Statistical Thinking of Prospective Teachers Across Gender, GPA, and Educational Field

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Abstract

Empirical evidence on how demographic and academic characteristics jointly influence prospective teachers' statistical thinking remains limited, particularly in Indonesian teacher education. This study examined differences in statistical thinking based on gender, Grade Point Average (GPA), activity status, and educational field. A quantitative cross-sectional design was employed involving 170 prospective teachers selected through stratified random sampling from a population of 233 students and graduates. Statistical thinking was measured using a modified test and analyzed using the Rasch model and multivariate analysis. The results indicated that statistical thinking remained at a low-to-moderate level, with the lowest performance in describing data (M = 0.39) and data presentation (M = 0.39). Significant differences were found for activity status (p = .023) and educational field (p = .046), but not for gender (p = .390) or GPA (p = .675). This study provides integrated empirical evidence to support the development of context-sensitive statistics curricula and instructional strategies in teacher education.

***Keywords**: Statistical Thinking Ability; Prospective Teacher Student; Statistics Education; Teacher Education; Rasch Model*

1. INTRODUCTION

The rapid expansion of data-driven decision-making has transformed statistical thinking into a core competency required across education, science, and professional practice. Teachers are increasingly expected to interpret educational data, evaluate evidence, and make instructional decisions based on empirical findings rather than intuition alone. Consequently, teacher education institutions are expected to prepare prospective teachers who can reason statistically and apply data effectively in both classroom practice and educational research (Garfield et al., 2015). Statistical thinking enables individuals to integrate data, analytical methods, and interpretation to solve complex problems while supporting logical, systematic, and evidence-based reasoning (Ulusoy & Altay, 2017).

Statistical thinking is particularly important in teacher education because future teachers are expected not only to understand statistical concepts but also to interpret classroom evidence, evaluate learning outcomes, and design instructional improvements using empirical data. These competencies extend beyond computational proficiency to include data comprehension, statistical reasoning, interpretation, and evidence-based decision-making (Chance, 2002). Consequently, insufficient statistical thinking may reduce teachers' ability to conduct classroom research, interpret assessment results, and foster students' quantitative reasoning (Huber et al., 2024).

Previous studies have demonstrated that statistical thinking develops through multiple cognitive processes involving data interpretation, contextual reasoning, critical evaluation of evidence, and statistical communication (Jones et al., 2000; Meylasari et al., 2021). Students with stronger statistical thinking are more capable of evaluating data quality, recognizing bias, selecting appropriate analytical procedures, and drawing valid conclusions (Garfield & DelMas, 2010; Delmas et al., 2007; Findley et al., 2023). These findings indicate that statistical thinking represents a higher-order competency influenced by various learner characteristics rather than merely statistical knowledge.

Despite its importance, empirical findings regarding the determinants of statistical thinking remain inconsistent. Gender has frequently been examined; however, previous studies have reported conflicting results. While Ovinda Fitri (2016) identified significant gender differences in logical thinking, Esnard et al. (2021) found no significant differences in statistical thinking performance. These contradictory findings indicate that gender alone cannot adequately explain variations in statistical thinking.

Similar inconsistencies appear in studies examining academic achievement. GPA has often been associated with stronger statistical literacy and critical thinking (Andriatna et al., 2021). Students with higher GPAs also tend to demonstrate greater motivation to learn statistics and apply statistical methods in research (Nemrawi et al., 2022). However, most existing studies have examined GPA independently without considering its interaction with other demographic and educational characteristics, limiting a comprehensive understanding of statistical thinking among prospective teachers.

Educational background represents another factor that may shape statistical thinking because each discipline provides different levels of exposure to statistical concepts and analytical practices (Wild & Pfannkuch, 1999; Tomasetto et al., 2009). Although prospective mathematics teachers generally demonstrate stronger statistical literacy than students from other educational programs (Andriatna et al., 2021), comparative evidence across multiple teacher education programs remains scarce.

More importantly, previous studies have predominantly investigated gender, GPA, educational status, or educational field as separate variables. Little attention has been given to examining these characteristics simultaneously within a single analytical framework, particularly among prospective teachers in Indonesia. As a result, existing evidence remains fragmented and provides limited guidance for designing teacher education programs that effectively strengthen statistical thinking.

Unlike previous studies that focused on a single demographic characteristic, this study simultaneously examines gender, GPA, and educational field to obtain a more comprehensive understanding of statistical thinking among prospective teachers. Integrating these variables within one analytical framework enables identification of the relative contribution of each characteristic and provides evidence for developing more targeted instructional strategies in teacher education.

This study compares the statistical thinking abilities of prospective teachers across gender, GPA categories, and educational fields in Indonesian higher education. The findings are expected to extend the current literature by providing an integrated understanding of demographic and academic factors associated with statistical thinking. Furthermore, the results may inform curriculum development, instructional design, and evidence-based strategies for strengthening statistical thinking as an essential component of teacher professional competence (Altaylar & Kazak, 2021; Marshman & Dunn, 2024; Franklin et al., 2015; Cobb et al., 2015).

2. METHOD

This study was conducted from October 16 to November 30, 2024, to describe the statistical thinking abilities of students based on factors such as gender, GPA, activity status, and field of study. From a total population of 233 students and graduates, 170 respondents were selected as samples using stratified random sampling. The sample includes four fields of study: 27 students and graduates from History Education, 35 from Economics Education, 65 from Mathematics Education, and 43 from English Education.

Out of the total 170 samples in this study, 122 were female and 48 were male. Based on GPA (on a 4.0 scale), the sample was divided into three categories: high ($IPK > 3.34$) with 82 respondents, medium ($2.33 < IPK \leq 3.34$) with 74 respondents, and low ($IPK \leq 2.33$) with 14 respondents. Regarding activity status, 110 respondents were active students, while 60 were graduates. The test used to measure the statistical thinking abilities of prospective teacher students (Garfield & DelMas, 2010) (Rossman & Chance, 2004). The test was designed using indicators proposed by Jones et al., (2000), consisting of a total of 20 multiple-choice questions. These questions included 5 items to measure the ability to describe data, 5 items to measure the ability to organize and reduce data, 5 items to measure the ability to represent data, and 5 items to measure the ability to analyze and interpret data. The instrument was declared valid based on expert assessment (see table 1).

Table 1. Instrument 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	S.Si., M.Si	Female	41/19	Mathematics Education (Statistics)	Subject Matter Expert, pedagogical expert, instrument

The data in this study were analyzed using a quantitative method with the Rasch Model approach to test the empirical validity of the questionnaire items. The Rasch Model was chosen because it has several advantages, such as providing estimates on the same latent scale (logit) for both persons and items (Zamora-Araya et al., 2018), improving the accuracy of calculations through the calibration of the measurement scale, persons, and items (Mulawarman et al., 2020), and being able to predict missing data based on systematic response patterns (Isnani et al., 2019). The statistical thinking abilities of students were categorized into five levels (see Table 2). Rasch analysis was performed using Winstep software version 3.73, which includes measurements (measure), person fit order, summary statistics, and scale mapping with the Wright Map. Additionally, SPSS software was used to analyze the relationships between gender, GPA, activity status, and field of study with statistical thinking abilities.

Table 2. Levels of Statistical Thinking Ability

Range	Level
$0{,}00 < x \leq 0{,}20$	Very low
$0{,}20 < x \leq 0{,}40$	Low
$0{,}40 < x \leq 0{,}60$	Medium
$0{,}60 < x \leq 0{,}80$	High
$0{,}80 < x \leq 1{,}00$	Very high

3. RESULT AND DISCUSSION

3.1 Result

This section presents the results of the analysis of students' statistical thinking abilities based on the variables of gender, GPA, activity status, and field of study. The analysis was conducted by evaluating respondents and questionnaire items using item fit criteria. Items that did not meet the item fit criteria indicated potential misconceptions in respondents' understanding. The evaluation of fit was carried out using two main indicators: mean-square (MNSQ) and Z-standardized (ZSTD). According to Boone et al., (2014), an item is considered valid if its Outfit Mean Square (MNSQ) value falls within the range of $0.5 < MNSQ < 1.5$, while respondents are categorized as valid if their Outfit Z-Standardized (ZSTD) value falls within the range of $-2.0 < ZSTD < 2.0$. This analysis provides a deeper insight into the validity of items and respondent fit in the study.

The Rasch analysis confirmed that the statistical thinking instrument possessed satisfactory psychometric properties (Table 2). Item reliability was very high (0.95), indicating excellent item quality, while person reliability (0.78) and Cronbach's alpha (0.83) demonstrated acceptable consistency of student responses. Furthermore, the item separation index (4.65) suggested that the instrument effectively distinguished different levels of statistical thinking ability among prospective teachers (Boone et al., 2014; Fisher, 2023).

Table 2. Summary of Rasch Measurement.

Statistical Thinking Test	Measure	Mean Outfit MNSQ	Outfit ZSTD	Std. deviation	Std. error	Separ-ation	Relia-bility	Cronbach's alpha
Persons (N=170)	-0,25	1,01	0,09	1,03	0,09	1,89	0,78	0,83
Item (N=10)	0,00	1,01	-0,43	0,81	0,19	4,65	0,95	

All twenty items satisfied the Rasch fit criteria, indicating that the instrument consistently measured the intended construct. Item difficulty ranged from −1.15 to 1.53 logits, while Outfit MNSQ values generally fell within the acceptable range. Positive PTMA correlations across all items further confirmed that every item contributed consistently to measuring statistical thinking.

Tabel 3. Item Measure and fit criteria

Indicator	Item Code	Measure (logits)	Outfit MNSQ	PTMA	Indicator	Item Code	Measure (logits)	Outfit MNSQ	PTMA
Describing data	S1	1,53	1,68	0,31	Representing data	S11	1,43	1,59	0,32
	S2	-1,02	1,01	0,40		S12	1,04	1,46	0,36
	S3	1,39	1,46	0,38		S13	0,22	0,98	0,49
	S4	-0,01	0,73	0,61		S14	0,39	0,67	0,66
Organizing and reducing data	S5	0,39	0,96	0,51	Analyze and interpret data	S15	-0,38	0,80	0,55
	S6	-0,23	1,19	0,37		S16	-1,15	1,06	0,37
	S7	0,59	0,58	0,70		S17	-0,98	0,88	0,44
	S8	-0,73	0,74	0,55		S18	-0,89	0,77	0,52
	S9	-0,23	0,75	0,59		S19	-0.38	1,25	0,32
	S10	-0.82	0,87	0,47		S20	-0,16	0,76	0,59

The Wright Map (Figure 1) indicates that the distribution of item difficulty adequately covered students' ability levels. However, the average person measure remained slightly below the average item difficulty, suggesting that the statistical thinking ability of prospective teachers was generally lower than the difficulty level of the instrument.

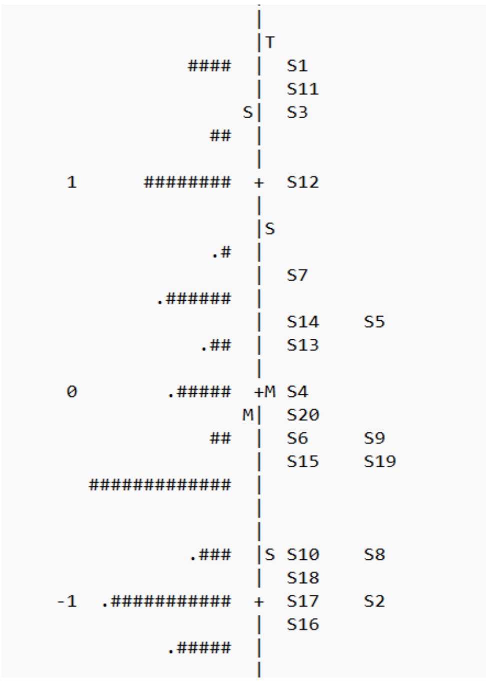

Figure 1. The result of wright map

3.1. Statistical thinking abilities based on indicators

Figure 2 shows considerable variation across test items. Students performed relatively well on several items but experienced lower achievement on others, indicating that statistical thinking was not uniformly developed across different aspects of the construct.

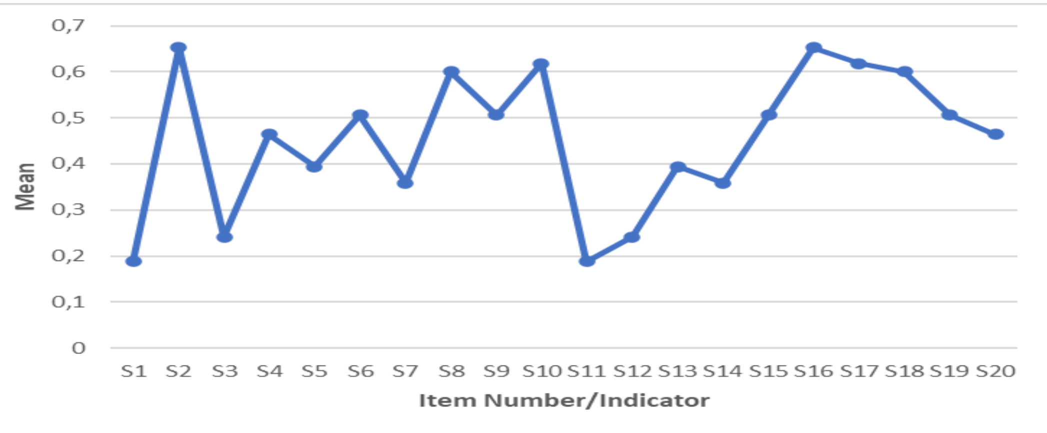

Figure 2. Average statistical thinking ability based on question items

As shown in Table 4, students demonstrated the strongest performance in analyzing and interpreting data, whereas describing data emerged as the weakest indicator. This finding suggests that prospective teachers encountered greater difficulty in identifying data characteristics and understanding fundamental statistical concepts than in interpreting analytical results.

Table 4. Average statistical thinking ability based on indicators.

Indicator	Mean Average	Level
Describing data	0,39	Low
Organizing and reducing data	0,52	Medium
Representing data	0,34	Medium
Analyze and interpret data	0,57	Medium

Statistical thinking also varied across statistical topics (Table 5). Students achieved their highest performance in hypothesis testing, whereas basic statistical knowledge, inferential statistics, and data presentation remained comparatively weak. These results indicate that conceptual understanding of statistics requires greater instructional attention than procedural hypothesis testing.

Table 5. Statistical thinking skills based on topic

Topic	Item Code	Mean average	Level	Topic	Item Code	Mean average	Level
Basic knowledge of statistics	S1 S2 S3 S6	0,40	Low	Measures of central tendency and dispersion of data	S4 S8 S9 S5 S19	0,49	Medium
Inferential statistics	S12 S13 S14 S17	0,40	Low	Hypothesis testing	S15 S16 S18 S20	0,56	Medium
Data presentation	S7 S10 S11	0,39	Low				

3.2. Statistical thinking abilities based on gender

Table 6 summarizes statistical thinking across gender. Female students obtained slightly higher mean scores than male students in most statistical topics, particularly inferential statistics, measures of central tendency, and hypothesis testing. Nevertheless, both groups showed relatively weak performance in data presentation, indicating that graphical interpretation and statistical communication remain common learning challenges regardless of gender.

Table 6. Statistical thinking ability based on gender

Topic	Male		Female	
	Mean Average	Level	Mean Average	Level
Basic knowledge of statistics	0,51	Medium	0,35	Low
Inferential statistics	0,32	Low	0,43	Medium
Data presentation	0,35	Low	0,40	Low
Measures of central tendency and dispersion of data	0,39	Low	0,53	Medium
Hypothesis testing	0,50	Medium	0,58	Medium

The multivariate analysis (Table 7) indicated no statistically significant difference in statistical thinking between male and female prospective teachers ($p > .05$). Before conducting the MANOVA test, it went through Normality and Homogeneity tests, and those assumption tests met the requirements. This finding suggests that gender was not a determining factor in explaining statistical thinking ability within this sample.

Table 7. Multivariate test results based on gender

	Effect	Value	F	Sig.
Gender	Pillai's Trace	.632	1.374^{a}	.390
	Wilks' Lambda	.368	1.374^{a}	.390
	Hotelling's Trace	1.718	1.374^{a}	.390

	Roy's Largest Root	1.718	1.374^{a}	.390

3.3. Statistical thinking abilities based on GPA

Students with high GPAs consistently achieved higher mean scores across most statistical topics than those with moderate and low GPAs. However, multivariate analysis revealed that these differences were not statistically significant ($p > .05$), indicating that GPA alone did not explain variations in statistical thinking ability

Table 8. Statistical thinking based on GPA

Topic	High		Moderate		Low	
	Mean Average	**Level**	**Mean Average**	**Level**	**Mean Average**	**Level**
Basic knowledge of statistics	0,46	Medium	0,41	Medium	0,29	Low
Inferential statistics	0,50	Medium	0,37	Low	0,48	Medium
Data presentation	0,35	Low	0,38	Low	0,40	Low
Measures of central tendency and dispersion of data	0,52	Medium	0,47	Medium	0,43	Medium
Hypothesis testing	0,58	Medium	0,52	Medium	0,50	Medium

Table 9. Multivariate test based on GPA

	Effect	Value	F	Sig.
GPA	Pillai's Trace	.766	.746	.675
	Wilks' Lambda	.374	$.636^{a}$	.756
	Hotelling's Trace	1.302	.521	.835
	Roy's Largest Root	.872	1.046^{a}	.469

3.4. Statistical thinking abilities based on active status

Active students consistently outperformed graduates across all statistical topics, with the largest difference observed in hypothesis testing. Unlike gender and GPA, multivariate analysis demonstrated a significant difference between active students and graduates ($p < .05$), indicating that learning status was associated with statistical thinking ability.

Table 10. Statistical thinking based on activity status

Topic	Active		Graduate	
	Mean average	**Level**	**Mean average**	**Level**
Basic knowledge of statistics	0,40	Low	0,39	Low
Inferential statistics	0,45	Medium	0,31	Low
Data presentation	0,41	Medium	0,35	Low
Measures of central tendency and dispersion of data	0,57	Medium	0,36	Low
Hypothesis testing	0,63	High	0,43	Medium

Table 11. Multivariate test based on activity status

	Effect	Value	F	Sig.
Status	Pillai's Trace	.991	43.707^{a}	.023
	Wilks' Lambda	.009	43.707^{a}	.023
	Hotelling's Trace	109.267	43.707^{a}	.023
	Roy's Largest Root	109.267	43.707^{a}	.023

3.5. Statistical thinking abilities based on educational field

Students from the Mathematics Education program demonstrated the highest statistical thinking scores across nearly all statistical topics, whereas students from History, Economics, and English Education generally showed lower performance. Multivariate analysis confirmed that statistical thinking differed significantly across educational fields (p ≤ .05), suggesting that disciplinary learning experiences contribute to the development of statistical thinking.

Table 12. Statistical thinking by field of education

Topic	History		Economic		Mathematics		English Language	
	Mean average	Level	Mean average	Level	Mean average	Level	Mean average	Level
Basic knowledge of statistics	0,42	Medium	0,31	Low	0,43	Medium	0,40	Low
Inferential statistics	0,32	Low	0,36	Low	0,53	Medium	0,29	Low
Data presentation	0,36	Low	0,32	Low	0,54	Medium	0,22	Low
Measures of central tendency and dispersion of data	0,30	Low	0,37	Low	0,66	High	0,46	Medium
Hypothesis testing	0,41	Medium	0,44	Medium	0,74	High	0,47	Medium

Table 13. Multivariate test based on education field

Effect		Value	F	Sig.
Educational Field	Pillai's Trace	1.396	1.741	.046
	Wilks' Lambda	.090	2.093	.050
	Hotelling's Trace	4.965	2.207	.050
	Roy's Largest Root	3.601	7.202^{a}	.004

4. Discussion

Overall, prospective teachers performed worst in data presentation, particularly in organizing and communicating information through tables and graphs. This finding suggests that students can generally perform statistical calculations but struggle to translate numerical results into meaningful visual representations. One possible explanation is that statistics instruction in teacher education often emphasizes computational procedures rather than the interpretation and communication of data. As a result, students become familiar with generating statistical outputs but have limited opportunities to explain patterns, compare trends, or present findings in ways that support evidence-based decision-making. This interpretation is supported by previous studies showing that students frequently encounter difficulties interpreting graphical data (Hariyanti, 2020; Mulya et al., 2018), while teachers often misunderstand the relationships among statistical measures when explaining data presented in tables (Ulusoy & Altay, 2017). Similarly, Maryati et al. (2019) reported that students' abilities to read, understand, and communicate statistical information remain relatively low, indicating that statistical communication continues to be one of the weakest components of statistical thinking.

Across the four indicators of statistical thinking, prospective teachers achieved only a moderate level of performance. This result indicates that students have developed basic statistical reasoning but have not yet reached the level required to critically evaluate data, justify statistical conclusions, and transfer statistical knowledge to authentic educational contexts. Statistical thinking develops progressively through repeated experiences involving investigation, interpretation, and reflection rather than through procedural instruction alone. Consequently, moderate achievement across all indicators may reflect limited opportunities for students to engage in inquiry-based statistical learning during their university studies. This interpretation is consistent with Masjudin et al. (2020), who found that statistical thinking generally remains at the intermediate level despite students demonstrating adequate procedural knowledge.

The consistently low performance in data presentation across gender, GPA, activity status, and educational field further indicates that this difficulty is a common instructional issue rather than a problem confined to a particular student group. Effective data presentation requires students to integrate statistical concepts with communication skills and contextual understanding, competencies that are rarely developed through conventional lecture-based instruction. Prospective teachers must not only interpret data accurately but also communicate statistical evidence clearly because these abilities are essential for classroom assessment and evidence-based teaching. Hammer & Berland (2014) and Wilkerson & Polman (2020) emphasize that meaningful data presentation supports scientific reasoning, while Selwyn (2021) argues that the ability to communicate data responsibly has become increasingly important in digital learning environments.

No significant difference was found in statistical thinking between male and female prospective teachers. This finding suggests that statistical thinking is influenced less by biological characteristics than by relatively similar educational experiences, learning opportunities, and curriculum exposure received by both groups. As teacher education programs generally provide identical learning environments regardless of gender, students are likely to develop comparable statistical competencies. This interpretation supports previous findings reported by Hasim et al. (2024) and Nemrawi et al. (2022). Nevertheless, the absence of gender differences does not imply that all students learn statistics similarly. Factors such as self-efficacy, motivation, attitudes toward statistics, learning strategies, and cognitive engagement may exert a stronger influence on statistical thinking than gender itself (Nemrawi et al., 2022; Salim & Ayub, 2017).

Similarly, GPA did not produce significant multivariate differences in statistical thinking, although differences appeared in specific statistical topics. This finding indicates that overall academic achievement does not necessarily reflect students' ability to reason statistically. GPA represents cumulative academic performance across diverse courses, whereas statistical thinking requires specialized reasoning skills developed through sustained engagement with authentic data analysis and problem solving. Consequently, students with high GPAs may not automatically demonstrate superior statistical thinking if their learning experiences have emphasized memorization rather than analytical reasoning. This finding highlights the importance of designing statistics instruction that explicitly develops higher-order reasoning skills across all levels of academic achievement.

Unlike gender and GPA, activity status significantly influenced statistical thinking ability. Active students generally demonstrated stronger performance because they remained engaged in ongoing learning activities, classroom discussions, and interactions with lecturers, allowing continuous reinforcement of statistical concepts. In contrast, graduates may experience reduced opportunities to practice statistical reasoning after completing formal coursework. These findings suggest that statistical thinking should be viewed as a competency that requires continuous practice rather than knowledge that remains stable after course completion. This interpretation aligns with Sardin et al. (2024), who argued that undergraduate students typically remain at transitional levels of statistical thinking, and with De Vetten et al. (2023), who emphasized that developing inferential reasoning requires continuous engagement with authentic statistical investigations.

Educational field also produced significant differences in statistical thinking, indicating that disciplinary learning experiences contribute substantially to the development of statistical reasoning. Students from Mathematics Education demonstrated stronger performance because they are exposed more frequently to mathematical modelling, quantitative reasoning, and statistical problem solving throughout their curriculum. In contrast, students from other education programs generally encounter statistics in fewer courses and within more limited contexts. These differences suggest that the intensity and context of statistical learning, rather than disciplinary labels alone, shape students' statistical thinking. This interpretation is consistent with Riwayani et al. (2024) and Tsaniyah (2020), who emphasized that both disciplinary content and students' cognitive characteristics influence their ability to solve statistical problems. Therefore, strengthening statistical thinking across teacher education programs requires contextualized instructional approaches that integrate statistics with authentic problems relevant to each educational discipline.

5. CONCLUSION

This study contributes to the literature by providing an integrated analysis of prospective teachers' statistical thinking across gender, GPA, activity status, and educational field, demonstrating that statistical thinking is influenced more by educational experiences and disciplinary contexts than by demographic characteristics alone. These findings offer practical implications for teacher education by highlighting the need to implement instructional approaches that explicitly promote statistical reasoning, data interpretation, and evidence-based decision-making across teacher education programs. Nevertheless, this study was limited to prospective teachers from a single higher education context and considered only demographic and academic characteristics. Future research should involve more diverse institutions, include additional variables such as statistical self-efficacy, learning motivation, digital literacy, and instructional approaches, and employ longitudinal or mixed-methods designs to provide a deeper understanding of how statistical thinking develops and how it can be effectively strengthened in teacher education.

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