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Strategies for Enhancing Students' Mathematical Reasoning and Disposition Ability in a Freedom Curriculum

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ABSTRACT

It is crucial to have suitable learning models in the Freedom curriculum, allowing students sufficient time to delve into concepts and improve skills, particularly in mathematical reasoning and disposition. CORE learning (Connecting, Organizing, Reflecting, and Extending) is a different approach to enhancing upper school students' mathematical reasoning and disposition abilities. This quantitative study employs descriptive and two-way multivariate analysis to examine the impact of learning models and gender on students' mathematical reasoning and disposition abilities. The study focuses on grade IX students at a public senior high school in Surakarta, Indonesia. The control group is class Phase E-8, which follows a direct learning approach and is known as the Non-CORE class. In the meantime, the Phase E-10 class is an experimental class implementing the CORE learning model. The study findings show variances in mathematical thinking and attitude among high school students in CORE versus non-CORE classes. Additionally, there is no reliance on enforcing CORE learning on male and female students, suggesting that CORE learning can be suggested for enhancing mathematical reasoning skills and disposition ability of all students irrespective of gender. CORE learning has been proven to be an effective strategy for improving students' mathematical reasoning and disposition through education oriented towards a constructivist approach centered on students, where students actively construct their knowledge through a series of processes that connect, organize, reflect, and extend concepts. This study contributes to the discourse on constructivist pedagogy by providing strong evidence that the CORE learning model improves mathematical reasoning and attitudes among upper secondary students. Those taught with CORE outperform peers in traditional settings in both cognitive and attitudinal measures. The lack of gender-based differences indicates CORE supports equitable learning. Aligned with Indonesia's Freedom Curriculum, the model promotes active, student-centered learning and shows promise as a scalable, inclusive approach to improving math proficiency and engagement.

Keywords: Mathematical Reasoning, Disposition, Freedom Curriculum

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INTRODUCTION

Numerous domestic and global studies indicate that Indonesia has been facing an education crisis for an extended period. These research findings indicate that numerous Indonesian children struggle to grasp basic reading comprehension or utilize fundamental mathematical principles. The results also indicate a significant disparity in education levels among different regions and social classes in Indonesia. To address this crisis and numerous obstacles, the Ministry of Education, Culture, Research, and Technology created the Freedom Curriculum as a crucial component in the initiative to recover education from the prolonged crisis. The Freedom Curriculum is designed to have various subjects for students to learn and spend more time exploring concepts and enhancing skills. Educators can select from a range of teaching resources to seamstress learning to suit students' needs and preferences. The initiative to enhance the attainment of the Pancasila student profile is formulated according to a particular topic designated by the government. The project does not have a specific learning goal to reach, therefore it is not connected to the subject material (Kementrian, 2022; Peranginangin, 2023; Lestari et al., 2024). Assessing the utilization of educational techniques in the freedom curriculum is very important to evaluate and recommend the best treatment in learning for improvement, such as Students' Understanding Ability, cognitive assessment, attitude, and skill evaluation. See (Pramesti, Surjatiningsih, & Nastiti, 2024) and (Santoso & Pramesti, 2024) for references. Enhancing Pancasila Student Profile in the freedom curriculum involves extensive conversations about reasoning skills. The freedom curriculum integrates knowledge, skills, and attitudes or dispositions necessary for learning.

A large number of high school seniors find mathematical reasoning difficult and have unfavorable attitudes toward the subject. Conventional teaching techniques may not effectively captivate students, resulting in a deficiency of confidence and enthusiasm towards mathematics. As math gains importance in different areas, students must work on enhancing their reasoning abilities. This study aims to fill this void by promoting critical thinking and problem-solving skills. Oz and Isk (2024) and Qi *et al* (2024) for the references. Further, a positive disposition toward mathematics is crucial for long-term success. Much research examines this ability using various methods, i.e., (Vo, Dai, & French, 2024), (Zhang, Guo, and Wei, 2023). The Freedom Curriculum enables more flexibility and customization in educational experiences. This adaptability aligns with current education trends that emphasize student independence and involvement. Holistic educational approaches take into account cognitive, emotional, and social aspects of the learning process (Lepore, 2024). The CORE (Connecting, Organizing, Reflecting, Extending) framework combines these components to form a complete educational setting. See (Atiyah and Priatna, 2023), (Supianti et al, 2022), (Sari et al, 2020). This learning enables students to assume responsibility for their learning and relate mathematical ideas to real-life situations.

The rollout of Indonesia's Kurikulum Merdeka (Freedom Curriculum) highlights the critical need for pedagogical models that provide students with sufficient time and cognitive space to engage meaningfully with academic content. In mathematics education, this translates into fostering both students' reasoning abilities and their positive dispositions toward the subject, skills that are essential for long-term academic success and effective problem-solving. Within this educational reform context, the CORE instructional model—Connecting, Organizing, Reflecting, and Extending—has gained traction as a constructivist-oriented approach that actively promotes conceptual understanding and deeper student involvement in the learning process.

Emerging evidence emphasizes the growing importance of reasoning in mathematics instruction. Oz and Isk (2024) identified mathematical reasoning as a key determinant of both problem-solving proficiency, and learner confidence among middle school students (Rusani e al., 2024). Complementing this, Qi et al. (2024) highlighted the interconnected roles of working memory, inhibitory control, and analogical reasoning in shaping mathematical skills in younger learners, thereby underscoring the need for pedagogical frameworks that address both cognitive and metacognitive development. Together, these studies suggest that reasoning and disposition are shaped not only by innate ability but also by instructional approaches and classroom environments.

Within the Indonesian educational landscape, preliminary investigations into the CORE model have shown encouraging results. Sari et al. (2020) demonstrated that CORE-based instruction significantly enhanced students' mathematical connection skills. Similarly, Ari and Abadi (2020) reported improved science learning outcomes through a set-theory-based adaptation of the CORE model. More specifically, Atiyah et al. (2023) found that CORE instruction improved mathematical reasoning in junior high school learners by promoting active learning and reflective thinking. However, while these studies validate the model's pedagogical potential, there remains a lack of quantitative research examining the interaction of learning models and gender in influencing both mathematical reasoning and student disposition, particularly at the senior secondary level within the Freedom Curriculum framework.

To bridge this research gap, the present study adopts a quantitative design to assess the impact of instructional approach and gender on students' mathematical reasoning and disposition. We believe that CORE emerges as a viable and scalable instructional strategy for enhancing mathematics education in diverse Indonesian classrooms. Thus, from the point of view of these components, particularly in mathematical reasoning and disposition ability, a pedagogue needs mathematics learning which is it can enhance these abilities. The study investigates how to incorporate autonomy, relevance, and engagement into mathematics teaching through a Freedom Curriculum by CORE learning. The research seeks to gauge enhancements in mathematical reasoning skills and students' disposition toward mathematics through assessing the effectiveness of CORE learning strategies. This involves recognizing successful methods that can be duplicated in different educational environments. In the end, the aim is to offer educators insights and advice to improve mathematics teaching and learning for senior high school students, making it more interesting and successful. However, assessing the utilization of the model is essential as employing suitable learning techniques in the freedom curriculum can lead to enhancing optimal learning achievements. This study investigates the pedagogical efficacy of the CORE learning model as a strategic intervention for enhancing students' mathematical reasoning and disposition, within the broader context of Indonesia's Kurikulum Merdeka (Freedom Curriculum). Given the curriculum's emphasis on learner autonomy, conceptual depth, and equity, there is a critical need for empirically validated, student-centered models that foster both cognitive and affective mathematical development. The research is structured around three core objectives. First, it seeks to evaluate the comparative effectiveness of the CORE model against conventional direct instruction in fostering students' mathematical reasoning skills and disposition toward mathematics. This aims to determine whether CORE learning facilitates deeper cognitive engagement and more favorable learner attitudes. Second, the study explores whether gender moderates the relationship between instructional model and student outcomes. This analysis is intended to assess the extent to which CORE learning supports equitable learning gains across male and female students, thereby contributing to ongoing discussions on gender-responsive mathematics education. Lastly, the study provides empirical evidence to support the integration of constructivist, student-centered methodologies into the national education system. By situating the CORE model within actual classroom practice, this research offers practical insights into how mathematics instruction can be innovated to align with contemporary curriculum reforms and address the diverse needs of Indonesia's student population.

METHOD

The goal of this study is to establish a nurturing educational setting to boost students' skills and confidence in mathematics. By evaluating the effectiveness of CORE learning strategies, the research aims to assess improvements in both mathematical reasoning skills and students' dispositions toward mathematics. Therefore, we propose the methodology of this research as follows.

The study population comprised all ninth-grade students enrolled at a public senior high school in Surakarta, Indonesia. Employing cluster random sampling, two distinct cohorts from Phase E classes—Phase E-8 and Phase E-10—were selected, each consisting of 36 students. The Phase E-8 class functioned as the control group, receiving traditional direct instruction and serving as the Non-CORE cohort. Conversely, the Phase E-10 class was designated as the experimental group, where the CORE learning model was implemented to evaluate its pedagogical impact.

The research delineated clear independent and dependent variables: the independent variables included the instructional approach (CORE versus direct instruction) and student gender (male and female), while the dependent variables comprised mathematical reasoning ability and disposition toward mathematics. Mathematical reasoning was measured via a five-item test structured in a grid format, developed in alignment with the Senior High School Mathematics curriculum for Class X, Semester 2 (Perbukuan, 2014; 2021) (Nugraha, 2024). Mathematical disposition was assessed through a 4-point Likert scale questionnaire containing both positively and negatively worded statements to gauge students' attitudes toward mathematics, with responses ranging from "very appropriate" to "very inappropriate." The CORE learning model framework used in the study was adapted from established models by Loka, Wena, and Wibawa (2020) and Nugraha (2024).

Both experimental and control groups completed the mathematical reasoning assessment and disposition questionnaire following their respective instructional experiences. These instruments were designed to capture both cognitive competencies and affective dispositions post-intervention. A quantitative analytical approach combined descriptive statistics with inferential statistics to examine the effects of the CORE learning model and gender on the outcome variables. A two-way multivariate analysis of variance (MANOVA) was conducted to detect significant differences and interaction effects. All data were processed using IBM SPSS software (Pramesti & Ario, 2021).

Instrument validity was established through expert content validation involving a mathematics education lecturer and a mathematics teacher. The mathematical reasoning test underwent item analysis, assessing discriminatory power and difficulty indices, both yielding favorable results. The test's reliability coefficient was 0.702, categorized as acceptable. The mathematical disposition questionnaire was similarly validated, piloted with 32 students, and demonstrated high reliability with a coefficient of 0.899, ensuring the instrument's robustness.To thoroughly evaluate the influence of CORE learning and gender, initial descriptive analyses summarized the dataset, followed by a two-way MANOVA to explore main effects and interactions. These analyses provided rigorous empirical evidence on the effectiveness and equity of the CORE instructional strategy.

This study's scope is confined to a comparative evaluation of the CORE learning model against a single alternative method direct instruction. Furthermore, only two dependent variables, mathematical reasoning and disposition, were investigated. These delimitations highlight opportunities for future research to expand on instructional models and investigate additional student outcomes.

1. Population and the methods of sampling. The population of this research was all students in grade 9 in a public senior high school in Surakarta Indonesia. We chose the sample using cluster random sampling. The participants in this research were students from two different groups in Phase E classes, namely Phase E-8 and Phase E-10, with 36 students in each class. Phase E-8 was chosen as the control class with non-CORE using direct learning while Phase E-10 was selected as the experimental class.
2. The instrumentation. We define variables in the research as the following.

2.1. Independent variables, namely learning model: CORE and Direct; Gender: Boy and Girl;

2.2. Dependent variables, namely students' mathematical reasoning and disposition ability.

3. The procedures. This research utilized tests assessing students' mathematical reasoning abilities and questionnaires evaluating students' mathematical dispositions. The assessment tool for mathematical reasoning skills is a set of five questions organized on a grid, designed to measure mathematical reasoning ability (Nugraha, 2024). The test questions on mathematical reasoning ability are organized based on the Mathematics Book for Senior High School Class X Semester 2 (Perbukuan (2014) dan Perbukuan (2021)). The 4-scale Likert questionnaire was designed to assess students' disposition towards mathematics. The survey questions included positive and negative statements about mathematical disposition indicators, with four possible responses: very appropriate, appropriate, inappropriate, and very inappropriate. The structure of the CORE learning model utilized in this research is based on the perspective of (Loka, Wena, & Wibawa, 2020) and follows the learning model provided in (Nugraha, 2024).

4. The analysis plan. The research plan uses quantitative analysis by combining descriptive and inferential analysis to provide empirical evidence of whether there is a significant influence between CORE learning and student gender on the variables of students' mathematical reasoning and disposition ability.
5. Validity and reliability. The validity of the mathematical reasoning ability test instrument includes content validity test, instrument item analysis, and reliability test. Content validity involves one mathematics education lecturer and one mathematics teacher. The discriminatory power test produces a discriminatory power index and questions difficulty level with a good category. The reliability test produces 0.702 with a reliable category. The mathematical disposition questionnaire instrument was also content validated by one mathematics education lecturer and mathematics teacher, with 32 questionnaires tried with a feasible category and reliability of 0.899 (reliable)
6. Statistical tests. Quantitative methods to gain a comprehensive understanding of the impact of CORE learning strategies, we do descriptive statistics and two-way multivariate analysis to investigate the learning model and gender of the student's mathematical reasoning and disposition ability. We use statistical software namely IBM SPSS in analyzing the data (Pramesti & Ario, 2021).
7. Scope and limitation. The limitation of this study is in the imposition of a model other than CORE learning, namely direct learning. In addition to the model, only two output variables were measured, namely the student's mathematical reasoning and disposition ability.

RESULT AND DISCUSSION

The full results of the reliability analysis for the mathematical disposition questionnaire are presented in Table 1.

Table 1. Reliability Assessment of the Mathematical Disposition Questionnaire

No\ Var	1	2	3	4	5	6	7	8
	0.340	0.673	0.656	0.879	0.549	0.549	0.229	0.244
	9	10	11	12	13	14	15	16
	0.292	0.542	0.193	0.390	0.694	0.311	0.523	0.387
	17	18	19	20	21	22	23	24
	0.218	0.199	0.504	0.333	0.218	0.161	0.485	0.180
	25	26	27	28	29	30	31	32
	0.486	0.454	0.523	0.885	0.250	0.530	0.237	0.314

From Table 1, we obtain a total variance of 106.190, and the reliability analysis of the mathematical disposition questionnaire, the instrument yielded a reliability coefficient of 0.899, indicating a high level of internal consistency and confirming its suitability for measuring students' mathematical disposition.

Retnowati & Aqiila (2017) pointed out that the CORE learning model enables students to enhance their mathematical reasoning skills effectively. The CORE learning model emphasizes four cognitive processes that students engage in while learning: connecting, organizing, reflecting, and extending. The CORE learning model principle is focused on student engagement in building knowledge based on constructivist learning theory (Sari et al, 2020). The CORE learning model is a type of learning model that utilizes a discussion technique. The engagement method in the CORE educational model promotes student-centered learning by urging students to actively participate in the learning process. Students can offer feedback to one another and strengthen their arguments to effectively solve problems through discussion. The way students engage in this discussion allows each student to grow and gain knowledge. Moreover, engaging in exchanging arguments during discussions can assist students in honing their ability to reason effectively. The CORE learning syntax used in this study follows (Nugraha, 2024). However, we will present evidence supporting the importance of utilizing CORE learning to enhance students' mathematical reasoning and disposition ability in a freedom curriculum. The discussion in this section is divided into three parts, namely starting with descriptive analysis, checking assumptions, and the last part is inferential analysis.

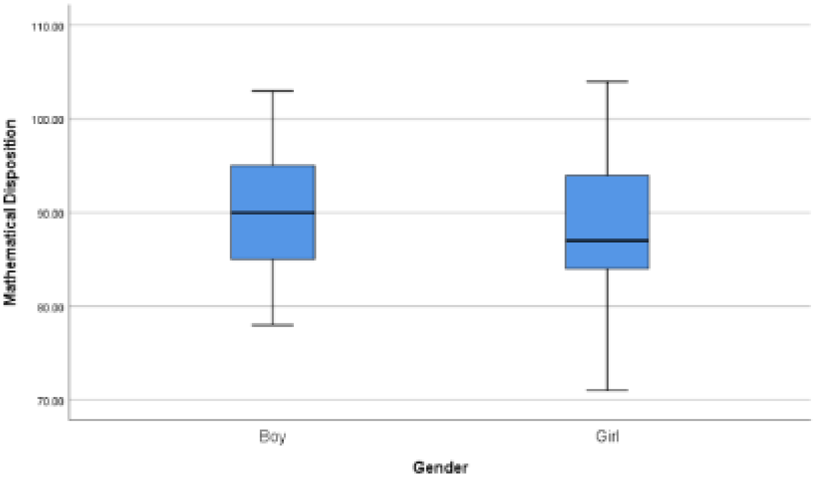
Descriptive Statistics Analysis

Table 2. Descriptive of mathematical reasoning and disposition ability based on gender

Measurement		Mean	Std.Dev
Math. reasoning	Boy	79.407	10.150
	Girl	78.311	12.105
Math. disposition	Boy	89.556	6.930
	Girl	87.600	8.228

According to the information in Table 2, male students have a greater average mathematical reasoning ability than female students. This also pertains to skills in a mathematical mindset. Male students do not have a wider range of mathematical reasoning and disposition abilities compared to female students, suggesting that female students exhibit greater diversity in these skills than male students. Figure 1 and Figure 2 illustrate these facts. Female students' mathematical reasoning and disposition abilities seem to be generally lower than those of male students.

Figure 1. Mathematical disposition ability based on gender



As shown in Table 2, male students exhibited marginally higher mean scores in both mathematical reasoning and disposition than their female peers. The mean mathematical reasoning score for male students was 79.407 (Std.Dev = 10.150), compared to 78.311 (Std.Dev = 12.105) for female students. While the difference in mean performance is minimal, the greater standard deviation among female students suggests a wider dispersion of reasoning ability within this group. A comparable trend is observed in mathematical disposition. Male students reported a mean disposition score of 89.556 (Std.Dev = 6.930), whereas female students had a slightly lower mean of 87.600, accompanied by a higher standard deviation of 8.228. Conversely, the greater variability among female students indicates a broader spectrum of mathematical disposition, suggesting more diverse affective engagement with the female students. Figures 1 and 2 visually reinforce these patterns, illustrating both the central tendencies and variability in mathematical disposition ability by gender. The tighter clustering of male students' scores around the mean contrasts with the wider distribution seen among female students, highlighting the heterogeneity of learning profiles within the latter group. These findings indicate the importance of responsive instructional approaches—particularly those that accommodate variability in cognitive and affective domains—to support the diverse needs of female learners in mathematics education.

Figure 2. Mathematical reasoning ability based on gender

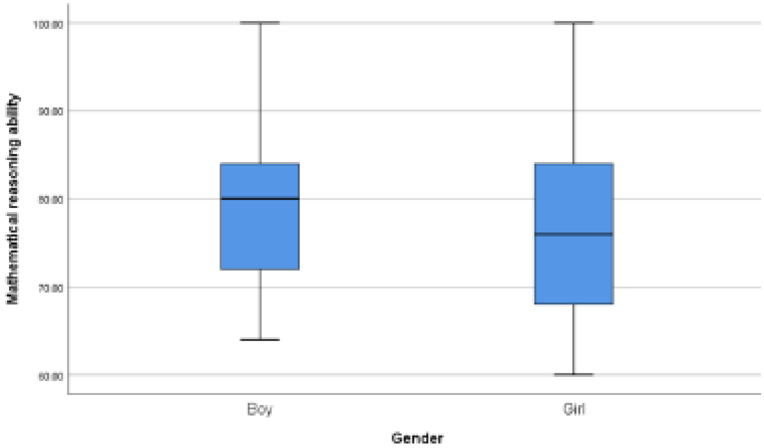
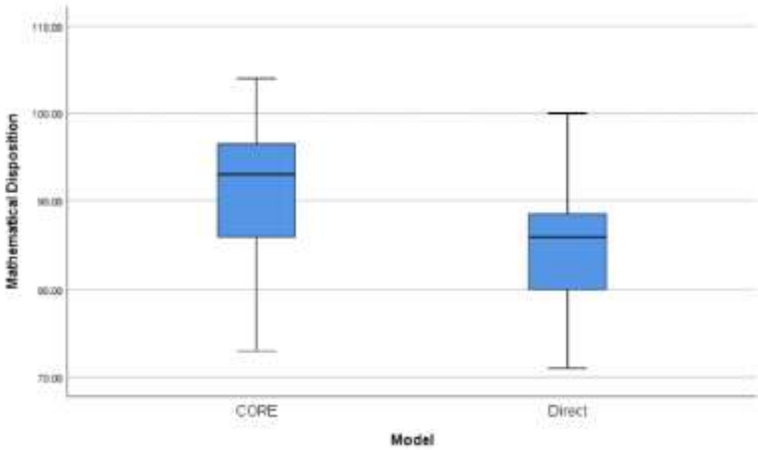


Table 3. Descriptive of mathematical reasoning and disposition ability based on model

Measurement		Mean	Std.Dev
Math. reasoning	CORE	84.889	10.523
	Direct	72.556	8.507
Math. disposition	CORE	91.444	7.792
	Direct	85.222	6.481

Refer to Table 3, where CORE learning shows a higher average mathematical reasoning and disposition ability compared to direct learning, but with a higher variability in values. This suggests that students' skills in CORE learning differ more than direct learning.

Figure 3. Mathematical disposition ability based on model

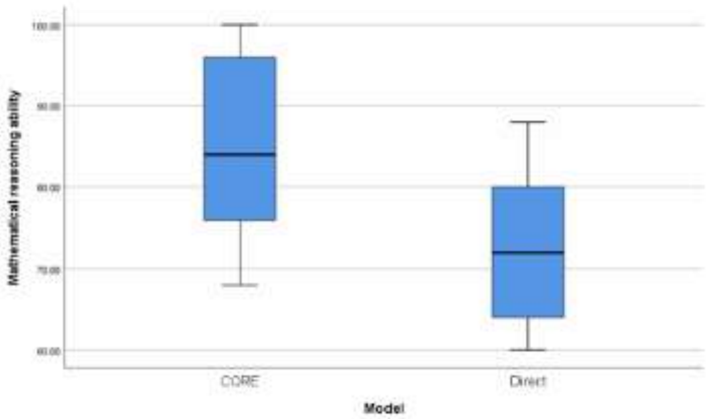


As detailed in Table 2, students exposed to the CORE learning model outperformed those receiving direct instruction in both mathematical reasoning and mathematical disposition. Specifically, the average mathematical reasoning score for students in the CORE group was 84.889 (Std.dev = 10.523), substantially higher than the 72.556 (Std.dev = 8.507) mean observed in the direct learning group. This 12.3-point difference indicates that the CORE model may foster deeper conceptual understanding and higher-order reasoning abilities, consistent with its constructivist, student-centered framework.

Similarly, CORE-based instruction was associated with a stronger mathematical disposition. Students in the CORE group reported a mean disposition score of 91.444 (Std.dev =

7.792), compared to 85.222 (Std.dev = 6.481) among students taught via direct instruction. This indicates that the CORE model not only supports cognitive development but also promotes more positive affective engagement with mathematics, potentially through its emphasis on active participation, reflection, and personal meaning-making. Figures 3 and 4 visually represent these findings, illustrating both the higher central tendencies and broader distributions in the CORE learning group.

Figure 4. Mathematical reasoning ability based on the model



Figures 3 and 4 depict the representation of mathematical thinking and attitude. Further discussion on the impact of gender and learning abilities will be explored in the following inference analysis. Before moving on to the inferential analysis, an assumption checking of parametric statistics will be conducted in the following subsection.

Assumption Checking

From Table 4 and Table 5, because α=0.05<Sig. then we can deduce that the normality assumption can be fulfilled.

Table 4. Tests of normality of the variables based on gender

Variables		Statistics	Sig. K-S
Math. reasoning	Boy	0.106	0.200
	Girl	0.121	0.095
Math. disposition	Boy	0.114	0.200
	Girl	0.109	0.200

The Kolmogorov-Smirnov test was employed to assess the normality of data distributions for both mathematical reasoning and mathematical disposition, disaggregated by gender. As summarized in Table 4, the test results indicate that the data for each group approximates a normal distribution. For mathematical reasoning, the male subgroup produced a test statistic of 0.106 with an asymptotic significance value (p-value) of 0.200, while the female subgroup yielded a test statistic of 0.121 and a p-value of 0.095. Although the p-value for female students is closer to the conventional α = 0.05 threshold, it remains above the cutoff, indicating no significant departure from normality in either group. In terms of mathematical disposition, male students showed a test statistic of 0.114 with a significance value of 0.200, and female students had a test statistic of 0.109, also with a significance value of 0.200. These results strongly support the assumption of normality for both male and female subgroups on the disposition variable.

Now, we move to Table 5. The results, presented in Table 5, indicate that the distributions for all subgroups do not significantly deviate from normality. For mathematical reasoning, students taught under the CORE learning model exhibited a test statistic of 0.145 with an asymptotic significance (p-value) of 0.054. Although this value approaches the α = 0.05

threshold, it remains above it, suggesting an approximately normal distribution. Similarly, students in the direct learning group yielded a test statistic of 0.137 and a p-value of 0.085, also indicating no significant departure from normality. In the case of mathematical disposition, the CORE learning group had a Shapiro–Wilk statistic of 0.946 with a p-value of 0.077, while the direct learning group recorded a test statistic of 0.972 and a considerably higher p-value of 0.489. Both values comfortably exceed the 0.05 threshold, reinforcing the assumption of normality for the disposition data across instructional conditions.

Table 5. Tests of normality of the variables based on the model

Variables		Statistics	Sig.
Math. Reasoning	CORE	0.145	0.054[a]
	Direct	0.137	0.085[a]
Math. disposition	CORE	0.946	0.077[a]
	Direct	0.972	0.489[b]

[a] is the significance of Kolmogorov-Smirnov
[b] is the significance of the Shapiro-Wilks

Next, we will check the homogeneity of variance assumption of the variables. To determine whether the assumption of homogeneity of variance was satisfied, Levene's Test was conducted for both dependent variables—mathematical reasoning and mathematical disposition—based on gender. As shown in Table 6, the results confirm that the variances across male and female student groups are statistically equivalent.

For mathematical reasoning, Levene's statistic was 1.781 with a significance value ($p = 0.186$), which exceeds the $\alpha = 0.05$ threshold. This indicates no significant difference in the variances of mathematical reasoning scores between male and female students. Similarly, for mathematical disposition, the Levene's statistic was 0.674 with a significance value of 0.414, further supporting the equality of variances across gender groups.

Table 6. Tests of Homogeneity of variance of the variables based on gender

Variables	Levene Statistics	Sig.
Math. Reasoning	1.781	0.186
Math. disposition	0.674	0.414

Table 7 presents the results of Levene's Test of Homogeneity of Variance for the learning model effects on both mathematical reasoning and mathematical disposition. The analysis for mathematical reasoning yielded a Levene statistic of 1.904 with a corresponding significance value of 0.172, indicating that the assumption of equal variances across groups is not violated. Similarly, the test for mathematical disposition returned a Levene statistic of 2.000 and a significance level of 0.162, further confirming homogeneity of variance. Collectively, these results support the suitability of parametric analyses by affirming that the variance distributions across the different learning model groups are statistically equivalent, thereby ensuring the robustness of subsequent inferential tests on both outcome variables.

Table 7. Tests of Homogeneity of variance of the variables based on the model

Variables	Levene Statistics	Sig.
Math. Reasoning	1.904	0.172
Math. disposition	2.000	0.162

These findings confirm that the assumption of homoscedasticity is upheld for both variables, validating the appropriateness of applying parametric tests such as MANOVA to examine main and interaction effects involving gender. The consistency in variance between male and female students suggests that any observed differences in mathematical outcomes are unlikely to be artifacts of unequal data dispersion. From Tables 6 and 7, we can conclude that the homogeneity of variance is satisfied, because α<Sig. This result is supported by Tables 8 and 9.

Table 8. Box's Test of Equality of Covariance Matrices

Measurement	Value
Box's M	9.442
F	0.988
Sig.	0.447

Table 8 reports the results of Box's Test of Equality of Covariance Matrices, conducted to evaluate the assumption of multivariate homogeneity of covariance matrices across groups. The test yielded a Box's M value of 9.442 with a significance level of 0.447. Given that the significance value exceeds the conventional threshold of 0.001, the assumption of equal covariance matrices is met.

Table 9. Levene's Test of Equality of Error Variances

Variables	Levene Statistics	Sig.
Math. Reasoning	1.674	0.181
Math. disposition	1.601	0.197

Table 9 displays the results of Levene's Test of Equality of Error Variances, conducted to assess the assumption of homogeneity of error variances for the dependent variables. For mathematical reasoning, the Levene statistic was 1.674 with a significance value of 0.181, while for mathematical disposition, the Levene statistic was 1.601 with a significance value of 0.197. As both significance values exceed the standard threshold of 0.05, the results indicate that the assumption of equal error variances is upheld for both variables. These findings validate the use of parametric tests by confirming the statistical equivalence of error variance across the learning model groups. Hence, based on the interpretation of Tables 3-Table 9, taken together, the normality and homogeneity assumptions across groups are sufficiently met, thereby validating the use of parametric inferential statistical procedures—such as MANOVA—for subsequent analyses.

Inferential Analysis

Inferential analysis was carried out to explore the impact of mathematical reasoning ability and mathematical disposition ability on students ' learning models, and the potential correlation between students of different genders on CORE and direct learning in both aspects. First, we examine the Multivariate analysis in Table 10.

Table 10. Multivariate Tests-Hotelling's Trace

Effects	Value	Sig.
Gender	0.041	0.261
Model	0.491	0.000
Gender*Model	0.005	0.851

Table 10 presents the results of the multivariate analysis of variance (MANOVA) using Hotelling's Trace to examine the effects of gender, learning model, and their interaction on students' mathematical reasoning and mathematical disposition. The analysis revealed that gender does not have a statistically significant multivariate effect on the combined dependent variables. The Hotelling's Trace value for gender was 0.041 with a significance level of 0.261 ($p > 0.05$), indicating that differences in mathematical reasoning and disposition cannot be attributed to gender alone. In contrast, the learning model demonstrated a statistically significant multivariate effect on the combined outcome variables, with a Hotelling's Trace value of 0.491 and a significance level of 0.000 ($p < 0.05$). This result indicates that the type of learning model employed has a substantial impact on both mathematical reasoning ability and mathematical disposition. Lastly, the interaction between gender and learning model was not statistically significant, as evidenced by a Hotelling's Trace value of 0.005 and a significance level of 0.851 ($p > 0.05$). This suggests that the influence of the learning model on students' mathematical reasoning and disposition does not differ by gender; in other words, gender and the learning model do not interact to produce differential effects on these outcomes. These results are supported by Table 11,

Table 11. Tests of between-subject effects

Source		F	Sig.
Gender	Math. reasoning	0.095	0.759
	Math. disposition	1.009	0.319
Model	Math. Reasoning	27.329	0.000
	Math. Disposition	12.904	0.001
Gender*M	Math. Reasoning	0.004	0.948
odel	Math. Disposition	0.097	0.756

namely:

1. Gender. Since Sig.>α=0.05, we can conclude that gender has no impact on mathematical reasoning ability and mathematical disposition ability. Using the results of Table 2, it can be visualized in Figures 5 and 6.

Figure 5. Estimated marginal means of mathematical reasoning ability based on gender

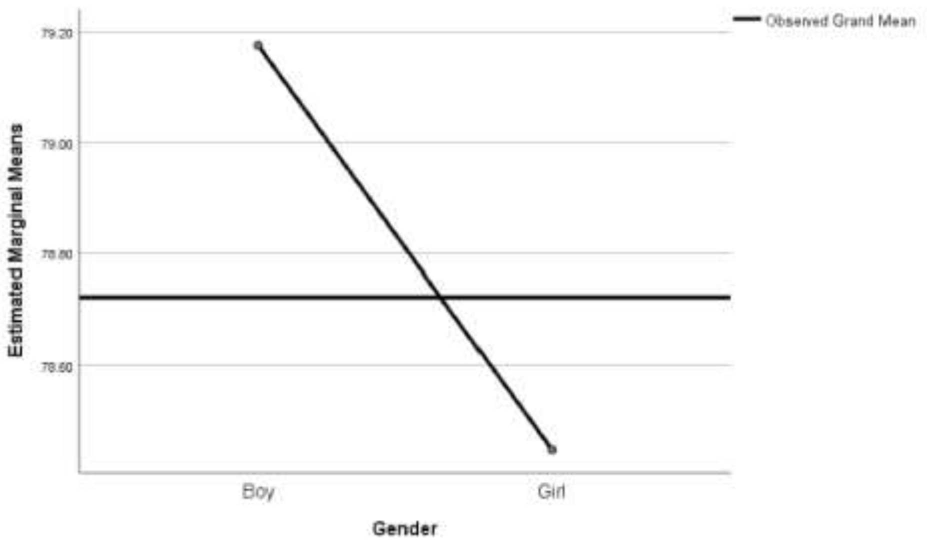
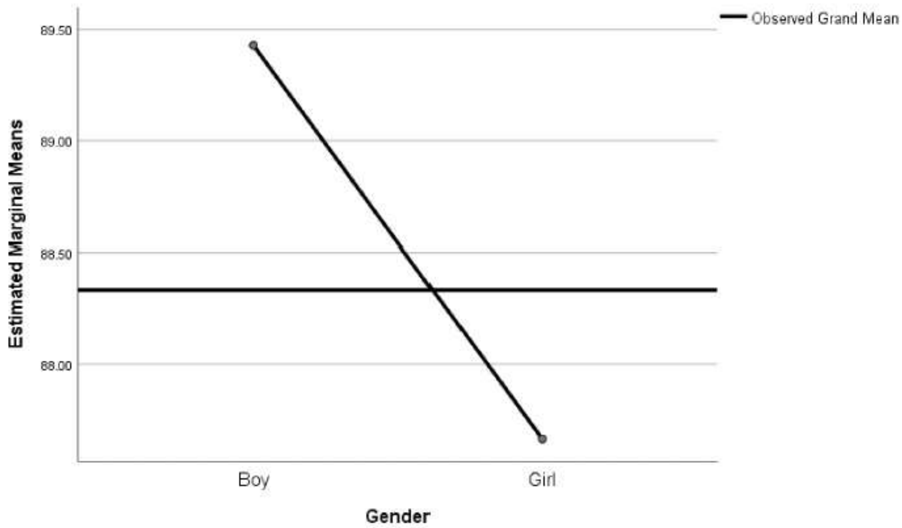


Figure 6. Estimated marginal means of mathematical disposition ability based on gender



the mathematical reasoning and mathematical disposition ability of the male students is greater than the grand mean. However, these disparities are not substantial. In simpler terms, male and female students have equal abilities in mathematical reasoning and mathematical disposition. Based on Figures 5 and 6 reveal that male students demonstrated slightly higher scores in both mathematical reasoning and mathematical disposition compared to the overall average (grand mean). However, these differences were not significant enough to suggest a meaningful gap between male and female students. In simpler terms, both male and female students showed comparable abilities in mathematical reasoning and mathematical disposition, indicating that gender does not play a major role in these mathematical skills.

2. Model. Since the Sig. Model-Mathematical reasoning ability is less than 0.05; it can be concluded that the learning model has an impact on mathematical reasoning ability. Further, because Sig. Model-Mathematical disposition ability=0.001<α=0.05, then it can be said that the learning model affects mathematical disposition ability. Further, using Table 3, we can observe the visualization depicted in Figures 7 and 8.

Figure 7. Estimated marginal means of mathematical reasoning ability based on model

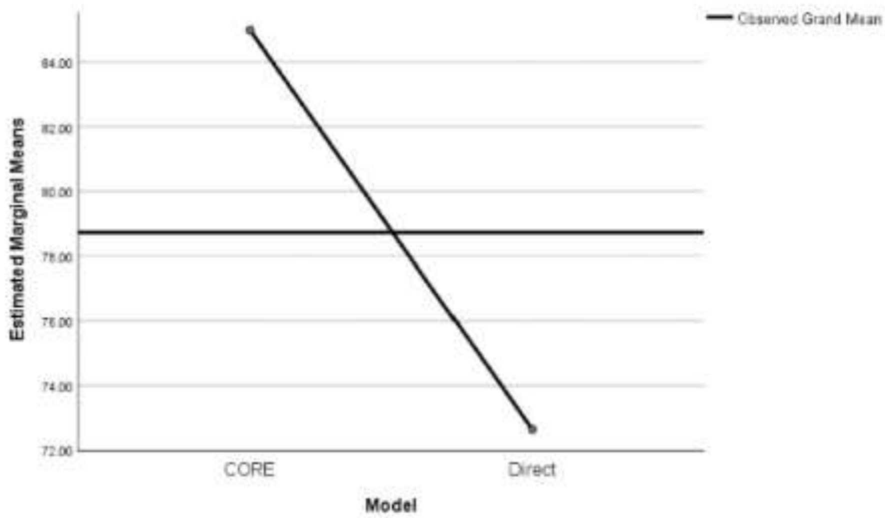
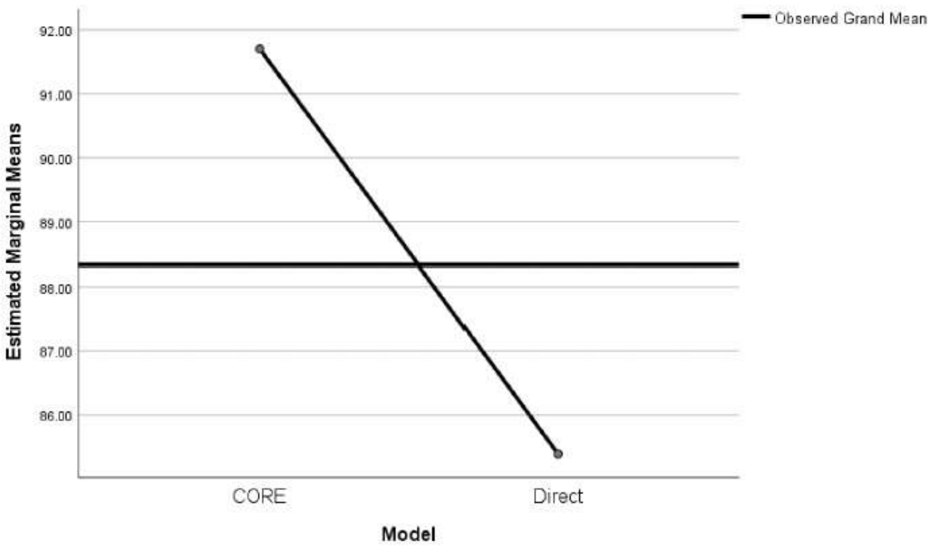


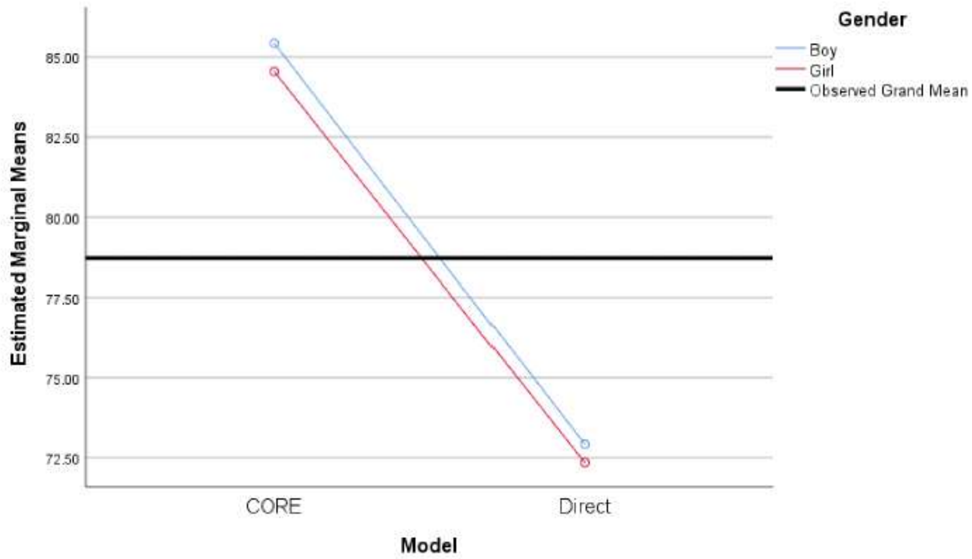
Figure 8. Estimated marginal means of mathematical disposition ability based on model



We can see that the mean of mathematical reasoning and mathematical disposition ability in CORE learning is greater than the grand mean and Direct learning. Moreover, these differences are significant. Figures 7 and 8 indicate that students engaged in CORE learning within the Freedom Curriculum exhibited significantly higher mean scores in both mathematical reasoning and mathematical disposition compared to those in Direct learning and the overall grand mean. These statistically significant differences suggest that CORE learning is more effective in fostering students' mathematical reasoning and disposition, supporting its recommendation for enhanced mathematics education outcomes.

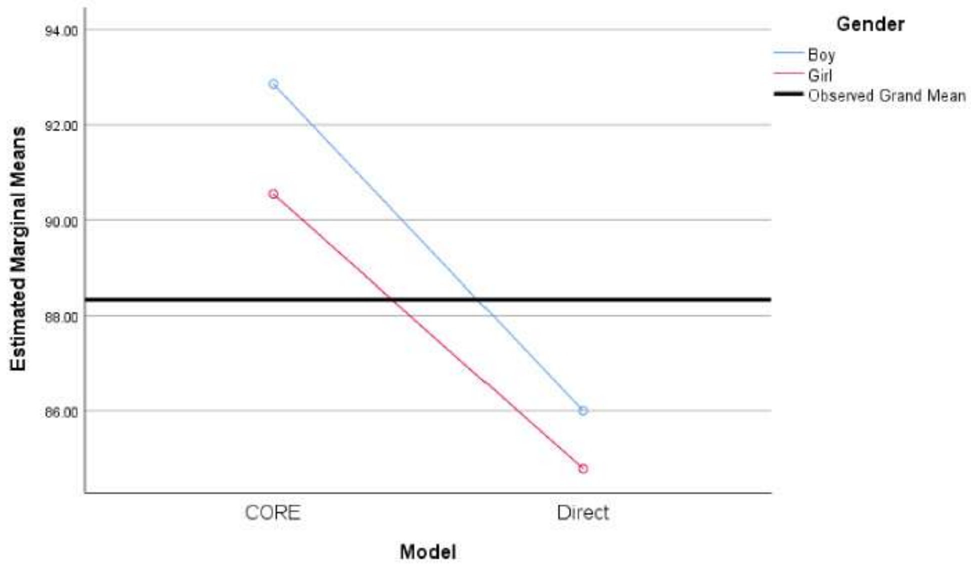
3. Gender and Learning Model. Since Sig. $>\alpha=0.05$, it can be said that the model and gender of students do not affect each other on mathematical reasoning ability and mathematical disposition ability. From Figures 9 and 10, it appears that the mean line of mathematical reasoning and mathematical disposition ability from CORE and Direct learning follows the same pattern in male and female students. This indicates that both CORE and Direct learning do not affect the mathematical reasoning and disposition abilities of male and female students.

Figure 9. Estimated marginal means of mathematical reasoning ability based on the model and gender



As illustrated in Figures 9 and 10 (parallel line) and Table 11, the analysis revealed no significant interaction between gender and learning model (CORE vs. Direct) on students' mathematical reasoning and disposition abilities. This indicates that the effectiveness of the learning model is consistent across genders. The mean trends for both CORE and Direct learning exhibit similar patterns for male and female students. Thus, the influence of the learning model on mathematical reasoning and disposition does not differ by gender, suggesting that both instructional approaches impact male and female students similarly.

Figure 10. Estimated marginal means of mathematical disposition ability based on the model and gender



DISCUSSION

This study demonstrates that gender does not exert a significant effect on students' mathematical reasoning or disposition abilities. While male students exhibited marginally higher mean scores than the overall average, these differences lacked statistical significance, indicating that male and female students possess comparable levels of mathematical competence and disposition. These findings corroborate prior research underscoring gender equity in both cognitive and affective domains of mathematics education.

In contrast, the instructional model employed significantly influenced both mathematical reasoning and disposition. Students engaged in the CORE learning model, implemented within the Freedom Curriculum, achieved notably higher scores than their counterparts in the Direct learning model. This outcome underscores the efficacy of the CORE approach, which promotes active learner engagement, conceptual depth, and reflective thought processes. The evidence suggests that CORE learning not only enhances mathematical reasoning but also cultivates more favorable attitudes toward mathematics, marking it as a valuable pedagogical strategy.
Moreover, no significant interaction emerged between gender and learning model regarding either mathematical reasoning or disposition. Male and female students exhibited parallel performance patterns across both instructional approaches. This consistency indicates that the effectiveness of the CORE and Direct models is invariant concerning gender, affirming the CORE model's capacity to deliver equitable educational benefits across diverse student populations. Also, the CORE learning framework as a strategy in various educational settings indicates that similar approaches could also improve learning in different subjects, see, i.e., (Muizaddin & Santoso, 2016), (Ari & Abadi, 2020), and (Ningsih et al, 2020) for references. This study contributes to the mounting evidence that gender exerts minimal influence on mathematical reasoning and disposition, corroborating findings by Hyde et al. (2008) and Else-Quest et al. (2010), who documented negligible gender differences in mathematics achievement and attitudes. Likewise, Wang and Degol (2017) highlight the ongoing reduction of gender disparities in STEM fields, a perspective reinforced by Stoet and Geary's (2018) concept of the "gender-equality paradox," which attributes such gaps to sociocultural factors rather than innate ability. Contrasting with these contemporary findings, earlier research (e.g., Fennema & Sherman, 1976; Maccoby & Jacklin, 1974) identified male advantages in mathematical reasoning, suggesting that changes over time or methodological variations may account for the observed shift toward gender parity.

In terms of pedagogical approaches, the superiority of CORE learning in enhancing both mathematical reasoning and disposition echoes Hattie's (2009) meta-analytic conclusions on the benefits of active learning, as well as Freeman et al.'s (2014) evidence that interactive instructional methods improve STEM outcomes. Additionally, Pekrun et al. (2017) emphasize the role of teaching strategies in shaping students' emotional engagement, further validating CORE's emphasis on active learner involvement.

The absence of a significant interaction between gender and learning model aligns with earlier observations by Fennema and Sherman (1976) and extends findings by Wang et al. (2013), indicating that conceptual learning interventions are broadly effective irrespective of gender. Nonetheless, nuanced gender differences in affective responses to instructional styles reported by Lubienski et al. (2013) suggest avenues for future research beyond the scope of the present study. Overall, these findings reinforce the diminishing relevance of gender in mathematical achievement and underscore the pivotal role of innovative instructional models like CORE in fostering equitable mathematics education.

The present findings have significant implications for mathematics education policy, instructional design, and future research. First, the demonstrated lack of significant gender differences in mathematical reasoning and disposition suggests that educational interventions and curricula should move beyond gender-based assumptions and focus on fostering equitable learning environments for all students. This aligns with Hyde et al. (2008) and Else-Quest et al. (2010), who advocate for minimizing gender bias in mathematics instruction. Second, the clear advantage of the CORE learning model in enhancing both mathematical reasoning and disposition highlights the importance of adopting active, student-centered pedagogies that promote engagement, conceptual understanding, and reflective thinking. Educators and curriculum developers should consider integrating CORE-like models to improve mathematics outcomes, as supported by Hattie (2009) and Freeman et al. (2014). Third, the finding that CORE's effectiveness is consistent across genders reinforces its suitability as an inclusive approach, capable of supporting diverse learners without exacerbating achievement gaps (Wang & Degol, 2017; Fennema & Sherman, 1976). This points to the value of interventions that prioritize cognitive and affective dimensions simultaneously, as Pekrun et al. (2017) emphasize. Additionally, the absence of interaction effects between gender and learning model suggests that scalable pedagogical innovations can be broadly implemented without the need for gender-specific modifications, simplifying policy and practice considerations (Wang et al., 2013; Stoet & Geary, 2018). Despite these encouraging findings, future research should explore subtle gender-related differences in affective responses to teaching styles, as indicated by Lubienski et al. (2013), to further optimize instructional strategies and support all learners' emotional engagement with mathematics. Finally, given the historical shifts from earlier reported gender gaps (Maccoby & Jacklin, 1974; Fennema & Sherman, 1976) to current parity, ongoing longitudinal studies are needed to monitor trends and ensure that educational equity continues to improve across contexts.

While this study offers important insights, several limitations must be acknowledged. First, the generalizability of the results is potentially constrained by the sample size and the demographic uniformity of the participants. As noted by Charles and Bradley (2009) and Else-Quest, Mineo, and Higgins (2013), educational and cultural contexts significantly shape gender-related outcomes, and thus, findings derived from relatively homogeneous groups may not be applicable across more diverse populations. Second, the cross-sectional design limits the ability to infer causal relationships or assess the sustained effects of the CORE learning model. Eccles and Wigfield (2002) and Sadler et al. (2012) emphasize the need for longitudinal studies to comprehensively track developmental trajectories in mathematical reasoning and disposition. Third, reliance on standardized instruments to measure mathematical reasoning and disposition may be insufficient to reflect the nuanced and multidimensional nature of these constructs, particularly affective components such as motivation, anxiety, and self-efficacy (Frenzel, Goetz, & Pekrun, 2007; Pekrun, 2006). Such unmeasured variables could potentially confound the interpretation of instructional and gender effects. Fourth, although no significant interaction between gender and instructional model was detected, subtle gender-specific variations in response to pedagogical approaches might have been masked due to limited statistical power or the sensitivity of the measurement tools (Areepattamannil & Freeman, 2008). Fifth, the study did not rigorously assess the fidelity of implementation of the CORE and Direct learning models. Variability in instructor expertise, classroom environment, and adherence to teaching protocols may have introduced uncontrolled variability impacting the observed outcomes (Prince, 2004; Michael, 2006). Finally, important contextual factors such as socio-economic status, prior academic achievement, and parental involvement were not accounted for, aligning with concerns raised by Benbow and Stanley (1980) and Gilligan (1982) about the influence of external variables on mathematical performance.

To address these limitations, future research should incorporate larger and more diverse samples, employ longitudinal designs, utilize comprehensive and multidimensional assessment tools, and rigorously control for contextual variables to better elucidate the complex interplay between gender, pedagogy, and mathematical learning outcomes. Building on the identified limitations, future research should expand to encompass larger and more heterogeneous samples to examine how intersecting factors such as ethnicity and socio-economic status influence gender equity in mathematics education (Steele, 2011; Cheryan et al., 2017). Employing longitudinal and experimental methodologies will be essential to determine the sustained effects of instructional models throughout students' developmental trajectories (Kurtz-Costes et al., 2014; Duckworth et al., 2019). Additionally, integrating multi-method approaches—including qualitative interviews and neuroscientific measures—can provide a more nuanced understanding of mathematical disposition that surpasses the scope of conventional standardized assessments (Martin & Marsh, 2006; Ashcraft & Moore, 2009).

Moreover, it is critical to explore gender-specific cognitive and affective responses to pedagogical practices, as aggregated quantitative data may obscure subtle but meaningful differences (Hyde & Linn, 2006; Else-Quest et al., 2013). Investigating the fidelity of instructional implementation alongside contextual influences such as teacher beliefs and classroom environment will further elucidate their roles in shaping student outcomes (Durlak & DuPre, 2008; Han & Weiss, 2005). Accounting for socio-economic status, familial background, and prior achievement is also necessary to disentangle their moderating effects on instructional efficacy (Sirin, 2005; Fan & Chen, 2001).

Future studies should also focus on emotional and motivational mediators—including math anxiety and self-efficacy—that can illuminate mechanisms through which teaching approaches impact student attitudes and achievement (Beilock & Maloney, 2015; Wigfield et al., 2015). The potential differential impacts of technology-enhanced and personalized learning environments by gender warrant thorough evaluation (Walkington, 2013; Kim & Baylor, 2016; ZA, H. A., & Aisyah, 2025). Cross-cultural and policy-oriented research will be valuable in guiding the broader adoption and adaptation of promising models like CORE across varied educational systems (Schleicher, 2018; OECD, 2019). Finally, applying intersectional frameworks that consider gender alongside race, class, and other identities will enrich our understanding of equity challenges and opportunities within STEM education (Crenshaw, 1991; Ong et al., 2011).

CONCLUSION

The freedom curriculum provides the flexibility needed for students to explore, reflect, and develop these attributes at their own pace. CORE learning can be recommended to teachers in order to improve students' mathematical reasoning and disposition ability. CORE is a learning that includes a framework of collaboration, organization, reflection, and engagement in the teaching and learning process that has been proven to improve students' mathematical reasoning and disposition ability in a freedom curriculum without looking at students of different genders. The study concludes that by adopting student-centered and reflective teaching strategies, mathematical reasoning and disposition can be significantly improved, resulting in better academic outcomes and a more enjoyable learning experience for students. The significant role of instructional design—particularly within the framework of the Freedom Curriculum—in fostering students' mathematical reasoning and disposition. The flexibility afforded by the Freedom Curriculum empowers students to engage more deeply with mathematical concepts, encouraging exploration, self-paced learning, and reflective thinking. Within this flexible learning environment, the CORE instructional model—emphasizing Collaboration, Organization, Reflection, and Engagement—has emerged as an effective pedagogical strategy for enhancing both cognitive and affective mathematical outcomes.

The findings indicate that students who participated in CORE learning demonstrated significantly higher levels of mathematical reasoning and more positive dispositions toward mathematics compared to those in traditional Direct instruction settings. Importantly, these gains were consistent across gender groups, suggesting that CORE learning offers an equitable and inclusive approach to mathematics education that benefits all learners regardless of gender. This aligns with broader educational goals that advocate for the removal of systemic barriers and the promotion of equity in STEM learning environments. The study concludes that the integration of student-centered, reflective teaching models such as CORE within the Freedom Curriculum can lead to meaningful improvements in student achievement and engagement. By shifting the instructional focus from teacher-centered delivery to active, collaborative, and introspective learning experiences, educators can cultivate deeper mathematical understanding and foster enduring positive attitudes toward the subject. These outcomes are not only essential for academic success but also for preparing students to apply mathematical thinking in real-world contexts.

Given these promising results, the implementation of CORE learning is strongly recommended for educators aiming to enhance mathematical reasoning and disposition in diverse and dynamic classroom settings. Future research should continue to explore its application across various educational levels and cultural contexts to validate and extend its effectiveness. In light of the study's findings, educators and curriculum designers are strongly advised to integrate the CORE learning model into instructional practices within adaptable curricular frameworks such as the Freedom Curriculum. This model has demonstrated a robust capacity to improve both mathematical reasoning and disposition, providing a pedagogical approach that is not only effective but also equitable across gender lines. By centering learning around active participation, structured inquiry, and reflective thinking, CORE promotes deeper conceptual understanding and fosters a more positive and enduring relationship with mathematics. Adopting such student-centered methodologies offers a strategic path toward more engaging, inclusive, and impactful mathematics education in diverse learning environments.

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AUTHOR CONTRIBUTION STATEMENT

The first author accommodates the entire study comprehensively, starting from the idea and framework to the overall research analysis. The second author conducts CORE learning and direct learning at the target school of the research, while the last author is an assistant researcher who supports this study to run well.

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