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StatCom Android Mobile-Based Teaching Materials: Enhancing Statistical Reasoning

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ABSTRACT

Statistical reasoning is a crucial mathematical competency that students often lack. While there have been studies on the use of Android teaching materials in statistics learning, few have focused on statistical reasoning using comic media. This study aimed to develop mobile Android-based teaching materials called StatCom to enhance students' statistical reasoning in schools. The ADDIE framework was employed for this purpose. The study involved 40 high school students (aged 15-17 years) in Indramayu, Indonesia. The main instruments included teaching materials based on mobile Android StatCom and statistical reasoning questions. Data analysis techniques, such as paired sample t-tests, were used. The results indicated that students benefited from interactive teaching materials like mobile Android StatCom. The teaching materials and supporting instruments demonstrated validity (tobs = 5,784 > ttable = 1,777 for pretest and tobs = 5,114 > ttable = 1,721 for post-test) and reliability (rpre = 0,777 and rpost = 0,745). The trial results confirmed the feasibility and practicality of the mobile Android StatCom-based teaching materials. Furthermore, the implementation of these materials effectively optimized students' statistical reasoning (t value = 15,686 with a significance value of 0,000). Future research could explore the impact of mobile Android StatCom-based teaching materials on overall competence.

Keywords: ADDIE, Mobile Android StatCom, Statistical Reasoning, Teaching Materials

INTRODUCTION

Statistical reasoning is a critical skill that involves analyzing data, identifying patterns, and drawing valid conclusions, making it essential in various fields (Fielding, 2024). It requires individuals to think critically about data, evaluate information (Lu et al., 2024), and make informed decisions (Sumpter & Hedefalk, 2018). Statistical reasoning is crucial for problem-solving and updating beliefs based on new evidence (Shepherd, 2021). Despite its importance, students often struggle with basic statistical concepts (Mason & Zaccoletti, 2021; Chowdhury & Shil, 2021), hindering their understanding of more complex topics (Manunure et al., 2020). Factors contributing to this include memorization-focused learning methods (Yeo & Fazio, 2019; Vu & Do, 2021) and teaching materials that do not prioritize statistical reasoning (Shepherd, 2021). To address this issue, leveraging digital technology, such as Android-based smartphones, can be a viable solution due to their accessibility and features (Chandran et al., 2022; Griol et al., 2017).

While several studies have explored the impact of technology (Papadakis, 2020; Papadakis & Orfanakis, 2018; Zourmpakis et al., 2023) or Android-based teaching materials on students' mathematical competence, limited research has specifically focused on statistical reasoning. For instance, Aziz and Amidi (2021) developed interactive Android-based learning media for statistics, demonstrating its validity and suitability for mathematics learning. The results of the study reveal that Android-based interactive learning media is proven to be valid and effective in optimizing students' understanding in statistics learning.

Similarly, Astuti et al. (2022) utilized the ADDIE design to assess the effectiveness of the Android-based smartphone *"mbarengi"* in learning. The study concludes that Android-based Mbarengi is valid and effective in optimizing student motivation and engagement in learning. Mulyono et al. (2023) employed the Plomp model to create Android-based learning media, showing positive outcomes on students' learning and attitudes. The results of the study reveal that Android-based learning media are proven to be valid, practical, and effective in optimizing students' learning outcomes, motivation, and positive attitudes in statistics learning. In summary, current research aims to fill the gap in understanding the impact of Android-based teaching materials on statistical reasoning, building on previous studies that primarily focused on mathematical competence, as shown in **Table 1.**

Table 1. Age distribution of the respondents

Research Article	Ability	Research Procedure	Technology
Aziz and Amidi (2021)	Mathematical understanding	Analyzing the needs to be developed, developing initial products, product validation, and revision (ADVR)	Android-based interactive learning media
Astuti et al. (2022)	Student motivation and engagement	Analyze, design, develop, implement, and evaluate (ADDIE)	Android *(mbarengi)*
Mulyono et al. (2023)	Mathematics achievement	Exploration, development, assessment, and application (EDAA)	Android *(stamulation)*
Zourmpakis et al. (2023)	Basic scientific concepts, motivation and learning participation	Quantitative experiments	Adaptive gamification systems and interactive digital platforms
Papadakis (2020)	Computational thinking and conceptual understanding	Quasi-experiments	Educational games and visual programming modules
Current research	Statistical reasoning	Analyze, design, develop, implement, and evaluate (ADDIE).	Android (statistics comic)

This study aims to develop mobile Android statistics comic (StatCom)-based teaching materials to enhance statistical reasoning among students. Comics have been shown to engage students and increase their motivation to learn (Farhan et al., 2024), which can lead to improved mathematical competencies (Johar et al., 2023; Widyasari & Nurcahyani, 2021), including statistical reasoning. The research questions guiding this study are as follows:

RQ1. How does the description of the need for statistical teaching materials enhance students' statistical reasoning?
RQ2. What are the components of the mobile Android StatCom-based teaching module?
RQ3. What is the evidence of validation and reliability estimation of the instruments that support mobile Android StatCom-based teaching materials?
RQ4. What is the description of mobile Android StatCom-based teaching materials?
RQ5. What are the results of the trial of mobile Android StatCom-based teaching materials?
RQ6. What is the impact of ile Android StatCom-based teaching materials on enhancing statistical reasoning skills?
RQ7. How do the evaluation results of developing mobile Android StatCom-based teaching materials enhance statistical reasoning skills?

METHODOLOGY

Research Design

This study utilized a development method following the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) design. The ADDIE design was chosen for its detailed and comprehensive nature, particularly suitable for developing teaching materials or learning designs for school teachers. The ADDIE design was a systematically structured model with two important steps, namely design and development, making it suitable for this study as it aimed to develop teaching materials in the form of innovative products, specifically Android-based digital comics. The ADDIE design also encouraged the integration of technology in learning, aligning with the objectives of this study to develop Android-based learning media. In addition, the ADDIE design facilitated the development of media based (Ge, 2020) on learning needs and objectives, making it appropriate for this study, which aimed to improve statistical reasoning skills (Ali, 2021; Alzoebi et al., 2023; Winaryati et al., 2021).

The research stages included analysis, design, development, implementation, and evaluation. During the analysis stage, the researchers identified the need for teaching materials in statistics learning by testing students with statistical reasoning questions and interviewing them and teachers to understand their experiences. The design stage involved creating teaching modules and instruments with input from three validators. Development focused on creating teaching materials using the mobile Android StatCom and conducting feasibility and practicality tests with five experts and students. Implementation involved introducing the teaching material to students who had not yet studied statistics, considering curriculum alignment. The evaluation stage assessed the entire research process, from analysis to implementation, to determine the feasibility, practicality, and effectiveness of the mobile Android StatCom-based teaching materials. See **Figure 1** for an overview of the research stages.

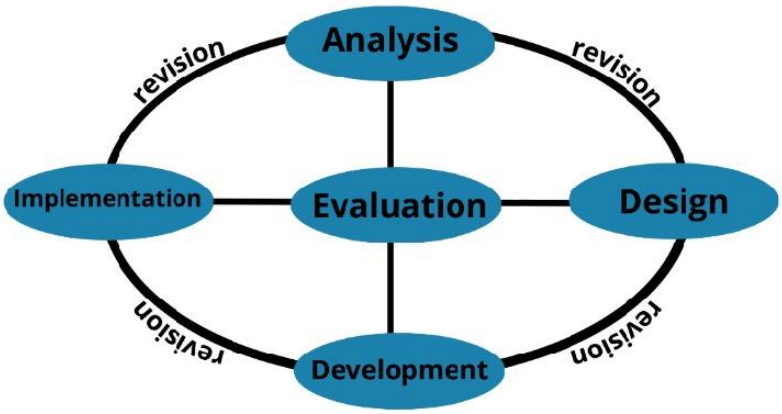

Figure 1. Research procedure

Participants

The study involved various groups of participants at different stages. In the analysis stage, three high school students from Indramayu, Indonesia, with varying levels of statistical reasoning were included, along with a high school mathematics teacher. Three validators participated in the second stage, while five experts in statistics, learning media, and pedagogy, as well as twelve students with different levels of statistical reasoning, were involved in the development stage. In the implementation stage, two groups of 40 students (aged 15-17), who had not studied statistics material were included. Research ethics were also fulfilled in this study. The researcher obtained permission from students and parents to include students as participants. The researcher explained in detail the purpose and procedures of the study to both students and parents, ensuring that participants understood their rights and obligations during the research activities. In addition, the researcher used initials when presenting data obtained from participants, especially data related to their deficiencies. This was intended to protect their identity and preserve their reputation. Finally, the researcher ensured that all data presented were actual and had been confirmed by the participants before being displayed. This was done to prevent misinformation and violations of participant rights.

Instrumentation and Data Collection Procedure

Several instruments were used to collect data throughout the study. In the analysis stage, three instruments were utilized to assess the need for teaching materials: statistical reasoning questions, student interview guidelines, and teacher interview guidelines. In the design stage, an expert validation sheet was used to ensure content validity of the teaching modules. This validation aimed to ensure that the questionnaire instrument was relevant and comprehensive and covered all aspects that the questionnaire was intended to measure. Two instruments were employed in the development stage: an instrument feasibility questionnaire and a practicality questionnaire. The feasibility questionnaire assessed the concept clarity, learning objectives, design consistency, and language use, while the practicality questionnaire evaluated ease of implementation, effective time to usage, and facility suitability (Plomp & Nieveen, 2013). In the implementation stage, pretest and post-test questions were used to measure students' statistical reasoning. The evaluation stage involved the use of a 5W + 1H questionnaire to comprehensively evaluate the research stages.

Data Analysis Procedure

In this study, various analysis techniques were employed. Firstly, qualitative data analysis was conducted using *Atlas.ti* to simplify the coding process during the analysis stage. Secondly, Aiken's V method supported by SPSS, was utilized for data analysis during the design stage. Experts evaluated an instrument's content validity using Aiken's V method. Aiken's V method was impacted by the researcher's ultimate choice of instrument. The instrument was deemed valid or relevant and deserving of being used to assess statistical reasoning skills if the V value was near 1. Thirdly, parametric (paired sample t-test chi-squared tests) and non-parametric (Wilcoxon rank test), also supported by SPSS, were employed to analyze data collected during the development stage. Fourthly, a difference test was conducted to analyze pretest and post-test data gathered during the implementation stage. Lastly, qualitative data analysis was used to analyze responses from the 5W + 1H questionnaire administered during the evaluation stage.

RESULTS

Analysis

How does the description of the need for statistical teaching materials enhance students' statistical reasoning?

Data collection involved providing statistical reasoning questions to students, followed by interviews with students and teachers to identify the need for teaching materials. The data was analyzed using *Atlas.ti*. The analysis revealed that statistics learning was primarily conducted through conventional methods, which were found to be ineffective in enhancing students' conceptual understanding. Teachers relied on simple media like PowerPoint and calculators, and direct explanations rather than encouraging independent concept exploration. Student interviews indicated a lack of understanding of basic statistical concepts, leading to errors in problem-solving due to incorrect solution processes and misconceptions.

Students expressed a preference for active and interactive learning, yet Android-based media was not utilized in the teaching process. Developing Android-based teaching modules was seen as an innovative solution to enhance statistical understanding. These modules could offer engaging data visualizations, interactive practice questions, and step-by-step problem-solving guides. They also enabled independent learning and the strengthening of statistical reasoning skills. Therefore, the development of Android-based teaching modules was deemed essential for improving the effectiveness of statistics learning and addressing students' conceptual challenges (**Figure 2**).

Design

What are the components of the mobile android StatCom-based teaching module?

In the design stage, the researchers developed a teaching module as a framework for StatCom-based Android mobile teaching materials. The teaching module was created following the school curriculum. The components of the teaching module can be seen in **Table 2**, which outlines the completeness of the module from identity to assessment. The module was designed for two sessions with learning objectives tailored to research requirements. These objectives focused on problem-solving using single and group data averages, as well as single and group data modes.

Table 2. Description of the statistics teaching module

Components	Content
Compiler Name	Full Name
Educational Unit	High School Equivalent
Phase/Class	E/X
Subject	Mathematics
Element	Data Analysis and Probability
Material	Statistics
Time Allocation	4 Learning Hours
Initial Competence	Dispersion and Tendency Statistics
Student Profile	Critical thinking in reasoning statistical understanding for everyday life applications. Creative in using statistical reasoning.
Facilities and Infrastructure	StatCom
Target Students	Regular students
Learning Model	Statistical learning reasoning environment
Learning Objectives	D.1 Solving problems with single data averages. D.2 Solving problems with group data averages. Solving problems with single data modes. Solving problems with group data modes.
Meaningful Understanding	Statistical reasoning skills are needed in decision making, especially in the concepts of averages and modes that are often applied in everyday life.
Initiator Questions	If you shop, play, or other things to choose a decision, what should you do?
Meeting 1 (2 JP)	Main Material: Average Learning Objectives: D.1 & D.2 Learning Steps: ▪ Introduction: Greetings, motivation, apperception, learning objectives, introduction to StatCom. ▪ Core: Problem-solving based learning through the StatCom application. ▪ Closing: Reflection, and information for the next learning.
Meeting 2 (2 Learning Hours)	Main Material: Mode Learning Objectives: D.3 & D.4 Learning Steps: ▪ Introduction: Greetings, motivation, apperception, learning objectives. ▪ Core: Problem-solving based activities with LKPD and StatCom. ▪ Closing: Reflection, information for the next learning.
Assessment	Formative: Answers to practice questions uploaded on StatCom. Summative: Written tests before and after learning. Remedial: Re-learning and peer tutoring. Enrichment: Average and Mode.

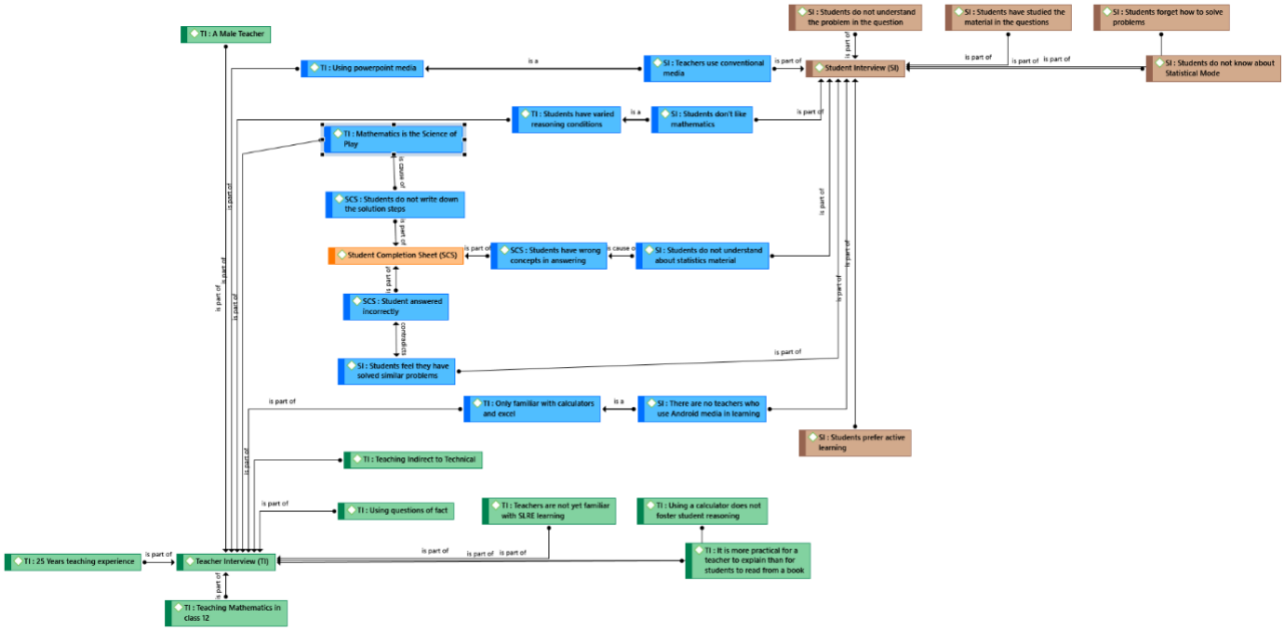

Figure 2. Results of the analysis of teaching material needs for statistics learning

What is the evidence of validation and reliability estimation of the instruments that support mobile Android StatCom-based teaching materials?

In addition to developing a teaching module, the researchers created instruments to support the implementation of the teaching materials. These instruments were designed to be feasible, practical, and effective. The instruments included both test and non-test components, which underwent content validity assessment by three expert lecturers with doctoral degrees in learning evaluation. The validation results were analyzed using *Aiken's V*, with the calculation resulting in $v = \frac{\sum s}{n(c-1)} = \frac{102}{120} = 0{,}85$; indicating a valid instrument. The validation results are summarized in **Table 3**.

Table 3. Validation results of the feasibility of the mobile android-based teaching module StatCom

Statement Item	Experts			S1	S2	S3	ΣS	n (c- 1)
	E1	E2	E3					
1st	5	4	5	4	3	4	11	12
2nd	4	4	4	3	3	3	9	12
3rd	5	5	4	4	4	3	11	12
4th	5	4	4	4	3	3	10	12
5th	5	4	4	4	3	3	10	12
6th	5	5	4	4	4	3	11	12
7th	4	5	4	3	4	3	10	12
8th	5	5	4	4	4	3	11	12
9th	4	4	4	3	3	3	9	12
10th	4	5	4	3	4	3	10	12
	Validation						102	120

Furthermore, the validation results of the student response questionnaire, teacher observation sheet, and teaching staff questionnaire are presented in **Table 4**, **Table 5**, and **Table 6** respectively. In **Table 4,** the value of $v = \frac{\sum s}{n(c-1)} = \frac{100}{120} = 0{,}83$ indicating that the student response questionnaire is valid as v > 0,08. Similarly, in Table 5, the value of $v = \frac{\sum s}{n(c-1)} = \frac{102}{120} = 0{,}85$; confirming the validity of the teacher observation sheet. **Table 6** shows a value of $v = \frac{\sum s}{n(c-1)} = \frac{103}{120} = 0{,}86$; indicating that the teaching staff questionnaire is also valid as v > 0,80.

Table 4. Student response questionnaire validation results

Statement Item	Experts			S1	S2	S3	ΣS	n (c- 1)
	E1	E2	E3					
1st	4	5	5	3	4	4	11	12
2nd	4	5	4	3	4	3	10	12
3rd	4	5	4	3	4	3	10	12
4th	4	5	4	3	4	3	10	12
5th	4	5	4	3	4	3	10	12
6th	4	5	4	3	4	3	10	12
7th	4	5	4	3	4	3	10	12
8th	3	5	4	2	4	3	9	12
9th	4	4	4	3	3	3	9	12
10th	5	5	4	4	4	3	11	12
	Validation						100	120

Table 5. Teacher observation sheet validation results

Statement Item	Experts			S1	S2	S3	ΣS	n (c- 1)
	E1	E2	E3					
1st	5	4	4	4	3	3	10	12
2nd	4	5	4	3	4	3	10	12
3rd	5	5	4	4	4	3	11	12
4th	4	4	4	3	3	3	9	12
5th	5	5	4	4	4	3	11	12
6th	5	5	4	4	4	3	11	12
7th	4	5	4	3	4	3	10	12
8th	4	5	4	3	4	3	10	12
9th	4	5	4	3	4	3	10	12
10th	4	5	4	3	4	3	10	12
	Validation						102	120

Table 6. Results of validation of teaching staff questionnaire

Statement Item	Experts			S1	S2	S3	ΣS	n (c- 1)
	E1	E2	E3					
1st	4	5	4	3	4	3	10	12
2nd	4	4	4	3	3	3	9	12
3rd	5	5	4	4	4	3	11	12
4th	5	5	4	4	4	3	11	12
5th	5	5	4	4	4	3	11	12
6th	5	5	4	4	4	3	11	12
7th	4	5	4	3	4	3	10	12
8th	5	5	4	4	4	3	11	12
9th	4	4	4	3	3	3	9	12
10th	4	5	4	3	4	3	10	12
	Validation						103	120

The researchers conducted validation stages for statistical reasoning questions, dividing them into logical and empirical stages. Logical validation involved expert assessments on indicator suitability, content, and language. Empirical validation tested the instrument on high school students who had studied statistics to estimate reliability. Results of logical validation were presented in **Table 7**, and empirical validation results in **Table 8**. The reproducibility coefficient was calculated as $(C_r) = 1 - \frac{e}{n} = 1 - \frac{0}{90} = 1$, indicating high reproducibility. The

scalability coefficient was also calculated as $(C_s) = 1 - \frac{x}{n} = 1 - \frac{0}{0{,}5\ x\ 90\ x\ 3} = 1$, showing good scalability. With reproducibility and scalability coefficients meeting criteria, the statistical reasoning questions were deemed valid. **Table 8** confirmed empirical validity evidence and reliability estimates for the instrument.

Table 7. Results of logical validation of statistical reasoning questions

Instrument Item	Experts			Valid Answers	Total Valid Answers	Total Valid Answers
	E1	E2	E3			
1st	1	1	1	3	9	3
2nd	1	1	1	3	9	3
3rd	1	1	1	3	9	3
4th	1	1	1	3	9	3
5th	1	1	1	3	9	3
6th	1	1	1	3	9	3
7th	1	1	1	3	9	3
8th	1	1	1	3	9	3
9th	1	1	1	3	9	3
10th	1	1	1	3	9	3
Total Correct Answers					90	30
Total Wrong Answers (Error)					0	
N					90	

Table 8. Empirical validation results and reliability of statistical reasoning questions

Question Item	r_{XY}	t_{obs}	t_{tabel}	Decision	Question Item	r_{XY}	t_{obs}	t_{tabel}	Decision
	Pretest					Post-test			
1st	0,667	4,200		Valid	1st	0,695	4,436		Valid
2nd	0,733	5,048		Valid	2nd	0,692	4,393		Valid
3rd	0,827	6,896	1,717	Valid	3rd	0,846	7,259	1,721	Valid
4th	0,792	6,091		Valid	4th	0,771	5,39		Valid
5th	0,748	5,280		Valid	5th	0,540	2,939		Valid
	r_{11}	t_{obs}	t_{tabel}	**Decision**		r_{11}	t_{obs}	t_{tabel}	**Decision**
	0,777	5,784	1,717	Reliable		0,745	5,114	1,721	Reliable

Development

What is the description of mobile Android StatCom-based teaching materials?

StatCom is a digital teaching material accessible via smartphones. It aims to help students enhance their statistical reasoning skills during learning. The material includes content on average and mode and utilized the statistical reasoning learning environment model. StatCom features four main menus: *Tujuan* (learning objectives), *Materi* (content presented in comic form), *LKPD* (student worksheets), and Latihan Soal (practice questions). Various applications like *Stylar.ai, D-id Studio, kdular.io, Canva, VN, YouTube,* and *Google Form* were used in creating this media. The initial display of the StatCom menu can be seen in **Figure 3**.

The *Tujuan* menu featured an explanatory video illustrating the learning objectives. The video presented in an animated format on *YouTube,* provided explanations for the average and mode materials. The display on the *Tujuan* menu can be seen in **Figure 4.** The *Materi* menu included comics that students could read to aid in understanding the material. There were two comics available: one for the average material in the first meeting and another for additional material in the second meeting. An example of a comic from the teaching material is shown in **Figure 5**.

Figure 3. Main view of the android mobile-based teaching material StatCom

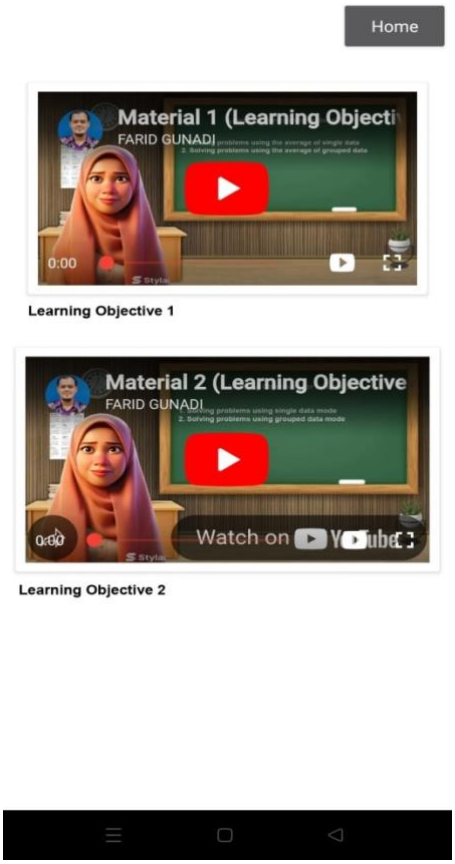

Figure 4. View for *Tujuan* menu

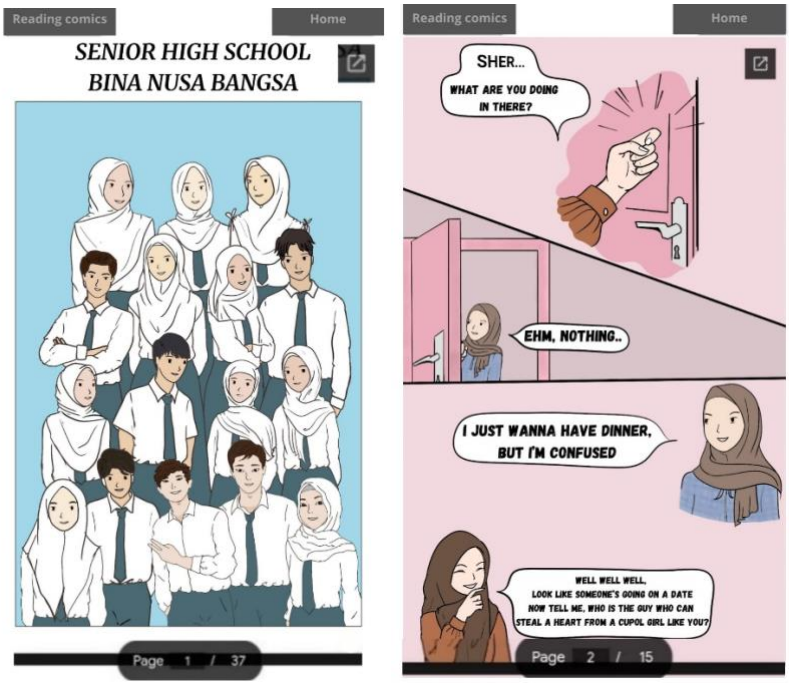

Figure 5. Example of the initial appearance of the comic

The *LKPD* menu was utilized by students for accessing and uploading answers, as well as summarizing the stories in the *Materi* (comic). Students completed the *LKPD* by reading the comic thoroughly and filling in the answers according to the instructions provided in the comic. To support students' cognitive processes, teachers also distributed a printed version of the *LKPD* for students to make notes. This approach aimed to enhance comprehension and reinforce the learning process. Additionally, students' responses and notes were uploaded to the *LKPD* menu. An illustration of the menu interface is shown in **Figure 6.**

Students used the *Soal Latihan* menu to answer questions after summarizing and uploading the *LKPD*. They were provided with printed practice questions to work on by hand, which served as authentic evidence for their statistical reasoning. An example of the *Soal Latihan* menu display is shown in **Figure 7**.

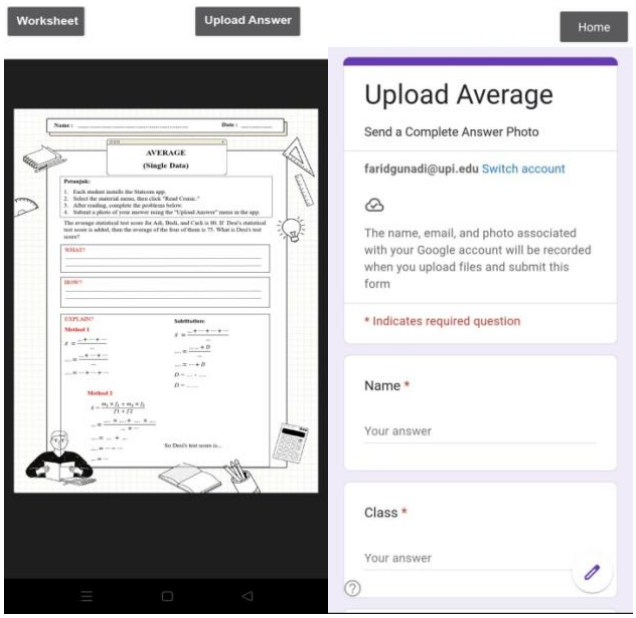

Figure 6. Example of *LKPD* menu display

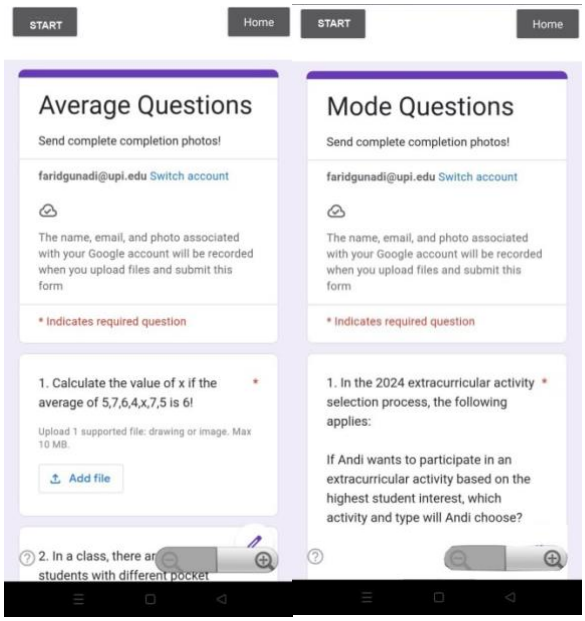

Figure 7. Example of the *Soal Latihan* menu display

What are the results of the trial of mobile Android StatCom-based teaching materials?

The trial of mobile Android StatCom-based teaching materials was evaluated by three experts in the fields of learning media, statistics, and pedagogy to determine their feasibility. The experts were given a questionnaire to assess the teaching materials, and a Chi-Square test was conducted to validate their feasibility. The analysis using SPSS yielded a chi-square value of 42,667 with a significance value of 0,000, indicating that the teaching materials were deemed feasible for statistical learning. A practicality test was then conducted with a mathematics teacher as the instructor, an observer, and students providing feedback after using the mobile Android StatCom-based teaching materials. The practical criteria required that the percentage of learning objectives achieved is over 75%. The results showed that the average percentage for each respondent exceeded 75%, indicating that the teaching materials were practical from the perspectives of teachers, observers, and students.

Table 9. Percentage of practicality of teaching materials

Category	Student Response		Teacher Response		Observer Response	
	N	Percentage	N	Percentage	N	Percentage
1 (Not Practical)	3	1%	0	0%	0	0%
2 (Less Practical)	26	8%	0	0%	0	0%
3 (Quite Practical)	54	16%	0	0%	0	0%
4 (Practical)	186	54%	2	20%	3	15%
5 (Very Practical)	76	22%	8	80%	17	85%
4+5 (Limit of Practical)		76%		100%		100%

Implementation

What is the impact of implementing mobile Android StatCom-based teaching materials on enhancing statistical reasoning skills?

In one sample group, the data was not normally distributed, so the *Wilcoxon rank* test was used for data analysis. The results from SPSS showed a *Z* value of -4,017 with a significance level of 0,000. Since the significance value was less than 0,05, it was concluded that the mobile Android StatCom-based teaching materials were effective in enhancing students' statistical reasoning. For the second sample group, the data was normally distributed, and the *Shapiro-Wilk* test was employed. The analysis in SPSS revealed a t value of 15,686 with a significance level value of

0,000. Again, with a significance value below 0,05, it was concluded that the mobile Android StatCom-based teaching materials were effective in improving students' statistical reasoning. An example of the SPSS output is shown in **Table 10.**

Table 10. SPSS output example

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Test After Treatment - Test Before Treatment	34,684	9,638	2,211	30,039	39,330	15,686	18	0,000

Evaluation

How do the evaluation results of developing mobile Android StatCom-based teaching materials enhance statistical reasoning skills?

At this stage, the researchers provided answers to various questions in **Table 11**, including *what was done, who the respondents were, when and where the implementation took place, why the stage was carried out, and the results obtained.*

Table 11. Results of research stage evaluation

	What?	Who?	When?	Where?	Why?	How?
A	Analyze product needs by means of statistical reasoning ability tests on students, student interviews, and teacher interviews.	Students who have studied statistical reasoning material and teachers who have taught statistical material.	This initial stage was carried out in October 2024.	The research location is at the high school level.	To get conclusions about product needs.	StatCom media-based teaching module products must be created to improve students' statistical reasoning.
D	Design StatCom teaching modules and media based on field needs.	Researchers are directly involved in making and involving professional services.	This design stage was carried out in November-December 2024.	The research location is at the high school level.	The initial product design is in the form of StatCom teaching modules and media.	The initial product was created as a basis for the need to improve statistical reasoning and then developed in the next stage.
D	Product development to meet the requirements of feasible and practical.	The feasibility test involves 3 experts, namely media experts, pedagogical experts, and material experts; Practical Test involves teacher practitioners, teachers as observers, and one small class.	Development stage conducted during December and January 2025.	The research location is the feasibility test online through focus group discussion, and the practical test takes a small class at a senior high school.	Meets the criteria for a feasibility and practical product.	StatCom teaching modules and media meet the criteria for practical and effective.
I	Products must meet the criteria for effective.	The test involves two class samples at different schools.	The implementation stage is conducted during January 2025.	Two senior high school.	Meets the criteria for effectiveness to achieve learning objectives.	StatCom teaching modules and media Effectively improve statistical reasoning.

DISCUSSION

This study highlights that statistics learning in secondary schools primarily relies on traditional methods, which may not effectively enhance students' conceptual understanding (Ersozlu. Usak, and Blake, 2022). Teachers often employ direct instruction and basic tools like *PowerPoint* and calculators, lacking guidance for students to explore concepts independently. This aligns with Garfield and Ben-Zvi's (2007) research advocating for problem-solving approaches and interactive technology to enhance statistical comprehension. Their findings underscore the inadequacy of conventional methods in fostering robust statistical reasoning, emphasizing the need for a more exploratory learning environment. Other studies (Setiawan et al., 2022; Tan et al., 2023) also indicate a prevalence of traditional teaching practices in statistics learning, with limited use of student-centered interactive approaches. Teachers commonly rely on direct explanations in face-to-face sessions (Casem, 2016), often due to their limited familiarity with technology suitable for statistics instruction (Suhermi & Widjajanti, 2020; Tam et al., 2024).

The study results indicate that students have a preference for active and interactive learning methods. This finding is consistent with previous research by Pfaff and Weinberg (2009), who found that students enjoy interactive learning in statistics education. Similarly, other studies (Aziz & Amidi, 2021; Hazudin et al., 2020; Marsan et al., 2016) have shown that active learning enhances students' enthusiasm, interest, motivation, and learning outcomes in mathematics. Active involvement in learning, both mentally and through hands-on activities, helps students grasp mathematical concepts deeply and apply them to real-world problems. This approach fosters cognitive development and enables students to utilize mathematical concepts effectively in everyday situations (Aziz & Amidi, 2021; Sulistyaningsih et al., 2018; van Keulen, 2018).

The study's results indicate a shift towards active and interactive learning in statistics education. The development of teaching materials for statistics learning on Android StatCom aims to enhance students' statistical reasoning abilities. This aligns with the global trend of integrating technology into education, as research by Chance et al. (2007) has shown that technology-based software can improve students' understanding of statistical concepts through simulation and data visualization (Salami & Spangenberg, 2024). StatCom is designed to offer a more interactive and engaging learning experience, addressing the need for innovative approaches in statistics education.

The results of this study also support the idea presented by Mulyono et al. (2023) that incorporating Android teaching materials in statistics learning can enhance students' mathematical skills. Android-based learning aids in visualization through diverse visual elements within the application. The interactive questions and clear instructions in Android-based learning make it appeal to students. Moreover, the flexibility of using Android teaching materials anytime and anywhere promotes independent learning, leading to improved student competence (Romadiah et al., 2022).

The Android-based teaching module used in this study is structured according to the components of the current curriculum. The module includes general information, such as the creator's name, educational unit, and class level, as well as core information like learning objectives, meaningful understanding, trigger questions, study materials, and assessments (Senjayawati et al., 2025). Previous studies on teaching modules often follow curriculum guidelines to develop effective learning materials for mathematics education in schools (Isnawan et al., 2025; Sridana et al., 2025.

Researchers developed Android StatCom mobile-based teaching materials and conducted trials on supporting instruments. The trial results showed that all instruments used were valid and reliable. This ensures trust in the research results for readers and future researchers (Hasnida & Ghazali, 2016; Mohamad et al., 2015). The teaching materials were developed using the statistical reasoning learning environment learning model to create an interactive learning environment for students (Conway et al., 2019). The StatCom app includes menus for objectives (*Tujuan), materials (Materi), worksheets (LKPD),* and practice questions (*Soal Latihan),* Aligning with learning theory principles. These components are essential for effective learning and assessment (Rhodes et al., 2024; Sridana et al., 2025; Sukarma et al., 2024; Yang & Xin, 2022).

StatCom utilizes learning videos to explain learning objectives, aiming to enhance students' understanding of the material. This approach aligns with previous research by Haq and Irawati (2022), highlighting the effectiveness of videos in simplifying complex information. Additionally, studies by Fathiyyah Firdaus & Marina Angraini (2023), Insorio et al. (2023), and Santagata et al. (2021) have shown that learning videos make the learning process more engaging and interesting for students. Moreover, the material menu on StatCom incorporates comic media to spark students' interest and motivation in learning statistics. Research by Lestari et al. (2021) supports this approach, indicating that comic media can enhance students' motivation and positively impact their mathematical abilities. Similarly, studies by Farhan et al. (2024), Johar et al. (2023), and Widyasari & Nurcahyani (2021) have demonstrated that the use of comic media can improve students' reasoning skills in educational settings.

The *LKPD* includes activities for accessing and uploading comic story summaries related to statistical material. Students are expected to complete the *LKPD* while or after reading the comic. By writing in the *LKPD*, students are encouraged to develop a solid understanding of the statistical concepts being studied. Research by Sari et al.

(2019) supports the idea that *LKPD* is a valuable tool for students to discover and build mathematical concepts. Previous studies by Basuki and Wijaya (2018), and Deda and Maifa (2021) have also shown that using *LKPD* promotes students' independence in learning, leading to enhanced mathematical competence, including statistical reasoning skills. *LKPD* allows students to explore their ideas more freely during learning and encourages the use of various forms of representation, making the learning experience more engaging (Sridana et al., 2025).

The study also found that the StatCom mobile Android-based teaching materials passed the feasibility and practicality test, as indicated by a *chi-square* significance value of less than 0,05 and a learning objective achievement level of over 75% among trial students. This suggests that the teaching materials are suitable for classroom implementation (Darma et al., 2021). The effectiveness test, based on pretest and post-test data from two schools, demonstrated that the use of StatCom mobile significantly enhanced students' statistical reasoning. These findings align with previous research by Delmas et al. (2007), which showed that technology-based learning can lead to a deeper understanding of statistical concepts compared to traditional methods.

The study utilized a statistical reasoning learning environment-based approach, which aligns with previous research by Biehler, Frischemeier, and Shaughnessy (2018), indicating that problem-solving and exploration-based learning designs can enhance students' critical thinking skills in data comprehension. By engaging students in learning activities that pique their interest, such as exploring data, they become more involved in learning statistics. This heightened interest leads to improved competencies during the learning process (Conway et al., 2019; Showalter, 2021). The evaluation of the research stages using the 5W + 1H questions demonstrated that each stage effectively addressed the research questions, providing comprehensive information. The results of this study support the idea that interactive and technology-driven statistics learning is an effective approach to enhancing students' statistical reasoning abilities, as evidenced by numerous reputable studies (Aziz & Amidi, 2021; Mulyono et al., 2023; Romadiah et al., 2022).

The results of this study are also in line with Papadakis and Orfanakis (2018), who reveal that Android-based learning media provides real benefits in learning-such as improving the understanding of programming concepts through a visual and interactive approach. It is also more practical to use due to its compatibility with lower-end devices and its user-friendly design. Furthermore, interactive learning media support the development of students' cognitive skills. In addition, the study encourages further exploration of the impact of technology in broader learning contexts. Zourmpakis et al. (2023) also highlight that one of the keys to successful learning is the presence of engaging and interactive content. Their study recommends that StatCom be further developed into an adaptive gamification tool tailored to students' developmental stages and ability levels to optimize cognitive achievement in learning.

The findings are also in line with Papadakis (2020), who emphasizes that interactive, project-based, and technology-driven learning media significantly help students grasp abstract concepts such as statistics. Moreover, the study underlines that the systematic development and evaluation of learning media should consider not only the content but also usability and the overall impact on learning outcomes. Student involvement in the creation and use of game-based educational media can also enhance their logical and systematic thinking skills.

Although there is a significant increase in students' statistical reasoning abilities, this study emphasizes several critical factors that contribute to its success. First, the media used in this study are developed based on students' specific needs-particularly their direct needs in learning statistics. Second, the media are engaging and aligned with students' cognitive development. The high school students in this study enjoy reading comics, which is why the researchers use comics as the primary learning medium. Third, the media leverage Android or smartphone platforms, allowing students to feel as if they are simply using regular gadgets rather than engaging in formal learning.

The development of mobile-based teaching materials like StatCom is not only relevant to national education goals but also reflects global research trends. However, several considerations must be addressed before implementing Android-based comic learning media. Are teachers equipped to develop such teaching tools? Not all mathematics teachers possess strong technological skills (Chance et al., 2007; Suhermi & Widjajanti, 2020). Therefore, intensive training is essential for teachers to master these competencies. Additionally, do all students own smartphones? This challenge necessitates alternative solutions, such as providing printed versions of the comics and learning materials so that students without smartphones can still participate effectively in the learning process.

The broader pedagogical implications of the findings of this study include the transformation of learning methods, increased student engagement and motivation, the empowerment of independent learning, the strengthening of digital and visual literacy, the development of 21st-century skills, and improved inclusivity and accessibility. The transformation of learning methods refers to a shift from conventional approaches to interactive, multimodal, and mobile technology-based learning, aligned with students' increasingly visual learning styles. This shift implies that teachers need to develop ICT competencies and implement digital learning strategies. Increased engagement and motivation contribute to more student-centered learning environments. The empowerment of

independent learning necessitates curriculum and assessment systems that support flexible and personalized learning. Education must also broaden the concept of literacy beyond reading, writing, and arithmetic to encompass digital literacy, visual literacy, and adaptive thinking skills. Finally, inclusivity and accessibility underscore the role of digital media as a tool to uphold the principle of equity in education.

CONCLUSION

This study has demonstrated the effectiveness of using Android mobile-based teaching materials, specifically StatCom, in enhancing students' statistical reasoning skills. The findings from the needs analysis revealed that traditional teaching methods in statistics often lack interactivity, leading to difficulties for students in grasping fundamental concepts like mean and mode. By incorporating technology into the learning process, StatCom offers a more engaging learning experience through visualizations, interactive exercises, and a statistical reasoning-focused approach. The feasibility test results indicate that StatCom meets the validity (t_{obs} = 5,784 > t_{table} = 1,777 for pretest and t_{obs} = 5,114 > t_{table} = 1,721 for post-test), reliability (r_{pre} = 0,777 and r_{post} = 0,745), and practicality criteria, as assessed by material experts, media experts, and educators. The trial results confirmed the feasibility and practicality of the mobile Android StatCom-based teaching materials. Future research could explore the impact of mobile Android StatCom-based teaching materials. Moreover, the effectiveness test conducted at two schools showed a significant improvement in students' statistical reasoning skills after using StatCom. Statistical analyses, including *paired sample t-test* (t value = 15,686 with a significance value of 0,000); further support the conclusion that the Android-based digital teaching material positively impacts students' comprehension of statistical concepts. This study underscores the importance of integrating technology into statistics education as an innovative and effective strategy to address challenges in learning statistical concepts at the secondary school level. However, the study is limited in scope, focusing on basic statistical concepts. Further research could expand the content of the StatCom application and test it on a broader student population to ensure its sustained positive impact on students' mathematical proficiency in education.

Recommendation

This study recommends the use of StatCom to optimize student engagement and understanding of statistical concepts. StatCom also needs to be developed for more complex statistical concepts that are relevant to students. A larger population is used to test StatCom's effectiveness. Mathematics teachers receive training on how to integrate technology into learning. Finally, long-term evaluation and collaboration between researchers, educators, and developers are needed to ensure the sustainability of StatCom's use.

Suggestion for Future Studies

Future research should focus on developing StatCom to optimize students' understanding of more complex statistical concepts. Using larger populations and testing StatCom's effectiveness for various mathematical competencies are also expected to be explored in future research. Research exploring students' experiences using StatCom could also be a valuable resource for future research.

Limitations of the Study

This research only developed StatCom on basic statistical concepts, so its effectiveness on more complex statistical concepts is unknown. The sample used was also limited to a single region, so it cannot be generalized more widely.

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Competing Interests

The authors declare that they have no relevant financial or non-financial interests to disclose.

Author Contributions

Gunadi: conceptualization, analysis, and writing. Kusumah: design, editing/reviewing, critical revision of the manuscript, final approval, and securing funding. Juandi: data acquisition, data analysis/interpretation, technical or material support, and final approval. Dasari: data acquisition, admin, and supervision.

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