment instrument is very consistent and reliable for measuring the variable in question. This value reflects good stability in the assessment results, which is very important to ensure measurement accuracy. CHAPTER III, with a reliability of 0.702, also exceeds the threshold and shows adequate consistency, although still slightly lower than BAB II.

Overall, this graph shows that all assessment instruments in the three chapters have quite good reliability and are reliable. However, further improvements to Chapters I and III can be made to achieve a more optimal level of reliability. By achieving higher reliability, these instruments can provide more consistent and accurate results, which is important for appropriate and effective evaluation in educational contexts.

After getting the validity and reliability value of the product in the form of an e-quiz, it gets a practicality value as seen in the graph below:

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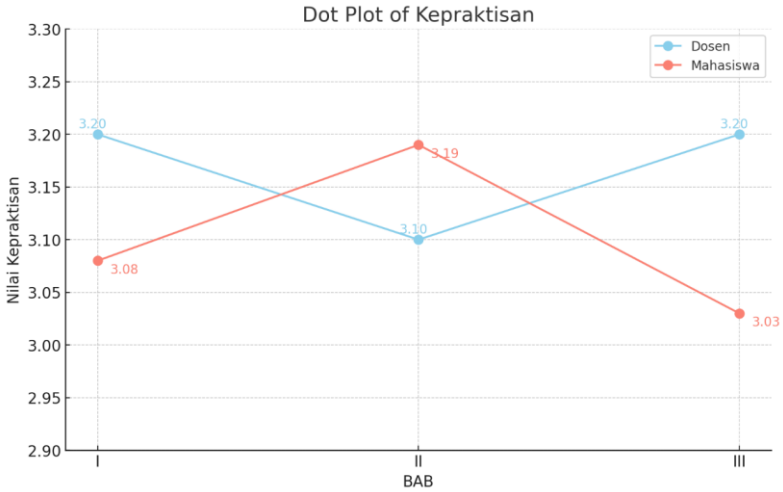

Fig10. Practical value results

The Dot Plot graph above presents the assessment of the practicality of the instrument by lecturers and students for each chapter (CHAPTER I, CHAPTER II, and CHAPTER III). Each point on the graph represents the practicality score given by both groups, with connecting lines showing changes in scores between chapters. In CHAPTER I, the lecturer gave a practicality score of 3.20, while students gave a slightly lower score, namely 3.08. This shows that both groups consider this instrument to be quite practical, although there are slight differences in their perceptions. In CHAPTER II, students gave the highest score among the three chapters, namely 3.19, which shows an increase in practicality assessment compared to CHAPTER I. The lecturer gave a score of 3.10, which also shows that the instruments in this chapter are considered practical, even though it is lower than the students' assessment. In CHAPTER III, the lecturer again gave a score of 3.20, showing consistency in assessing practicality throughout the chapters. Students gave a score of 3.03, which is lower than their assessment in BAB II but still in the practical category. This Dot Plot graph provides a clear view of the differences in practicality assessments between lecturers and students. Student assessments tend to show greater variation between chapters, while lecturer assessments are more consistent. This shows that there are differences in perceptions regarding the practicality of the instrument between the two groups, which can be an important consideration in evaluating and developing assessment instruments.

DISCUSSION

The results of this research indicate that the assessment instrument developed is valid and reliable for assessing students in the mathematics study program at Medan State University in the Field and Space Geometry course. In CHAPTER I, the lecturer gave a practicality score of 3.20, while students gave a score of 3.08. For BAB II, students rated the highest practicality with a score of 3.19, while the lecturer gave a score of 3.10. Meanwhile in CHAPTER III, the practicality assessment from the lecturer was again at 3.20 and students gave a score of 3.03. This assessment shows that the instrument used is quite practical, with the average value of both groups being above the minimum threshold. Consistent assessments from lecturers and students in the three chapters show that this instrument has met the practical criteria expected in the learning context.

Previous research conducted by Kaitelidou et. al (2019) and Boateng et. al (2018) also focus on evaluating the practicality of assessment instruments in higher education settings. Kaitelidou et. al (2019) found that instruments with a clear structure and well-defined objectives tended to receive more positive ratings from users. Meanwhile, Booateng et. al (2018) highlights the importance of involving various stakeholders in the instrument evaluation process to increase relevance and acceptability. These two studies support the finding that instruments that are considered practical are not only effective in measuring learning outcomes but are also well received by users, both lecturers and students.

However, the weakness of previous research is the lack of in-depth comparative analysis between lecturer and student perceptions (Gómez-Rey, Barbera, and Fernández-Navarro 2018). Smith et al. focuses more on the lecturer's perspective, while Johnson & Lee focuses more on quantitative results without deeper exploration of the factors that influence student assessment. Additionally, previous research often does not take into account differences in cultural context and curriculum that may influence the perceived practicality of assessment instruments.

The advantage of this research is its holistic approach which involves assessments from two main user groups, namely lecturers and students, to get a more comprehensive picture of the instrument's practicality (Thalhah, Tahrim, and Sari 2022). This study also highlights differences in perceptions between the two groups, which may serve as a basis for improving instrument design in the future. By using comparative analysis methods, this study provides deeper insight into how each group assesses the practicality of the instruments, and why such differences may occur. This allows researchers to identify specific areas of improvement and provide more targeted recommendations for improving assessment instruments.

Overall, this research shows that the assessment instruments used are quite practical and well received by lecturers and students. These results are in line with findings from previous research, but this research manages to add a new dimension by exploring differences in perceptions between user groups. By understanding these differences, educators and instrument developers can make appropriate adjustments to increase the effectiveness and acceptability of the instruments. Therefore, this research not only contributes to the academic literature but also offers important practical implications for the future development of assessment instruments. This research also emphasizes the need for a more inclusive and contextual approach in evaluating the practicality of assessment instruments to reflect the needs and expectations of all stakeholders involved.

CONCLUSIONS

This research succeeded in developing a computer-based assessment instrument using Articulate Storyline for the Plane and Space Geometry course, which significantly improves the quality and efficiency of the evaluation process by providing an interactive and comprehensive evaluation of students' mathematical spatial abilities. The research results show that the instrument developed has high validity and reliability, and received a positive response from students and lecturers, supported by the students' ability to utilize digital devices and adequate network access. However, this research was limited to three of the six planned material chapters and was only conducted at one institution, so the generalizability of the results needs to be investigated further. In addition, network access problems for a small number of students highlight the need to improve supporting

infrastructure. Therefore, it is recommended that future research cover the entire material, expand the application in various institutions to test the validity of the instrument in different contexts, and explore the long-term impact of the use of technology in educational assessment on student learning outcomes. These findings contribute significantly to the development of innovative assessment methods relevant to developments in educational technology, paving the way for further improvements in the quality of higher education.

CONFLICTS OF INTEREST STATEMENT

The authors declare no conflicts of interest related to the content of this manuscript. All co-authors have reviewed and approved the final version of the manuscript. Furthermore, the authors affirm that there are no financial interests to disclose. This manuscript is original and has not been submitted for publication elsewhere.

AUTHOR CONTRIBUTIONS

Ade Andriani conceptualized the research idea and developed the theoretical framework. **Izwita Dewi** was responsible for data collection and initial analysis. **W.L Sihombing** provided expert guidance, contributed to the interpretation of findings, and supervised the overall research process. All authors actively discussed the results and contributed to writing and refining the final manuscript.

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