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Developing Digital Descriptive Statistics Modules Through Hybrid Flipped Classroom Learning to Improve Students' Statistical Thinking Skills

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ABSTRACT

This study addresses the challenge of enhancing statistical thinking among prospective mathematics students' through the development of interactive digital modules delivered via Android applications. Traditional learning resources in descriptive statistics often emphasize computational procedures at the expense of conceptual understanding and reasoning. Guided by the ADDIE (Analysis, Design, Develop, Implement, Evaluate) model within a research and development framework, this study designed and evaluated a digital module integrating learning activities, multimedia explanations, practice videos, exercises, and formative assessments. Validation by subject matter, media, and pedagogical experts indicated high levels of validity (0.90–0.91). Pilot and field trials demonstrated strong practicality (74.73% and 82.67%), while a paired sample t-test and N-Gain analysis confirmed significant improvements in students' statistical thinking skills, with effectiveness reaching 80.36%. These findings suggest that Android-based modules not only provide valid and practical learning resources but also deliver measurable learning gains. The study contributes to the growing body of research on mobile and technology-enhanced learning by highlighting the pedagogical potential of interactive digital modules in higher education, particularly in bridging the gap between procedural knowledge and conceptual reasoning in statistics education.

Keywords: Digital Module, Descriptive Statistics, Flipped Classroom, Hybrid Learning, Statistical Thinking.

INTRODUCTION

Statistical thinking skills are a core competency that prospective mathematics students' need to possess in order to design data-based learning, assess empirical evidence, and guide students in data literacy. Without this competency, prospective students' risk perpetuating statistical misconceptions and being unable to interpret or use data informatively in learning practices—ultimately impacting the quality of learning and educational decision-making (Soumyamol & Smitha, 2025). The literature emphasises that the development of statistical literacy and statistical thinking in students' plays an important role in improving the quality of teaching and data-based decision-making in schools (Pfannkuch & Ben-Zvi, 2011).

Empirical evidence shows that early-level students and prospective teachers often experience substantive difficulties with descriptive statistical concepts—including data presentation, histogram/table interpretation, understanding measures of central tendency and variation, and simple modelling—as reflected in the high frequency of misconceptions and procedural errors in studies examining descriptive statistical reasoning (Chan et al., 2016). Meta-studies and qualitative reviews state that errors in graphical interpretation and misconceptions about central tendency and variation are still prevalent among the student population (Boels et al., 2019).

Traditional approaches (lectures, printed modules, and static slides) are often ineffective for developing statistical thinking due to their lack of interactivity, limited real-time feedback, and limited opportunities for exploring real data. Therefore, interactive digital modules—especially those based on Android as a widely accessible mobile platform—offer advantages in terms of accessibility, multimedia, and interactive activities that support independent learning and concept repetition outside of face-to-face sessions (Naveed et al., 2023). Research on the development and evaluation of Android-based learning applications shows improved learning outcomes and instructional validity in various courses, thus supporting the selection of the Android platform for descriptive statistics modules (Lo et al., 2024).

The hybrid learning model combined with the flipped classroom shifts content-based learning to the independent phase (pre-class) so that face-to-face time can be focused on high-cognitive activities such as modelling, data discussion, and statistical reasoning—strategies that meta-analyses and systematic reviews have found to be effective in increasing engagement and learning outcomes in higher education (Kus, 2025; Baig & Yadegaridehkordi, 2023). To ensure instructional quality, systematic development frameworks such as ADDIE (Analysis, Design, Development, Implementation, Evaluation) are often used in educational R&D studies and digital media development because they provide structured methodological and procedural legitimacy in feasibility validation (Spatioti et al., 2022).

Although there have been studies on the effectiveness of flipped/hybrid learning and a number of studies on Android application development, a systematic review shows that there is relatively little research that specifically combines (a) Android-based digital modules, (b) hybrid flipped classroom implementation, (c) feasibility evaluation (expert and user validity), and (d) measurement of statistical thinking outcomes in a sample of prospective students—indicating a relevant research gap for the context of statistical education (Baig & Yadegaridehkordi, 2023; Mohamad Hasim et al., 2024). Therefore, this study aims primarily to assess the feasibility (content, design, technical, practicality, and effectiveness validity) of an Android-based descriptive statistics digital module developed according to the ADDIE model, and secondarily to measure changes in statistical thinking skills in 63 students after the hybrid flipped classroom intervention. The brief research questions/hypotheses proposed are, "Is the module considered feasible by experts and users (students and lecturers)?" and "Is there an increase in students' statistical thinking skills after using the digital module?"—which will be tested through feasibility assessments and pretest-posttest comparisons.

Beyond the local context, this study contributes to the global discourse on technology-enhanced learning by demonstrating how mobile-based instructional design can address persistent challenges in teaching statistics. The integration of Android-based modules within flipped–hybrid frameworks highlights a scalable and transferable model that can inform statistical education practices in diverse higher education systems worldwide.

LITERATURE REVIEW

Statistical thinking skills are understood as the capacity to understand, interpret, evaluate, and make critical generalisations about data and information from statistical analysis. Operationally, these skills encompass four main domains measured in this study, namely: (1) describing data, (2) organising and reducing data, (3) representing data, and (4) analysing and interpreting data—a framework consistent with the statistical education literature that emphasises the integration of concepts, representations, and application contexts in the development of statistical thinking in prospective students' (Ben-zvi & Garfield, 2004; Jones et al., 2000). The study of statistical learning theory and practice confirms that assessments that include tasks of graphical representation, interpretation of measures of central tendency/dispersion, and analysis of empirical contexts are most relevant for measuring this construct (Pfannkuch & Ben-Zvi, 2011).

In an effort to improve statistical thinking skills, an adaptive learning approach to technological developments is crucial. One strategy that is developing is hybrid learning, a model that integrates traditional face-to-face learning with technology-based online learning, as well as independent learning activities (Baig & Yadegaridehkordi, 2023; Méndez-Romero et al., 2023). This model emerged as a response to the Fourth Industrial Revolution, which demands the utilisation of digital technology in various aspects of life, including education. By utilising video conferencing platforms, digital modules, and online media, hybrid learning creates a collaborative, interactive, and flexible learning experience that supports digital literacy and student engagement (Breitschwerdt et al., 2025; Romero-Carbonell et al., 2023).

Furthermore, the flipped classroom has emerged as a specific form of hybrid learning implementation. This model reverses the traditional learning pattern by placing basic material exploration outside the classroom through digital modules or videos, while face-to-face time is focused on discussion, problem solving, and collaboration (Deng et al., 2024; Hussain et al., 2020). This approach gives students the opportunity to develop an initial understanding independently before class, so that face-to-face discussions can be directed towards reinforcing concepts and applying knowledge. A series of synchronous and asynchronous pre-class, in-class, and post-class activities allow students to hone their critical, collaborative, and reflective thinking skills (Mohamed & Lamia, 2018; Mizza et al., 2025; Aidoo et al., 2022).

Thus, flipped classroom can be seen as an operational form of hybrid learning, and its effectiveness depends heavily on the quality and accessibility of pre-class learning resources. At this point, mobile modules—particularly Android-based ones—play a crucial role as digital infrastructures that make flipped–hybrid strategies feasible, providing interactive and flexible access to learning content anytime and anywhere.

The link between the flipped classroom and hybrid learning is increasingly relevant when applied to statistics learning. By moving content delivery to the pre-class phase, face-to-face time can be focused on higher-order activities such as discussion, modelling, and statistical argumentation. Meta-analyses and quasi-experimental studies indicate that this combination effectively enhances student engagement and achievement, particularly when pre-class digital modules contain real data analysis guides. To ensure that digital modules are developed according to instructional standards, the ADDIE framework (Analysis, Design, Development, Implementation, Evaluation) is often used in R&D research as a systematic reference from needs analysis to effectiveness evaluation (Budoya et al., 2019).

In this integrated view, hybrid and flipped strategies provide the pedagogical framework, while Android-based mobile modules serve as the technological medium that operationalises them. Empirical evidence also confirms that the combination of flipped/hybrid learning with practical sessions and formative quizzes during face-to-face sessions has a positive impact on statistical learning outcomes (Strelan et al., 2020).

In line with this integration, the use of Android-based modules further strengthens opportunities for improving statistical thinking skills. These modules offer high accessibility, dynamic visualisation, interactivity, instant feedback, gradual scaffolding, and integration of formative tests structured according to the interrogative cycle (generate → seek → interpret → criticise → judge) (Wild & Pfannkuch, 1999; Zuo et al., 2023). A meta-analysis of mobile learning shows a moderate effect on academic outcomes, especially when the module design includes optimal scaffolding and feedback (Güler et al., 2022; Talan, 2020). Module feasibility evaluation usually involves content validity testing (Aiken's V) and effectiveness through normalised gain (N-Gain) calculations, which have been widely used in educational media development research (Blegur et al., 2025; Hake, 1998).

Although a number of studies have examined aspects of hybrid learning, flipped classrooms, and mobile learning separately, a review of the literature shows that there is still limited research that simultaneously combines Android-based modules with hybrid-flipped implementation and comprehensive feasibility evaluations in measuring the statistical thinking abilities of prospective students'. Therefore, this study was designed to fill this empirical gap by presenting an integrative approach that can serve as a reference in statistical learning innovation in higher education.

METHOD

This study employed a research and development (R&D) design guided by the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) (Robert Maribe, 2009). The ADDIE framework was selected because it provides a systematic and iterative structure for developing educational media, ensuring that formative evaluations at each stage contribute to continuous refinement of the product.

The research was conducted in the Mathematics Education Study Programme at Dayanu Ikhsanuddin University, Indonesia, with the aim of developing and testing an Android-based digital module on descriptive statistics. Participants included two statistics lecturers, three subject matter experts, two media experts, and 63 undergraduate students representing diverse academic abilities. Student involvement was organised in three phases—one-on-one evaluations ($n = 6$), small-group trials ($n = 15$), and field implementation ($n = 42$)—to progressively assess the validity, practicality, and effectiveness of the module in enhancing statistical thinking skills.

Data were collected through expert validation sheets, student questionnaires, interviews, and pre–post tests. Expert evaluations covered three dimensions: (1) content validity (accuracy, presentation, and contextual relevance), (2) pedagogical validity (alignment with learner characteristics, objectives, strategies, and assessment), and (3) media validity (visual design, accessibility, and technical quality) (Darmawan et al., 2023). Student feedback was obtained through practicality questionnaires, while statistical thinking skills were measured via tests adapted to four domains: describing, organising, representing, and interpreting data. All instruments underwent prior validation, and internal consistency was confirmed (Cronbach's α > 0.80).

Quantitative data were analysed using descriptive statistics, Aiken's V (≥ 0.75) for expert validation, practicality thresholds (> 75%), paired sample t-tests ($p < 0.05$), and N-Gain scores (> 0.75) to determine learning effectiveness. Qualitative feedback from experts and students was analysed thematically and used to refine the module design. This mixed-method evaluation approach ensured that the developed Android-based module met the criteria of validity, practicality, and effectiveness, while also capturing user experiences that provide pedagogical insights for technology-enhanced statistics education. Figure 1 below shows the stages of digital module development using the ADDIE model.

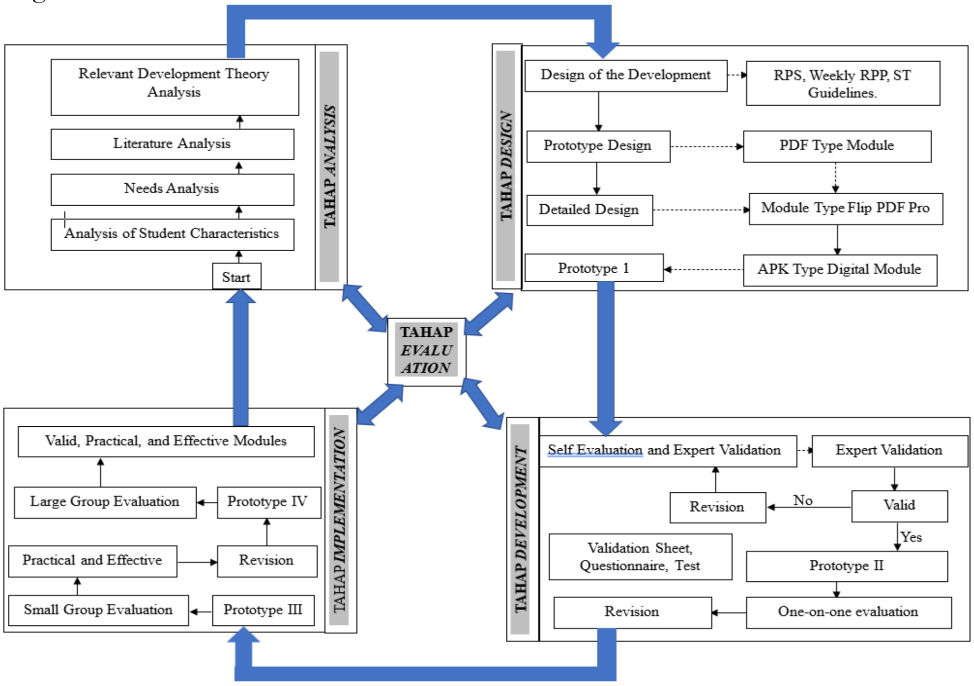

Figure 1. Stages of Digital Module Development using the ADDIE Model

RESULT

This study followed the ADDIE development cycle, which emphasises iterative evaluation to ensure product quality and pedagogical alignment. The findings at each stage are presented below.

Analysis

The analysis phase identified the baseline conditions of students' statistical thinking skills and learning needs. Four sub-analyses were conducted: student characteristics, needs, literature, and development theory.

Student Characteristics: Results indicated that students experienced persistent difficulties in solving statistical problems and had limited exposure to hybrid learning environments. Nevertheless, their interest in using interactive digital modules was high.

Needs Analysis: Observations, interviews, and curriculum reviews revealed the absence of a systematic instructional strategy for developing statistical thinking indicators.

Literature Analysis: Existing textbooks and articles were limited in differentiating literacy, reasoning, and statistical thinking, underscoring the need for targeted learning media.

Development Theory Analysis: The design was grounded in constructivism (Wibowo et al., 2025), multimedia learning principles (Huang et al., 2020), and andragogical approaches (Ferreira & Maclean, 2018), as well as the dimensions of statistical thinking (Wild & Pfannkuch, 1999). This theoretical integration provided a strong pedagogical basis for the module.

Design

Based on the analysis stage, a descriptive statistics module was designed through three components: outcome design, prototype, and detailed design. **Development outcomes:** Semester and weekly instructional plans (RPS and RPP) were prepared using a hybrid learning framework combined with Problem-Based Learning (PBL). A test grid was also constructed, aligned with Wild & Pfannkuch's interrogative cycle. **Prototype design:** The module prototype included a concept map, learning outcomes, problem orientation, scaffolding activities, QR code–linked instructional videos, exercises aligned with statistical thinking dimensions, and formative assessments. **Detailed design:** The prototype was converted into a digital format using Flip PDF Professional and Website 2 APK Builder Pro, enabling offline and online access via smartphones and laptops. Figure 2 illustrates the final digital module interface.

This systematic design ensured that the module not only addressed students' identified needs but also aligned with established pedagogical frameworks for mobile and technology-enhanced learning.

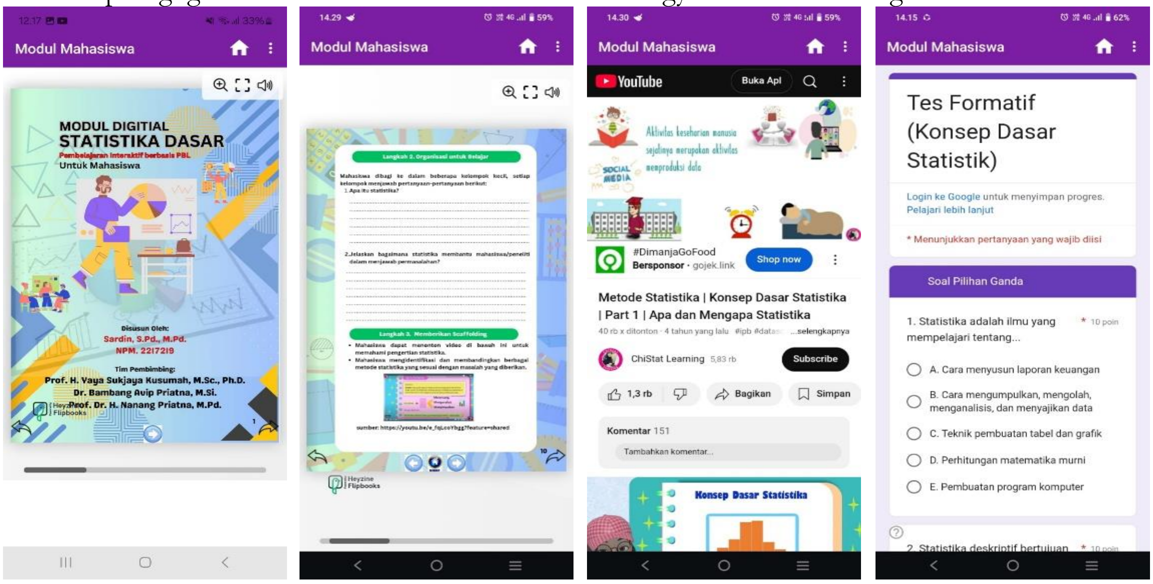

Figure 2. The Digital Module is Opened using a Smartphone

Development

During the development stage, the designed digital statistics module was subjected to a multi-layered evaluation process consisting of self-evaluation, expert validation, and one-to-one evaluation. Self-evaluation focused on identifying technical issues such as typographical errors, completeness of learning outcomes, consistency of media presentation, and logical flow of the module structure. Expert validation was conducted by a panel of specialists in educational research, mathematics education, and instructional media (see Table 1). The validation covered media feasibility, content quality, language clarity, and pedagogical appropriateness. The results indicated that the module achieved an overall validity score exceeding 0.90 across all categories, which falls within the "very valid" range. Suggested improvements included refining the steps of Problem-Based Learning (PBL) to enhance scaffolding, adding more contextualised examples, correcting technical terminology, and adjusting the duration of embedded instructional videos to reduce cognitive overload.

One-to-one evaluation was carried out with six students representing high, medium, and low academic achievement levels. Feedback revealed that students could navigate the module flow smoothly, access features easily, and comprehend the content. Minor issues, such as interface navigation and content density in some sections, were revised based on their feedback. Overall, these iterative revisions confirmed that the developed module met validity and practicality standards, making it ready for further testing at the small-group and field-trial stages.

Table 1. Expert Validators

No	Education	Gender	Age/Work Experience (year)	Expertise	Validator
1	Prof., Dr., M.Pd	Male	57/31	Educational research and evaluation	Media and testing expert
2	Prof., Dr., Dra., M.S	Female	59/32	Applied mathematics	Subject matter and testing expert
3	Dr., S.Si., M.Si	Male	60/32	Mathematics Education (Statistics)	Subject Matter Expert, Instrument Expert
4	Dr., M.Pd.	Female	41/16	Mathematics Education	Media and Test Expert
5	Dr., M.Pd.	Female	36/5	Mathematics Education	Media and Test Expert

6	SPd., M.Pd.	Male	48/19	Mathematics Learning Media	Media expert, pedagogical expert, instrument
7	S.Si., M.Si	Female	41/19	Mathematics Education (Statistics)	Subject Matter Expert, pedagogical expert, instrument
8	S.Pd., M.Pd.	Female	39/12	Mathematics Education	Subject Matter Expert and pedagogical expert

Implementation

The implementation of the Descriptive Statistics digital module through hybrid flipped classroom learning was conducted in two phases: small-group trial and field testing.

Small-group trial. This stage involved 15 prospective mathematics students' with heterogeneous academic abilities across nine meetings that combined offline and online sessions. Early sessions emphasised mastering basic statistical concepts, data types, and measurement scales, while subsequent sessions developed skills in frequency distributions, data visualisation (histograms, polygons, ogives, stem-and-leaf diagrams), and measures of central tendency and location. Each session followed the flipped-hybrid syntax, beginning with pre-class engagement through videos, QR codes, and hyperlinks, followed by collaborative discussions and problem solving.

Results indicated positive improvements in students' statistical thinking, particularly in their ability to calculate, interpret, critique, and justify analyses. However, practicality scores revealed constraints related to time allocation (Table 2), suggesting that additional scaffolding or reallocation of instructional time may be required. Pre–post comparisons (Table 3) showed substantial gains in all statistical thinking indicators, with average scores increasing from 38.53 to 82.07, confirming the effectiveness of the digital module at this stage.

Table 2. Results of Student and Lecturer Responses to the Practicality of the Digital Module during the Small Group Trial Phase

No	Practicality Indicator	Average (%) Response to the Practicality of the Digital Module	
		Students	**Lecturers**
1	Usage	77,56	90,00
2	Instructions	80,00	90,00
3	Time	51,33	60,00
4	Usability in learning	81,33	80,00
5	Design	83,41	93,33
Average		**74,73**	**82,67**

Table 3. Average Pre-Test and Post-Test Scores for Statistical Thinking Skills in Small Group Trials

No	Statistical thinking ability indicators	Average Results of Small Group Trials	
		Before Treatment	**After Treatment**
1	Describing data presentation	11,07	20,47
2	Organising and reducing data	10,67	20,53
3	Representing data	10,07	20,40
4	Analysing and interpreting data	6,73	20,67
Average		**38,53**	**82,07**

Field testing. This stage involved 42 fourth-semester students across nine meetings using the hybrid learning model integrated with Problem-Based Learning (PBL). The learning sequence progressed from basic statistical concepts to more advanced topics such as measures of dispersion, boxplots, normal distribution interpretation, and skewness and kurtosis. Students engaged with QR-linked videos and hypertexts prior to class and solved contextual problems collaboratively during class.

Results demonstrated that students of varying ability levels were able to participate actively, interpret results accurately, and justify their analyses. Practicality responses (Table 4) indicated high levels of usability, design quality, and instructional clarity, with averages exceeding 85% for students and 88% for lecturers. Pre–post comparisons (Table 5) confirmed marked improvement, with average scores rising from 38.55 to 88.26, which places effectiveness in the "high" category.

Table 4. Results of Student and Lecturer Responses to the Practicality of the Digital Module during the Field Testing Stage

No	Practicality Indicator	Average (%) Response to the Practicality of the Digital Module	
		Students	Lecturers
1	Usage	88,25	90,00
1	Instructions	83,57	90,00
2	Time	80,24	70,00
3	Usability in learning	86,59	96,67
4	Design	86,46	93,33
Average		**85,02**	**88,00**

Table 5. Average Pre-Test and Post-Test Scores for Statistical Thinking Skills in the Field Test

No	Statistical Thinking Ability Indicators	Average Field Test Results	
		Before Treatment	After Treatment
1	Describing data presentation	11,05	22,71
2	Organising and reducing data	9,79	22,31
3	Representing data	10,36	21,52
4	Analysing and interpreting data	7,36	21,71
Average		**38,55**	**88,26**

Comparative insight. When comparing the two stages, it is evident that practicality improved markedly from the small-group trial (74.73% for students) to the field test (85.02%). Similarly, effectiveness increased from an average N-gain of 82.07 to 88.26. These findings align with principles of iterative instructional design, where initial constraints (e.g., time allocation) were addressed, leading to improved results in the broader field implementation.

Overall, the implementation stage confirms that the digital module is interactive, flexible, and effective in supporting active learning, while also highlighting areas for further refinement such as time management and scaffolding strategies. These outcomes provide a strong foundation for the evaluation stage of the ADDIE model.

Evaluation

The evaluation stage, which encompassed both small-group and field trials, confirmed the practicality and effectiveness of the developed digital module for descriptive statistics.

Practicality outcomes. In the small-group trial, student responses averaged 74.73% (practical), which increased to 85.02% in the field test. Lecturer responses similarly rose from 82.67% to 88.00%. These gains reflect improvements in usability, clarity of instructions, and alignment with collaborative and independent learning processes. The rise in practicality scores from small-group to field testing illustrates how iterative refinements within the ADDIE cycle enhanced the module's readiness for broader implementation.

Effectiveness outcomes. Statistical thinking skills showed consistent and significant improvement across both stages. In the small-group trial, the average pre-test score (38.53) increased to 82.07 post-test, with a paired sample t-test yielding $p < 0.05$ and an average N-Gain of 0.7049 (70.49%), indicating moderate effectiveness. In the field test, pre-test scores (38.55) rose to 88.26 post-test, with a similarly significant p-value ($p < 0.05$) and an N-Gain of 0.8036 (80.36%), categorised as high effectiveness. These consistent improvements across indicators—describing, organising, representing, analysing, and interpreting data—affirm that the module successfully supports the development of higher-order statistical reasoning.

Interpretation. The progression from small-group to field testing not only validated the practicality of the module but also demonstrated that iterative improvements yielded stronger learning gains at scale. This pattern is consistent with principles of multimedia learning (Huang et al., 2020) and constructivist approaches (Wibowo et al., 2025), which emphasise iterative refinement and learner engagement. Furthermore, the flipped-hybrid integration allowed students to engage with content prior to class and deepen conceptual understanding through peer interaction and problem solving, thereby strengthening their statistical thinking.

Conclusion of evaluation stage. Overall, the evaluation results confirm that the Android-based interactive module is valid, practical, and effective for use in higher education. Beyond improving statistical thinking in the local context, the findings contribute to broader discourses in technology-enhanced learning by illustrating how flipped-hybrid mobile modules can bridge procedural and conceptual gaps in quantitative disciplines. This reinforces the pedagogical potential of digital modules not only in mathematics education but also in other subject areas that require a balance between computational fluency and conceptual reasoning.

DISCUSSION

The developed digital module has fulfilled the validity criteria as confirmed by media experts, pedagogical experts, and subject matter experts. Media expert assessment ensured visual clarity, accessibility, and technological performance; pedagogical expert assessment confirmed alignment with learning objectives and student characteristics; while subject matter expert assessment verified content accuracy, presentation, and contextual relevance. Together, these validations demonstrate that the module is theoretically sound and practically robust for use in hybrid flipped classroom contexts. This finding aligns with previous research showing that validated digital mathematics modules can outperform conventional approaches in strengthening students' conceptual understanding (Siti Kholisah et al., 2024).

Beyond validity, the digital module demonstrated a high level of practicality, being self-contained, user-friendly, and consistent in structure, which supports both independent learning and lecturer-guided delivery. Flexible access via digital devices allows students to engage with content anytime and anywhere, while lecturers can integrate the module into both synchronous and asynchronous instruction. This resonates with findings by Başol et al. (2020) and Aslan (2024), who highlight that digital modules embedded in flipped-hybrid models enhance accessibility, motivation, and learning efficiency.

The field implementation further reinforces the module's effectiveness in supporting learning achievement. Students successfully engaged in a progressive range of statistical activities, from basic descriptive tasks to more advanced analyses of dispersion and coefficients. The hybrid design—blending offline problem-based learning with online synchronous discussions—promoted deeper engagement, collaborative learning, and inclusivity. These outcomes mirror Mizza et al. (2025) and Anthony Jnr (2024), who emphasise that blended flipped models in higher education foster equitable participation, higher engagement, and improved performance through collaborative online platforms such as Zoom.

Importantly, the digital module not only facilitated comprehension but also strengthened students' statistical thinking skills by integrating interactivity, contextual material, and iterative evaluation. This supports Zhou et al. (2024), who demonstrated that interactive and multimedia-rich digital resources significantly contribute to students' deep learning, and Veytia Bucheli et al. (2024), who highlight the role of multiple representations in fostering higher-order thinking. Thus, the present findings extend the literature by showing how hybrid flipped modules can be specifically tailored for statistical education, a domain often considered challenging for prospective students'.

The effectiveness of the digital module is further enhanced by its dual role as a self-instructional tool and a pedagogical resource for lecturers. Clear instructions, contextual content, and integrated formative assessments provide scaffolding that ensures sustainable learning outcomes. These findings are consistent with Buil-Fabregá et al. (2019) and Sizemore et al. (2024), reinforcing that digital modules are most impactful when designed to combine independent exploration with structured lecturer facilitation.

From a broader perspective, the validated, practical, and effective digital module contributes to the discourse on technology-enhanced higher education. It illustrates how digital learning innovations can promote collaboration, critical thinking, and self-regulated learning among pre-service students'. This is consistent with Golden (2023), who notes that instructional strategies focused on critical thinking development significantly enhance students' academic competence.

Nevertheless, this study also has limitations. The trials were conducted within a single institution and focused on descriptive statistics, which may restrict generalisability to other contexts or more advanced statistical content. Future research could explore cross-institutional implementation, long-term retention effects, and integration with mobile learning platforms to further expand accessibility and impact. Overall, the findings confirm that flipped-hybrid digital modules can serve as a scalable, effective, and globally relevant strategy for developing statistical thinking skills in higher education.

CONCLUSION

The findings of this study demonstrate that the implementation of the Descriptive Statistics digital module through a flipped-hybrid approach significantly enhances students' statistical thinking skills. The improvement was evidenced by increased pre-test and post-test scores, supported by statistical analyses showing normality, significance, and high N-Gain effectiveness (80.36%). These results confirm that the digital module is not only valid and practical, but also highly effective in strengthening students' ability to describe, organise, represent, analyse, and interpret data. Beyond statistical evidence, this study contributes to the growing body of literature on technology-enhanced learning by showing how a digital module specifically designed for descriptive statistics can function as both an independent learning resource and a pedagogical tool for lecturers. The integration of multimedia, interactivity, and hybrid learning delivery proved to be critical factors in promoting active learning, engagement, and self-regulated study among pre-service students'. Practically, the developed module provides a scalable solution for higher education institutions seeking to enhance students' conceptual mastery through flexible and interactive digital learning. Its design allows for broad implementation across varied instructional settings and can inform future development of digital modules in other areas of mathematics and beyond. However, this study is limited by its focus on a single institution and topic scope. Future research should investigate long-term retention effects, cross-institutional applications, and integration with mobile learning platforms to further extend accessibility and impact. In conclusion, the study confirms that hybrid flipped digital modules represent an effective and globally relevant strategy for improving statistical thinking in higher education, with the potential to inform pedagogical innovation and digital learning practices internationally.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

AI Tools Declaration

Artificial intelligence tools (e.g., ChatGPT) were used to support language editing and grammar refinement of the manuscript, while the ideas, analyses, and interpretations are solely the authors' responsibility"

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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