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DEVELOPING A DEEP LEARNING-BASED INSTRUCTIONAL MODULE USING THE UNDERSTANDING BY DESIGN FRAMEWORK FOR LEARNING BIVARIATE DATA

Syelvira Nova Zulfaidany*[1], Tiara Mastura Nafisa[2], Alifiani[3]
[1,2,3] Universitas Islam Malang

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ABSTRACT

The development of the digital era has increased the need for statistical literacy and data interpretation skills as essential competencies for the 21st century. However, some students still have difficulty interpreting relationships between data. The application of the Understanding by Design (UbD) learning design framework and the deep learning approach in instructional modules has been widely carried out, but those that integrate both in the development of instructional modules for learning bivariate data are still limited. Therefore, the purpose of this study is to develop a valid and effective deep learning-based instructional module using Understanding by Design for learning bivariate data. The type of research conducted is research and development (R&D) with the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation). The subjects of the study were 29 11th-grade students. Data collection was carried out using test and non-test techniques. The instruments used were validation sheets and pretest and posttest question sheets. Based on the validator's assessment, the developed instructional module produced a total average score of 3.40 which is included in the "valid" validity level. As for the results of the students' pretest and posttest, the developed instructional module was declared effective as assessed by an n-gain score of 0.32, which means there was an increase in learning outcomes between before and after the use of the developed instructional module with the criteria of "medium". Based on the results of the study, it can be concluded that the developed instructional module is valid and effective for use for learning bivariate data. These findings indicate that the integration of the deep learning approach and the Understanding by Design framework not only improves student learning outcomes but also helps students build a deeper conceptual understanding in interpreting data and understanding the relationships between variables meaningfully.

Corresponding Author:

Syelvira Nova Zulfaidany,
Department of Teacher Professional Education,
Universitas Islam Malang, Indonesia
Email: novadany1453@gmail.com

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1. INTRODUCTION

The development of the digital era has increased the need for statistical literacy and data interpretation skills as essential competencies for the 21st century. Various decisions in education, economics, health, and everyday life increasingly depend on the ability to critically understand, analyze, and interpret data. Therefore, statistics learning in schools is no longer understood merely as a calculation activity, but also as a means of understanding real phenomena through data analysis and interpretation (Crismono et al., 2026; Purwadi & Suhana, 2026). In line with the Programme for International Student Assessment (PISA), the ability to interpret data and evidence in various real-world contexts is a crucial component of mathematical reasoning and literacy skills that students need to develop through learning (OECD, 2023).

One statistical topic that contributes significantly to the advancement of statistical literacy is bivariate data. This material helps students understand relationships between variables, identify the direction and shape of data trends, and make predictions based on emerging patterns. Understanding bivariate data also contributes to the development of critical thinking skills and data-based decision-making through the interpretation of scatterplots and correlation diagrams (Soetewey et al., 2025). However, various studies show that students still experience difficulties in interpreting relationships between variables and understanding the meaning of correlation regarding causal relationships (Veldhuis et al., 2020). This difficulty occurs because learning is often only oriented towards calculation procedures and the use of formulas without providing adequate opportunities for students to build in-depth conceptual understanding (Aydın-Güç et al., 2022; Sa'idah et al., 2026). Consequently, students tend to memorize correlation formulas without understanding how data relationship patterns are formed and how the analysis results can be contextually interpreted in real-world contexts.

These issues highlight the need for a learning approach that emphasizes not only procedural mastery but also conceptual understanding and active student engagement in constructing meaning. One relevant approach is immersive learning, which emphasizes experiential learning involving understanding, application, and reflection. In mathematics learning, this approach encourages students to connect concepts to real-world experiences, construct knowledge through exploration, and develop higher-order thinking skills through active learning experiences (Crismono et al., 2026). Several studies have shown that implementing an immersive learning approach in mathematics learning can improve conceptual understanding (Katrina et al., 2025; Siregar et al., 2025), problem-solving skills (Bariroh, 2025; Gumilar et al., 2025; Hamzah et al., 2026), critical thinking skills (Ratnasari et al., 2025), and student learning outcomes (Fu'at et al., 2025). In the context of bivariate data, data exploration activities, interpretive discussions for application, and reflection on analysis results have the potential to help students understand the relationships between variables more deeply and develop their statistical inference skills (Kazak et al., 2021). Furthermore, the mindful, meaningful, and joyful application of deep learning principles makes learning more active, reflective, and contextual, thereby deepening students' understanding (Widyastuti et al., 2025). However, the application of deep learning approaches in developing statistics instructional modules, particularly for bivariate data, is still relatively limited.

Besides the learning approach, systematic learning design is also an important factor in creating meaningful learning experiences. One learning design framework widely used to support meaningful learning is Understanding by Design (UbD). This framework emphasizes the principle of backward design, starting from designing learning objectives, assessments, and learning activities based on the final understanding that students want to achieve (Mctighe & Wiggins, 2012). Research shows that UbD can improve conceptual understanding, inquiry skills, and learning retention because learning is focused on achieving enduring understanding, not just short-term mastery of material (Luthfiralda & Hakim, 2026; Namus et al., 2024; Rahmawati & Astuti, 2023). In mathematics learning, UbD also helps students connect abstract concepts with real-life contexts through authentic and reflective learning activities (Pramesti & Dewi, 2023; Wiratomo et al., 2025). Various studies have developed UbD-based instructional modules on numeracy materials (Amalia et al., 2025), trigonometric ratios (Putra et al., 2023), and measures of central tendency (Usfira et al., 2024).

Although research on deep learning and UbD has expanded, most studies still examine the two separately. Research on statistics instructional modules in the digital era also tends to focus on the use of technology, data visualization, or technical data analysis skills (Taqwa & Taufik, 2019), while aspects of conceptual understanding, interpretation of relationships between variables, and reflection on the meaning of data have not received optimal attention (Dobesova, 2024). Some statistics instructional modules have integrated contextual approaches and conceptual understanding (Nery et al., 2025; Rachmi et al., 2024), but most still focus on procedural and general application of the material. Therefore, the instructional modules have not fully facilitated students to construct statistical meaning through contextual exploration, reflection on thought processes, and interpretation of learning experiences in real life. Therefore, there has been no research specifically developing statistics instructional modules for learning bivariate data that integrate deep learning principles with the Understanding by Design framework to facilitate a more meaningful student learning experience.

Based on the aforementioned description, this study aims to develop a deep learning based instructional module using the Understanding by Design framework for learning bivariate data. The developed instructional module is designed to help students understand the concept of correlation, identify the direction and shape of data trends, analyze relationships between variables, and build statistical understanding through reflective and contextual learning activities. The development of this instructional module integrates the principles of deep learning with the backward design of the UbD framework so that learning objectives, assessments, and learning activities are systematically connected. Thus, this research is expected to produce a valid and effective development instructional module and contribute to the development of statistics learning that supports conceptual understanding, statistical reasoning, and the ability to interpret data meaningfully.

2. METHOD

This study employed a research and development (R&D) design aimed at producing a deep learning based instructional module using the Understanding by Design (UbD) for learning bivariate data. The development model used is ADDIE, which consists of five stages: analysis, design, development, implementation, and evaluation (Branch, 2009).

The analysis phase was conducted through an analysis of the curriculum, student needs, and students' prior abilities related to bivariate data. The initial ability analysis was conducted using a diagnostic test (pretest) to identify students' level of understanding of the concept of correlation, the direction of relationships between variables, and the interpretation of scatter diagrams. The analysis results were used as the basis for designing instructional modules tailored to the characteristics and needs of the students.

The design phase included developing learning objectives, designing assessments, developing learning activities, and structuring the instructional module based on the principles of backward design within the Understanding by Design (UbD) framework (McTighe & Wiggins, 2012). This phase also included designing learning activities that integrate deep learning principles through understanding, application, and reflection on learning. Instructional module design refers to the WHERETO framework, which encompasses activities such as building learning readiness, exploring concepts, applying concepts in real-world contexts, and reflecting on learning.

The development phase involved the development of an initial product in the form of a deep learning based instructional module using the Understanding by Design (UbD) framework and the development of research instruments. The developed instructional module consists of five main parts. The first part is identification, which includes student profiles, topic criteria, and graduate profile dimensions that form the basis for learning design. The second part is learning design, which includes learning outcomes, learning objectives, pedagogical practices, partnerships, learning environments, and the use of digital technology. The third part is the learning experience, which consists of introductory, core, and closing activities. Introductory activities include apperception, material triggers, learning motivation, and delivery of learning objectives. Core activities include concept exploration, application of concepts in the context of bivariate data, presentation of work results, and learning reflection. Closing activities include material conclusions, final learning assessments, and delivery of material at the next meeting. The fourth part is assessment, which consists of diagnostic, formative, and summative assessments. The final part is an appendix containing learning support tools. Next, the product was validated by two validators: a mathematics education lecturer with a doctorate and a mathematics teacher with over ten years of teaching experience. The validation process aims to assess the feasibility of the module identity aspects, learning materials, learning media, learning scenarios, and assessments contained in the instructional module.

The implementation phase was conducted through a limited pilot test with students to determine the instructional module's feasibility and effectiveness in improving understanding of bivariate data concepts. At this stage, students participated in learning using the revised instructional module based on input from the validators. After the learning process was completed, students were given a posttest to measure improvements in conceptual understanding.

The evaluation phase was conducted in both formative and summative ways. Formative evaluation was conducted at each stage of development through product improvements based on validation results and findings during implementation. Summative evaluation was conducted to determine the effectiveness of the developed instructional module (Branch, 2009).

The subjects of this research were 29 students of 11th-grade who participated in learning using the developed instructional module. The study also involved an expert lecturer and a mathematics teacher as validators. The object of this research was the developed instructional module. The research instruments consisted of an instructional module validation sheet, pretest questions, and posttest questions. The validation sheet was used to obtain data on the instructional module's feasibility based on aspects of identity, learning materials, learning media, learning scenarios, and assessment. Assessment used a four-level Likert scale with a score range of 1–4. The test instrument was used to measure students' understanding of bivariate data concepts before and after using the instructional module.

Data collection techniques were conducted using testing and non-testing techniques. Testing techniques used pretests and posttests to measure the instructional module's effectiveness in improving students' conceptual understanding. Non-testing techniques used validation sheets to obtain data on the instructional module's feasibility from expert validators and practitioners.

The data analysis technique was descriptive quantitative and qualitative. The qualitative data of this study consisted of suggestions and input from validators to be used as a reference for revising and improving the developed product. The quantitative data consisted of validation scores and student pretest and posttest scores. The validity analysis results from expert lecturers and mathematics teachers were then calculated using formula (1).

$$\text{Average Score of Validity } (Vr) = \frac{\text{Number of scores obtained}}{\text{many indicator statements}} \qquad (1)$$

The calculation results were then interpreted based on the validity criteria adapted from Qohar et al. (2021) in table 1. The instructional module was declared suitable for testing if it obtained the minimum valid category (Vega & Eppendi, 2021).

Table 1. Validity Level

Average Score of Validity	Validity Level
$1 \leq Vr < 2$	Invalid
$2 \leq Vr < 3$	Less Valid
$3 \leq Vr < 4$	Valid
$Vr = 4$	Very Valid

The effectiveness of the developed instructional module was determined through data analysis of pretest and posttest scores. The analysis of the effectiveness of product implementation was conducted using the Normalized Gain (N-gain) test calculation developed by Hake (1999). The N-gain value was calculated using formula (2) by comparing pretest and posttest scores to determine the increase in understanding of bivariate data concepts after using the instructional module.

$$N-Gain = \frac{\text{Score posttest - Score pretest}}{\text{Score max - Score pretest}} \tag{2}$$

The N-gain score obtained was then interpreted based on the criteria developed by Hake (1999) in table 2. The development instructional module is declared effective if the N-gain score obtained reaches the medium or high criteria (Geong & Mahmudi, 2023).

Table 2. N-gain criteria

Score	Criteria
$N - gain < 0{,}3$	Low
$0{,}3 \leq N - gain \leq 0{,}7$	Medium
$N - gain > 0{,}7$	High

3. RESULTS AND DISCUSSION

3.1. Result

Analysis

At this stage, interviews with teachers, classroom observations, and cognitive tests were conducted. Based on the results of the interviews and observations, data indicated that students enjoy learning through question-and-answer sessions, collaboration, games, and are accustomed to project-based learning. However, for discovery-based learning, they still require structured scaffolding from the teacher at the outset to prevent confusion. Most students living in the city center require the use of examples relevant to their background. The diagnostic test administered to 29 students showed that their initial proficiency still needs to be improved. The average score obtained by the students was 68 out of a maximum score of 100. More detailed analysis results are presented in Table 3.

According to table 3, the indicator with the lowest achievement was the ability to identify types and trends in correlation, also contextual applications and real world examples. This finding highlights the need to develop instructional materials that not only emphasize procedural aspects but also encourage students to understand the conceptual and contextual significance of relationships between variables.

Table 3. Results of the Analysis of Students' Initial Abilities

Indicator	Percentage of Correct Answer
Visual Interpretation and Characteristics of Scatter Plots	88%
Identifying Types and Trends in Correlation	57%
Understanding Fundamental Concepts	87%
Contextual Applications and Real-World Example	66%

The researcher developed a instructional module for learning bivariate data with a subtopic on types of correlation using a deep learning approach. The selection of the material based on research which explained that correlation requires not only memorization of formulas but also the ability to understand relationships between variables, analyze data, and interpret results in real-world contexts (Podworny et al., 2022). The connection between learning materials and real-world contexts is a key element of deep learning approach (Astono et al., 2026).

Design

The design phase was conducted based on the results of the analysis of student needs and the characteristics of the bivariate data. In this stage, the researcher developed an instructional module design by integrating the Understanding by Design (UbD) framework and the deep learning approach. The instructional module design followed the backward design principle, which consists of three main stages: identifying desired learning outcomes (Identify Desired Results), determining acceptable evidence of learning outcomes (Determine Acceptable Evidence), and designing learning experiences (Plan Learning Experiences and Instruction).

In the Identify Desired Results stage, learning objectives were established to ensure students are able to identify the type, direction, and shape of trends, as well as the strength of bivariate correlations by analyzing scatter plots and participating in creative challenges based on contextual problems. Students are also expected to formulate new problems and interpret the relationships between variables logically and in accordance with the given context. Additionally, essential questions are formulated to foster higher-order thinking skills, such as : “How would you determine whether the two variables are related when the data is presented in a scatter plot?”.

In the Determine Acceptable Evidence phase, an assessment system was designed that includes diagnostic assessments, formative assessments, learning reflections, and summative assessments. The evaluation is conducted through group performance assignments in the form of creative challenges to design, present, and interpret contextual problems based on random correlations and trends. This assessment is supported by various other forms of evidence, including a diagnostic assessment (oral questions on prerequisite material), a formative assessment via concept-exploration worksheets, self-reflection (exit tickets) through the Kuesio platform, and a final summative assessment in the form of an interactive individual quiz via Zep Quiz to evaluate the achievement of learning objectives.

In the Plan Learning Experiences and Instruction stage, learning activities were designed using the WHERETO framework combined with deep learning principles according to the Problem-Based Learning approach. Learning activities included contextual problem orientation, data exploration, group discussions, presentation of analysis results, learning reflection, and evaluation. The following is a lesson plan based on the WHERETO framework :

- W (Where/What) : The teacher introduces the topic of bivariate data correlation and its objective, which is to enable students to analyze data objectively.
- H (Hook/Hold) : Presenting the contextual problem “Ms. Mira's Data” regarding the relationship between study duration and test scores to spark curiosity.
- E (Equip/Explore) : Students explore the concepts of direction and trends through worksheets with structured scaffolding support from the teacher.
- R (Rethink/Revise) : Through group presentations, students receive feedback from peers and confirmation from the teacher to correct misconceptions.
- E (Evaluate) : Students evaluate their own learning process through an Exit Ticket, and the teacher evaluates learning outcomes through a summative quiz.
- T (Tailored) : Instruction uses examples relevant to students’ urban backgrounds (such as selling iced tea) and provides group discussion opportunities for those who prefer collaboration.
- O (Organized) : Instruction is systematically organized from the problem-orientation stage, through group investigation, to final reflection and evaluation.

A brief overview of the instructional module design is presented in table 4, which serves as the basis for product development in the next stage.

Table 4. Instructional Module Blueprint

Component	Description
Content	Types of correlation in bivariate data
Approach	Deep Learning
Framework	Understanding by Design (UbD)
Learning Model	Project-Based Learning (PjBL)
Activity Framework	WHERETO
Assessment	Diagnostic, formative, reflective, and summative
Supporting Media	Canva, Kuesio, and Zep Quiz

Development

At this stage, researchers translated the designed blueprint into a tangible product in the form of a deep learning-based mathematics instructional module. The development of this instructional module includes formal structural components aligned with the current curriculum, encompassing the instructional module framework, learning elements, learning outcomes, achievement indicators, learning objectives, and core content on types of correlations in bivariate data. Additionally, this instructional module integrates step-by-step learning activity scenarios using the Project-Based Learning (PjBL) model. To incorporate the characteristics of deep learning, the researchers embedded the principles of mindful, meaningful, and joyful learning, which are directly linked to students' real-life experiences. These characteristics of deep learning are reflected in activity steps that emphasize deep thinking processes, an interdisciplinary approach, collaborative learning, reinforcement of the dimensions of student profile, and an assessment system focused on applied understanding and students' awareness of their own learning processes. This instructional module is also enriched with the use of supporting digital media, which have been developed and can be seen on Figure 1, Figure 2, and Figure 3.

Figure 1. Canva

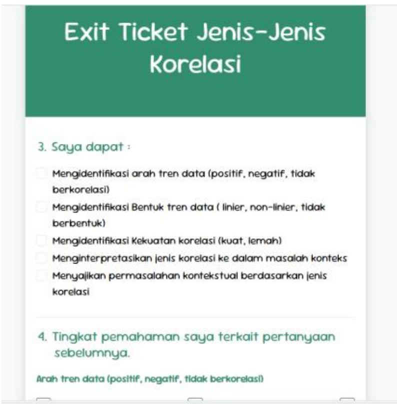

Figure 2. Kuesio

Figure 3. Zep Quiz

After the initial product was developed, a validation process was conducted by two validators : a mathematics education lecturer and an experienced mathematics teacher. The validation assessed five aspects : module identity, learning materials, learning media, learning scenarios, and assessment. The results of the instructional module validation are presented in Table 5.

Table 5. Analysis Validation

Aspect	Validator 1	Validator 2	Average	Category
Identity	3,00	3,50	3,25	Valid
Learning Material	3,00	3,00	3,00	Valid
Learning Media	3,50	4,00	3,75	Valid
Learning Scenario	3,00	3,00	3,00	Valid
Assessment	4,00	4,00	4,00	Very valid
Average	**3,30**	**3,50**	**3,40**	**Valid**

Based on the validation results, the instructional module received an average score of 3.40, which falls within 'the valid' validity level. These results indicate that the instructional module meets the criteria of identity, learning material, learning media, learning scenario, and assessment, and is therefore suitable for use in the implementation phase.

Development

At this stage, the researchers implemented the instructional module they had developed with 11th-grade students. Overall, the students' responses based on observations were fairly active engagement and considerable enthusiasm throughout the series of activities. Those responses particularly happened on comprehension activities where students were actively engaged in group discussions. Students frequently asked questions regarding the instructions on the worksheets used. During the class debriefing session, students again demonstrated quite active responses, particularly because they were supported by conceptual reinforcement.

The use of Canva-based visual media in opening activities has proven to help encourage active student participation. Canva is known as a popular digital tool in the field of education thanks to its user-friendly interface, which makes it easy to create visually engaging learning materials. In the closing activity, the use of Zep Quiz as a game-based assessment tool proved to be quite effective in encouraging active participation and friendly competition among students. Students appeared highly focused and enthusiastic while working on this game-based final assessment. However, the activity could not be completed during the in-person session and was ultimately finished as homework due to time constraints, highlighting the need for more careful time management in the implementation of future instructional modules.

Implementation

In this study, evaluation was conducted through expert reviews during the design and development phases, as well as through classroom observations carried out by mentor teachers during the implementation phase. Formative and summative evaluations both serve to assess instructional effectiveness and measure student learning outcomes. The feedback obtained from this formative evaluation process then serves as the basis for continuous instructional module improvement before and after classroom implementation.

One of the most significant sources of formative evaluation in this study was feedback from the supervising teacher, who observed the teaching process directly. The supervising teacher assessed that, in general, the teaching materials on types of correlation were good and that the delivery of the material (teaching) had gone well. However, the supervising teachers also emphasized that the "educating" aspect, the dimension of shaping students' character and attitudes, still needs improvement. This feedback underscores the importance of the teacher's role not only as a conveyor of cognitive content but also as an educator who actively shapes students' character and positive values throughout the learning process.

Based on the expert validation process, several substantive revisions were identified for the instructional materials. The validators noted that the initial learning objectives lacked operational verbs reflecting Higher-Order Thinking Skills (HOTS), specifically at the C4 (Analyzing) and C5 (Evaluating) levels. Consequently, the materials did not explicitly guide students to examine the relationships between variables. In response to this feedback, the researchers revised the learning objectives by integrating HOTS-based operational verbs. The modified objectives now explicitly direct students to analyze patterns of relationships and evaluate the strength as well as the direction of correlations between variables based on the provided datasets.

The summative evaluation in this study was conducted through the administration of pre-tests and post-tests to measure the improvement in students' understanding of the material on types of correlation. Summative evaluation provides a true understanding of the actual value of the developed design because it focuses on the final outcomes of the educational program. The effectiveness of the instructional module was analyzed using pretest and posttest scores. The results of the analysis are presented in table 6.

Table 6. Pretest, Posttest, and N-Gain Results

Component	Criteria
Pre-test Mean	68,00
Post-test Mean	78,14
N-Gain	0,32
Category	Medium

Based on Table 6, the average student score increased from 68.00 on the pretest to 78.14 on the posttest. The calculation results show an N-gain value of 0.32, which falls into the medium category. These results indicate that the use of a deep learning instructional module based on Understanding by Design is capable of improving students' understanding of the material on types of correlation in bivariate data.

In addition to improving learning outcomes, the implementation of the instructional module also showed that students were more actively engaged in the learning process through exploration, discussion, and reflection activities. These findings indicate that the integration of deep learning principles and the Understanding by Design framework can support more meaningful statistics learning oriented toward conceptual understanding.

3.2 Discussion

This study aims to develop a deep learning instructional module based on Understanding by Design (UbD) for bivariate data. The results indicate that the developed instructional module meets validity level with an average validity score of 3.40 and effectively enhances students' understanding, as evidenced by an N-gain value of 0.32, which falls into the medium category. These findings suggest that the integration of the deep learning approach and the Understanding by Design framework can create a more meaningful learning experience and support the development of students' conceptual understanding of bivariate data.

The validity of the instructional module indicates that the developed learning components meet the aspect criteria for content appropriateness, presentation, media, learning scenarios, and assessment. This high level of validity is likely due to the application of the backward design principle within the Understanding by Design framework. Through this approach, learning objectives, assessments, and learning activities are designed in an integrated manner based on the final understanding that learners are expected to achieve (Mctighe & Wiggins, 2012). This integration ensures that each learning activity has a clear connection to the targeted competencies, thereby making the quality of the instructional design more systematic. This finding aligns with the research by Rahmawati and Astuti (2023), Namus et al. (2024), and Luthfiralda and Hakim (2026), which shows that the application of UbD can produce learning materials that are more structured and oriented toward achieving deep understanding.

In addition, the validation process yielded important insights regarding the need to use operational verbs that reflect higher-order thinking skills. The revisions made to the learning objectives shifted the focus of learning from merely identifying or explaining to analyzing and evaluating relationships between variables. This change is important because understanding bivariate data cannot be sufficiently developed through procedural mastery alone, but requires the ability to analyze data patterns, interpret relationships between variables, and evaluate the statistical significance contained in the data. Anderson and Krathwohl (2001) explain that analytical and evaluative skills are part of higher-order cognitive processes that play a crucial role in the formation of conceptual understanding. Therefore, refining learning objectives is one of the factors contributing to the quality of the developed instructional module.

The results of the implementation show that students were actively engaged in data exploration activities, group discussions, presentations of analysis results, and learning reflections. These activities are key characteristics of the deep learning approach, which emphasizes the processes of understanding, applying, and reflecting on knowledge in a meaningful way. In bivariate data learning, students' active engagement is crucial because the concept of correlation requires not only computational skills but also the ability to understand relationships between variables and interpret data in real-world contexts. These findings support the view of Kazak et al. (2021), who state that exploration and reflection activities can help students develop statistical inferences and gain a deeper understanding of data relationships.

The improvement in students' understanding, as indicated by an N-gain score of 0.32, also suggests that the developed instructional module is capable of having a positive impact on the learning process. Although this improvement falls into the medium category, these results indicate that students demonstrated progress in their understanding after participating in instruction using the developed instructional module. This improvement is believed to have occurred because students had the opportunity to build their knowledge through contextual, collaborative, and reflective learning experiences. Unlike statistics instruction focused on the use of formulas and procedures, the developed instructional module encourages students to analyze relationships between variables based on real data, making the concept of correlation easier to understand. These research results support the findings of Katrina et al. (2025) and Siregar et al. (2025), which indicate that a deep learning approach can enhance students' conceptual understanding through meaningful learning experiences.

The group discussion activities integrated into the instructional module also contributed to increased student engagement during instruction. Through these discussions, students had the opportunity to express their opinions, compare their analysis results, and build a shared understanding of the data being studied. This finding aligns with the research by Aflah et al. (2023), which indicates that group work can enhance student participation and engagement in the learning process. However, during implementation, several challenges were still encountered, such as varying levels of participation among group members and the need for additional guidance during the initial exploration phase. These conditions indicate that the teacher's role as a facilitator remains essential to provide scaffolding so that all students can participate optimally in learning activities (Li, 2025).

The results of this study also indicate that the use of digital tools such as Canva, Kuesio, and Zep Quiz serves as a supportive medium that aids the learning process. However, improvements in students' understanding are not solely attributable to the use of these technologies. A more influential factor is how technology is utilized to support the processes of exploration, reflection, and assessment, which have been designed in accordance with the principles of deep learning and Understanding by Design. In other words, technology acts as a tool that reinforces the implementation of instructional design, not as the primary factor determining learning success. This finding aligns with the views of Sugiarni et al. (2024) and Ali et al. (2025), who state that the effectiveness of technology in learning is highly dependent on the quality of the underlying instructional design.

From a research and development perspective, these findings offer both theoretical and practical contributions. Theoretically, this study expands the body of research on the integration of deep learning approaches and the Understanding by Design framework in statistics education. Previous studies generally developed instructional modules based on Problem-Based Learning (Hayati et al., 2024; Jamil et al., 2024), Discovery Learning (Dalimunthe et al., 2025), or UbD separately (Putra et al., 2023; Usfira et al., 2024). Meanwhile, the deep learning-based research conducted by Anggraini et al. (2025) still focuses on improving general learning outcomes and has not yet integrated backward design principles into the development of learning materials. Therefore, the novelty of this study lies in the integration of deep learning principles and the Understanding by Design framework into a bivariate data instructional module specifically designed to support conceptual understanding, statistical reasoning, and data interpretation skills.

Nevertheless, this study has limitations. The product trial was conducted in only one class with a relatively small number of students, so the generalizability of the findings should be interpreted with caution. Future research could test the effectiveness of the instructional module on a larger sample and employ an experimental design that includes a control group, thereby allowing for a more comprehensive assessment of the instructional module's impact on improving students' statistical skills.

4. CONCLUSION

This study successfully developed a deep learning instructional module based on Understanding by Design (UbD) for bivariate data that meets the criteria for validity and effectiveness in mathematics education. The developed instructional module supports students' improved understanding of the concepts of relationships between variables, the direction and strength of correlation, and data interpretation in real-world contexts. These findings indicate that integrating deep learning principles with the Understanding by Design framework can create a more meaningful, reflective, and conceptually oriented learning experience.

The novelty of this research lies in the integration of the deep learning approach and the Understanding by Design framework in the development of a bivariate data instructional module, which emphasizes not only procedural mastery but also the development of statistical reasoning and data interpretation skills. Thus, the developed instructional module has the potential to serve as an alternative instructional material supporting the implementation of mathematics learning oriented toward deep understanding.

This study is still limited to a small-scale pilot test in a single class. Therefore, future research is recommended to implement the instructional module on a broader scale and test its impact on other statistical competencies, such as statistical reasoning, statistical literacy, and data-driven decision-making skills.

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