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THE EFFECT OF DIGITAL DIDACTIC INTERVENTION ON MEASURES OF CENTRAL TENDENCY TOWARDS STUDENTS' STATISTICAL THINKING

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ABSTRACT

Statistical thinking is an essential competency for prospective mathematics teachers in responding to data-driven decision making within the context of Society 5.0. However, learning obstacles frequently emerge in higher education statistics courses due to instructional practices that emphasize procedural computation rather than conceptual and contextual understanding. This study aims to describe the implementation of a didactical design to reduce students' learning obstacles in statistical thinking through the topic of measures of central tendency. A qualitative descriptive method was employed involving 38 mathematics education students enrolled in an introductory statistics course. The didactical design integrated the *Theory of Didactical Situations* (TDS) and the DORA model (Describe, Organize, Represent, Analyze–Interpret) and was delivered through an interactive e-module developed on the AnyFlip platform. Data were collected using a post-implementation statistical thinking test based on DORA, classroom observations, semi-structured interviews, and reflective field notes. Learning activities were organized into four TDS stages action, formulation, validation, and institutionalization to support reflective and adidactical learning processes. The results indicate that students were able to construct statistical concepts more meaningfully and reduce previously identified learning obstacles, particularly in linking numerical results with graphical representations. In conclusion, the integration of TDS and the DORA model supported by interactive e-modules effectively enhances students' statistical thinking skills, as evidenced by the reduction of learning obstacles among prospective mathematics teachers.

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INTRODUCTION

Statistical thinking is one of the essential 21st-century competencies that must be developed in mathematics education, particularly in the context of Society 5.0, where data literacy and digital adaptability are increasingly critical. This capability involves cognitive processes used to understand, analyze, and interpret data critically within real-world contexts (Cipta et al., 2024; Garfield & Ben-Zvi, 2009; Garfield et al., 2008). In higher education, statistical thinking serves as a foundation for students to build data literacy and engage in evidence-based decision making amid rapid digital transformation (Ologbosere, 2023; Burrill & Pfannkuch, 2024; OECD, 2022). The pedagogical shift from content-focused instruction toward data-driven and problem-solving–oriented learning requires innovative approaches that integrate digital technology with conceptually robust learning theories (Sá et al., 2021; Cipta et al., 2023). This orientation aligns with the Merdeka Belajar Kampus Merdeka (MBKM) policy, which emphasizes mastery of higher-order thinking skills, data-driven problem solving, and contextual learning, as well as ongoing efforts to transform higher education in Indonesia toward adaptive and sustainable learning in the digital era (Kemendikbud, 2020a; Kemdikbud, 2020b).

However, several studies indicate that students continue to experience difficulties in conceptually understanding descriptive statistics, particularly the measures of central tendency (mean, median, and mode). These difficulties often arise because students tend to memorize formulas without understanding the representative meaning of the central values (Garfield et al., 2008; Chance, 2000); Arifin & Aprisal, 2020). Other studies reveal that students frequently misinterpret the relationship between data distributions and measures of central tendency, and they often fail to connect these concepts to real-world contexts (Balkaya & Kurt, 2023; Yanti, 2022). Similar findings were reported by Amdar et al. (2023), who noted that most students encounter the following learning obstacles: (1) epistemological obstacles, referring to limited understanding of basic statistical concepts; (2) ontogenic obstacles, referring to limited reflective thinking related to data variation; and (3) didactical obstacles, referring to instructional approaches that are predominantly procedural and lack reflective activities.

Several previous studies have attempted to address these issues through the use of digital media and technology-based approaches. Zulkardi et al., (2022) demonstrated that interactive flipbook-based e-modules can enhance student participation in mathematics learning, while Rachmayani et al., (2023) found that digital e-modules can stimulate students' critical thinking by enabling independent exploration of concepts. However, these studies have not specifically integrated didactical designs grounded in Brousseau's Theory of Didactical Situations, (2002) within descriptive statistics instruction, particularly in relation to measures of central tendency. Prior research has also tended to emphasize cognitive learning outcomes rather than the comprehensive development of students' statistical thinking processes (Garfield & Ben-Zvi, 2009; Wild & Pfannkuch, 1999). In this regard, didactical design plays a crucial role in aligning content characteristics, potential learning difficulties, and instructional strategies (Suryadi, 2019; Chevallard, Y., & Bosch, 2020). A structured and reflective didactical approach allows instructors to design learning situations that support meaningful construction of understanding in measures of central tendency—for example, through contextual data exploration (Garfield & Ben-Zvi, 2009). and helps students interpret mean, median, and mode as representative measures of data rather than mere computational results (Cipta, Suryadi, Herman, Jupri, et al., 2024); Balkaya & Kurt, 2023).

Along with the advancement of digital technology, the use of AnyFlip-based e-modules as interactive learning media has become a promising innovation to support the implementation of didactical design. This platform allows the integration of text, graphics, animations, and interactive links, making the learning process more engaging, flexible, and contextual (Zulkardi et al., 2022; Sari et al., 2021). The integration of AnyFlip-based e-modules with didactical design is believed to address students' learning obstacles and enhance their statistical thinking skills through meaningful and reflective learning experiences.

Based on bibliometric analysis (Cipta, Suryadi, Herman, & Jupri, 2024), research related to the implementation of didactical design in statistics education remains relatively limited, particularly studies that integrate digital approaches using interactive flipbook-based media. Therefore, a research gap exists in the integration of the Theory of Didactical Situations and interactive digital media to develop students' statistical thinking skills in the context of measures of central tendency. In addition, previous studies have tended to focus on media development without examining its impact on higher-order cognitive aspects such as data analysis and interpretation (Rachmayani et al., 2023); (Zulkardi et al., 2022).

Thus, this study offers scientific novelty by implementing a didactical design integrated with an AnyFlip-based e-module to support the development of students' statistical thinking skills in the context of measures of central tendency. This study also addresses existing research gaps by emphasizing process-oriented learning rather than solely focusing on learning outcomes. Therefore, the purpose of this study is to describe the implementation of the didactical design through an AnyFlip-based e-module on measures of central tendency and to evaluate its contribution to the development of students' statistical thinking skills based on the DORA components (describing, organizing, representing, analyzing, and interpreting data).

Therefore, this study aims to examine the implementation of a digital didactical design integrating the Theory of Didactical Situations (TDS) and the DORA model to support the development of students' statistical thinking in learning measures of central tendency. By focusing on the learning process and the reduction of learning obstacles through structured and reflective instructional design, this study seeks to contribute both theoretically and practically to the development of data literacy and statistical thinking in higher education.

METHOD

This study is part of a series of research conducted within the framework of Didactical Design Research (DDR), which consists of three stages: prospective analysis (analysis of didactical situations before instruction), metapedadidactic analysis, and retrospective analysis (Suryadi, 2016). This article specifically focuses on the stage of metapedadidactic analysis, namely the implementation of the developed didactical design and the observation of the learning dynamics that occur in the classroom.

Within the framework of the Theory of Didactical Situations (TDS), the implementation of instructional design in this study follows four essential stages: the action situation, the formulation situation, the validation situation, and institutionalization (Brousseau, 2002). These stages provide a structured and reflective learning trajectory that enables students to construct knowledge through interaction with contextual tasks and through reflection on the outcomes of their actions (Suryadi, 2019b). In the context of teaching measures of central tendency, the TDS stages were operationalized through a sequence beginning with data exploration, followed by students' formulation of solution strategies, validation of their results, and subsequent conceptual generalization. Furthermore, the learning process was examined using the four components of statistical thinking defined in the DORA model Describing, Organizing, Representing, and Analyzing data which served as analytical indicators for tracing the development of students' statistical thinking throughout the implementation.

The research employed a descriptive qualitative approach, as it aims to provide an in-depth description of the implementation process of the didactical design on the topic of measures of central tendency. The research subjects consisted of 38 students from the Mathematics Education Study Program at a private university in Bandung, selected through purposive sampling. The selection of participants was based on preliminary findings indicating that this group of students experienced learning obstacles related to measures of central tendency, making them relevant for examining the effectiveness of the didactical design implementation.

Data were collected using three main techniques:

1. Statistical thinking test, which was used to examine the extent to which the implementation of the didactical design could reduce students' learning obstacles. The test consisted of four open-ended questions that measured indicators of statistical thinking based on the DORA components (describing, organizing, representing, and analyzing/interpreting data). Test validation was conducted through expert judgment by three specialists in statistics and mathematics education.
2. In-depth interviews, conducted with several students to obtain information about their learning experiences, the difficulties they encountered, and their perceptions of the AnyFlip-based e-module.
3. Researcher reflections, in which the researcher who also served as the course instructor recorded reflective field notes to describe didactical interactions, didactical anticipations, and instructional adaptations made throughout the implementation process.

Data were analyzed descriptively through three stages: (1) data reduction, by selecting and coding the results of observations, interviews, and student tests based on indicators of statistical thinking; (2) data display, presented in the form of narrative descriptions that illustrate the dynamics of didactical interactions and their alignment with the instructional design; and (3) conclusion drawing, which focused on identifying metapedadidactic characteristics and changes in learning obstacles that emerged during the implementation of instruction.

RESULTS AND DISCUSSION

Results

The hypothetical didactical design for the topic of Measures of Central Tendency was developed by incorporating the principles of Brousseau's (1997) Theory of Didactical Situations (TDS) and the DORA model (Describe–Organize–Represent–Analyze), which is contextualized as four components of statistical thinking: describing, organizing, representing, and analyzing/interpreting data. The integration of these two approaches aims to ensure that students' learning trajectories are not only oriented toward procedural skills but also foster conceptual and reflective understanding of the meaning of data (Garfield & Ben-Zvi, 2009).

The structure of the didactical design was built through the four main situations in TDS—action, formulation, validation, and institutionalization each of which is connected to statistical thinking activities. Every stage enables students to interact actively with data, identify patterns, and formulate the concepts of measures of central tendency (mean, median, and mode) within meaningful contexts. This design is visualized in Figure 1, which illustrates a progressive flow from the exploration of raw data to the interpretation of analytical results in both professional and academic contexts.

The color intensity in Figure 1 becomes progressively stronger from the component of describing data toward analyzing and interpreting data. This color gradation is intended to emphasize that learning in an introductory statistics course does not end with the ability to recognize or organize data; rather, it continues toward the stages of representing as well as analyzing and interpreting data in depth. Thus, the hypothetical didactical design places stronger emphasis on these final two components of statistical thinking, as both represent higher-order thinking processes that constitute the primary learning goals of the Statistics course for prospective mathematics teachers.

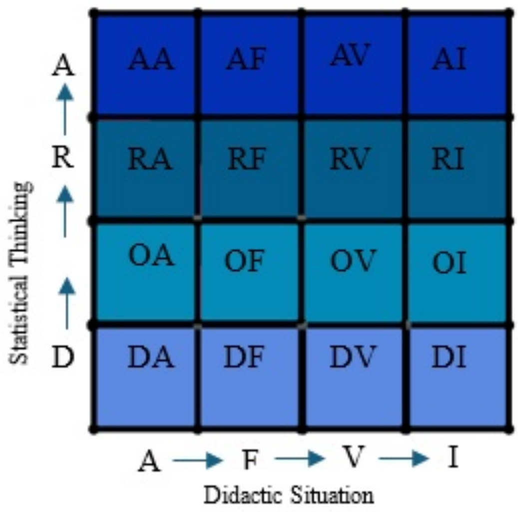

Figure 1. Hypothetical Didactical Design for the Topic of Measures of Central Tendency

To support the implementation of the didactical design, an interactive AnyFlip-based e-module was developed, incorporating activity stages aligned with the TDS structure, accompanied by reflection guides and contextual exercises based on real data. The e-module allows students to independently interact with the material, explore datasets, construct frequency tables, create diagrams, and interpret measures of central tendency. The appearance of the e-module is presented in Figure 2.

Figure 2. Display of the E-Module on the Anyflip Platform

The implementation of the didactical design on the topic of Measures of Central Tendency was carried out by referring to the four main situations in the Theory of Didactical Situations (TDS), namely action, formulation, validation, and institutionalization. Each stage was designed to foster components of statistical thinking: describing, organizing, representing, and analyzing–interpreting. The following presents a description of the implementation of each learning situation.

1. Action Situation

The action stage begins with students reading contextual data in the form of students' exam scores presented in the e-module. The lecturer stimulates students' thinking through open-ended questions such as, *"If this data needs to be summarized into a single value, which measure could you use?"* Some students mention the mean, while others mention the median, indicating that they are familiar with measures of central tendency, although their conceptual understanding is not yet fully developed.

Students then organize the raw data into a frequency distribution table and present it using bar or line charts. Through prompting questions such as, *"Does this table help you see the pattern in the data?"* students are encouraged to reconsider the representations they have created. This activity guides them to recognize distributional patterns and select the most informative form of representation.

The action stage concludes with exercises in calculating the mean, median, and mode based on the processed data. Students demonstrate varied strategies in their calculations, while the lecturer observes without providing direct intervention to foster an adidactic situation. These activities strengthen students' abilities to describe and organize data, while also beginning to connect visual representations with their corresponding numerical measures of central tendency.

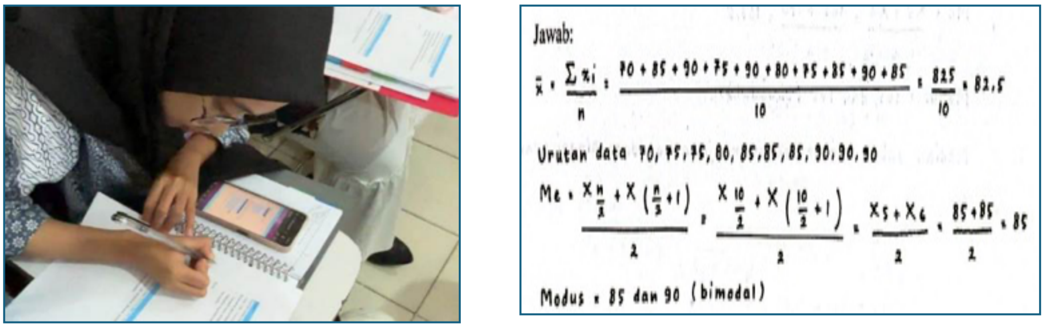

Figure 3. Students' Activities in the Action Stage

2. Formulation Situation

In the formulation stage, students begin constructing conceptual understanding based on their prior explorations. They calculate the mean, median, and mode for both ungrouped and grouped data, and subsequently compare the results across these measures. During this process, discussions emerge regarding the differences among mean, median, and mode in symmetric versus skewed distributions. The instructor reiterates that the relationships among these measures of central tendency can reflect the shape of the data distribution.

Next, students are asked to relate the numerical results to visual representations through histograms. Discussions on the positions of the median and mode within the histogram help students understand the connection between numerical data and graphical displays. In the final part of this stage, students interpret the meaning of the measures of central tendency within real-world contexts—such as student achievement data or social data—and recognize the specific function of each measure depending on the situation.

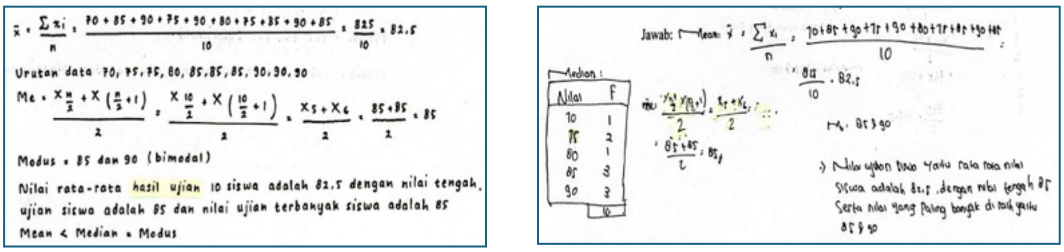

Figure 4. Students' Activities in the Formulation Stage

This stage plays an important role in developing students' ability to describe, represent, and analyze data conceptually rather than merely procedurally. The instructor serves as a facilitator who provides guiding questions and encourages students to connect the concepts with their contextual applications.

3. Validation Situation

The validation stage focuses on reflective activities aimed at reviewing calculations and interpretations. Students present the results of their group work, while other groups examine the calculation steps, particularly the correct use of cumulative frequencies in determining the median. Class discussions evolve into a process of cross-checking the consistency between the distribution tables, numerical results, and graphical representations.

Some students identify errors caused by inconsistencies between the data in the distribution table and the raw data. This validation process helps students understand the importance of data consistency and verifying each calculation step. Validation is also applied to visual representations: students match the peaks of histograms with the mode values and review the accuracy of their interpretations.

The validation stage fosters students' critical thinking by engaging them in analyzing and interpreting results across different representations. They learn that validation is not only about numerical correctness but also about the accuracy of the conceptual meaning.

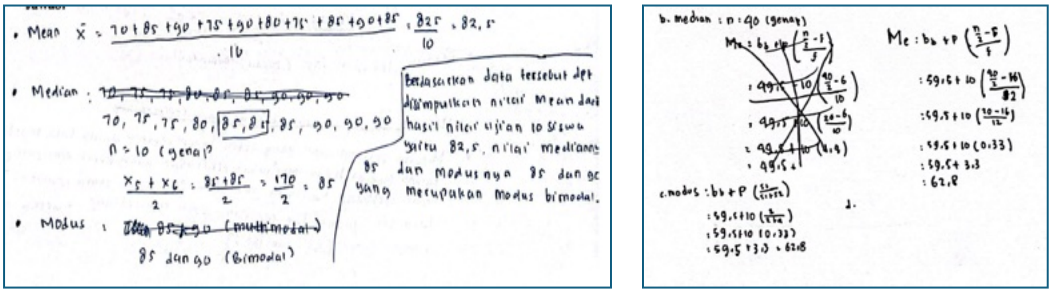

Figure 5. Students' Activities in the Validation Stage

4. Institutionalization Situation

In the final stage, students relate the results of their exploration and validation to formal concepts and their applications in real-world contexts. The discussion begins with the instructor asking about the shape of the data distribution based on the calculated mean, median, and mode. Students conclude that when the mean is higher than the median, the data tend to be right-skewed. The instructor then institutionalizes the concept of the relationship between measures of central tendency and the shape of data distributions.

Next, students present a summary of their calculations and interpret the results using tables and diagrams. They recognize that distribution tables serve not only as calculation tools but also as a means of communicating statistical information. During the presentation activities, students demonstrate the ability to select the most appropriate form of representation (bar chart or pie chart) and justify their choices.

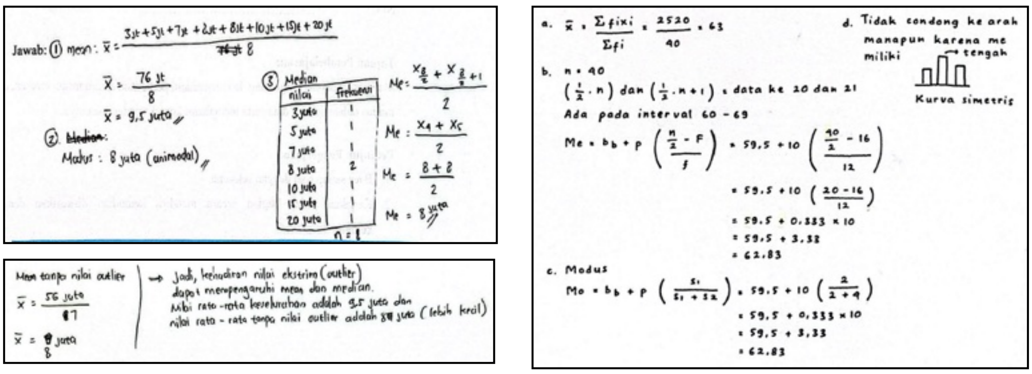

Figure 6. Students' Activities in the Institutionalization Stage

Finally, students discuss the application of measures of central tendency in decision-making. For instance, using the median to evaluate exam results with extreme values, or using the mode to represent the most common income category in a survey.

The institutionalization stage emphasizes the role of measures of central tendency as concepts that are not only mathematical but also functional in real-life contexts. At this stage, students integrate all components of statistical thinking describing, organizing, representing, and analyzing/interpreting data while demonstrating mature conceptual understanding.

Observations and in-depth interviews conducted by the instructor-researcher indicate a shift in students' thinking from merely following procedures toward conceptual understanding. The main challenge identified was difficulty in interpreting calculation results into visual and contextual representations. However, with reflective guidance provided during the validation and institutionalization stages, students began to exhibit higher levels of statistical thinking.

Retrospective analysis of the implementation shows that the relationship between the hypothetical didactical design and its classroom realization was relatively consistent. Most of the predicted student responses were confirmed, although some adjustments were necessary, particularly regarding learning time and additional visualization support. Overall, the design proved effective in fostering adidactic situations that support the learning of measures of central tendency.

After the completion of the instructional sequence, students were administered a statistical thinking test based on the DORA framework. The test was not intended to measure quantitative gains in performance, but rather to identify whether the learning obstacles predicted during the prospective analysis phase persisted in students' statistical thinking. The instrument was used to examine potential obstacles across all components of statistical thinking. Figure 7 presents an example of a student's response to the test.

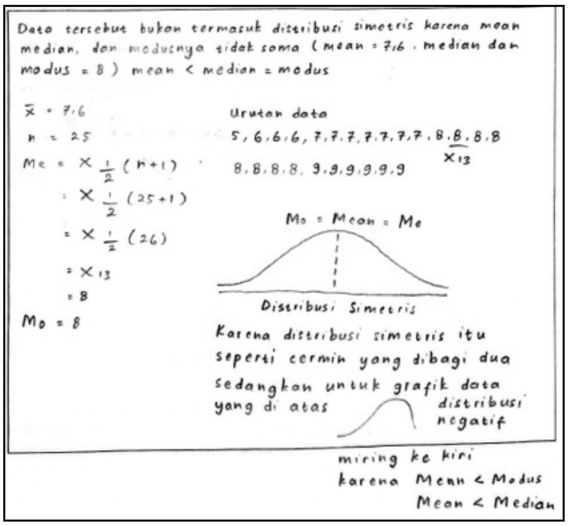

Figure 7. Student Response on the DORA-Based Statistical Thinking Test

Figure 7 illustrates that the student was able to analyze and interpret the relationship among the mean, median, and mode in a right-skewed distribution. This interpretative ability was not evident when the same instrument was previously used to identify learning obstacles, during which students tended to focus solely on procedural calculations without relating numerical results to distributional characteristics. This finding indicates a shift from procedural engagement toward conceptual understanding in students' statistical thinking.

Overall, the results of the didactical design implementation indicate that instruction grounded in TDS and the DORA model can facilitate the development of students' statistical thinking in a more structured and reflective manner. Through systematically managed didactical situations, the learning obstacles predicted during the prospective analysis particularly those related to data analysis and interpretation were reduced, although not entirely eliminated

Discussions

This section discusses the meaning and implications of the implementation of the didactical design on the topic of Measures of Central Tendency, focusing on the metapedadidactic stage within the framework of Design Didactical Research (DDR). The analysis emphasizes how didactical interactions between students and the instructor in each TDS situation (action, formulation, validation, and institutionalization) contribute to the emergence and reduction of learning obstacles, as well as how the components of statistical thinking are facilitated throughout the process.

The implementation of the didactical design demonstrates that the patterns of interaction among students, the instructor, and the learning materials develop progressively in accordance with TDS principles. In the action stage, students are given the freedom to explore the data without direct intervention from the instructor, creating an adidactic situation that allows them to construct an initial understanding of the data and measures of central tendency. This aligns with Brousseau's (2002) view that the action situation serves as a space where students learn through confrontation with problems rather than through direct instruction.

The formulation stage serves as a bridge for students to reorganize their exploration results into more systematic concepts. Instructor-facilitated discussions give rise to a new didactical contract, in which the instructor's role shifts from being an information provider to a facilitator of meaning. This process demonstrates an epistemological shift from "performing calculations" toward "interpreting measures of central tendency as tools for reading data distributions."

Subsequently, the validation stage reveals the emergence of reflective and evaluative activities. Students not only check the accuracy of numerical results but also examine the consistency between tables, graphs, and interpretations. This validation process reflects the formation of a dynamic didactical milieu, in which students and the instructor collaboratively construct justifications for the statistical concepts being studied.

The institutionalization stage functions to connect the results of exploration and discussion with formal knowledge. The instructor emphasizes the relationships among the mean, median, mode, and the shape of the data distribution, while also linking them to real-world applications. Consequently, statistical concepts move beyond procedural understanding and become internalized as tools for data-driven decision-making.

Metapedadidactic analysis indicates that the implementation of the didactical design successfully reduced the learning obstacles previously identified during the initial design stage. Some of the main obstacles observed at the early stage included: (1) difficulty distinguishing the positions and values of the mean, median, and mode; (2) misunderstandings in connecting the mean, median, and mode with the skewness of the distribution; and (3) challenges in determining the mode from histograms or data distributions.

The primary factors contributing to the reduction of these obstacles include the TDS-based activity design, which placed students in adidactic situations allowing them to construct knowledge through exploration and validation; instructor-triggered questions serving as didactical variables to stimulate reflection and mathematical argumentation; and the use of an AnyFlip-based e-module, which enriched learning interactions through data visualization and context-based activities, enabling students to represent statistical ideas more meaningfully.

These findings are consistent with previous research indicating that didactical designs based on the Theory of Didactical Situations (TDS) are effective in enhancing reflective thinking processes while reducing conceptual obstacles in statistics and mathematics learning. This aligns with the findings of Lestari & Umbara (2022), which showed that the application of TDS can facilitate knowledge construction through adidactic situations, as well as the study by Tonra et al. (2024) which confirmed that didactical design plays a significant role in gradually reducing learning obstacles. Furthermore, Suwangsih et al. (2023) emphasized that the development of instructional materials and learning media grounded in didactical principles can strengthen students' conceptual understanding and improve the quality of learning interactions. Therefore, the results of this study reinforce the empirical evidence that integrating TDS into instructional design is an effective and adaptive approach for enhancing students' statistical competencies.

Based on the implementation results, the development of students' statistical thinking can be identified through four main components (Jones et al., 2002). The ability to describe data was evident in the action stage, when students observed and recognized the characteristics of raw data. The ability to organize data developed during the formulation stage through the construction of frequency distribution tables and determination of class intervals. Data representation skills were demonstrated by selecting appropriate types of charts and ensuring consistency between numerical calculations and graphical displays during the validation stage. Finally, the ability to analyze and interpret data reached its most mature form in the institutionalization stage, when students were able to accurately explain the meaning of measures of central tendency in both professional and social contexts.

This progression of statistical thinking demonstrates that the didactical design serves as an important didactical tool, enabling the transition from procedural activities to conceptual and interpretative thinking. This aligns with Garfield & Ben-Zvi (2009) view that statistical thinking develops through active engagement in authentic contexts that require data analysis and reflection.

A retrospective analysis was conducted to compare the hypothetical didactical design with its classroom implementation. The results indicate that most of the learning flow aligned with the original design, although some spontaneous adaptations were made by the instructor to respond to classroom dynamics.

For instance, during the action stage, the instructor extended the discussion time because students needed more time to understand the difference between the median and the mode. This adaptation reflects an active metapedadidactic process, in which the instructor does not merely follow the design but adjusts strategies to ensure that learning objectives are achieved..

This retrospective analysis emphasizes that the success of a design is determined not only by the initial plan but also by the instructor's ability to manage the dynamics of didactical situations reflectively, particularly in adjusting the evolving didactical contract in the classroom (Sensevy, 2014; Sensevy, 2019).

Based on the results and analysis above, several important implications can be drawn. First, didactical designs based on TDS and DORA have proven to be effective models for developing statistical thinking skills in prospective teacher education (Brousseau, 2002; Suryadi, 2019a), while the use of interactive e-modules expands the space for adidactic interaction and allows students to engage in deeper self-reflection (Mayer, 2021). Furthermore, metapedadidactic and retrospective processes serve as key elements to ensure that the design remains adaptive to the actual learning context and students' responses during instruction (Suryadi, 2013). Consequently, the findings of this study reinforce the position of DDR as an approach that not only produces applicable instructional design products but also enriches conceptual understanding of the dynamics of didactical interactions in the development of statistical thinking (Gravemeijer, 1994; Jones et al., 2002).

CONCLUSION

The implementation of the didactical material design for measures of central tendency, grounded in the *Theory of Didactical Situations* (TDS) and the DORA model, supported the holistic development of students' statistical thinking, including the abilities to describe, organize, represent, analyze, and interpret data. The structured learning process through the stages of action, formulation, validation, and institutionalization enabled students to actively construct knowledge and reflect on the conceptual meaning of the mean, median, and mode in meaningful contexts. The use of an interactive AnyFlip-based e-module further enhanced student engagement by facilitating multiple data representations and supporting reflective learning. Retrospective analysis indicated that this design effectively reduced previously identified learning obstacles, particularly those related to conceptual misunderstandings of central tendency, the validity of grouped data calculations, and the interpretation of numerical results in relation to graphical representations.

Nevertheless, this study has several limitations. The implementation was conducted with a single group of students in an introductory statistics course, limiting the generalizability of the findings. Moreover, the study focused on analyzing learning processes and changes in learning obstacles rather than on quantitatively measuring learning gains or long-term impacts. Future research is therefore recommended to involve more diverse samples, apply experimental or quasi-experimental designs, and conduct longitudinal investigations to examine the sustained effects of TDS and DORA based didactical designs across different statistical topics and educational contexts.

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