



## ***Gender and Feedback Effects in Digital Game-Based Learning for Primary Mathematics Education***

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### **Abstract**

*Digital game-based mathematics learning has been widely implemented to enhance student engagement and learning outcomes. However, many studies overlook the role of gender differences in responding to instructional feedback, despite literature suggesting that males and females may react differently to digital stimuli. This study aims to explore the interaction between gender and feedback type in influencing cognitive learning outcomes and intrinsic motivation, which includes interest, perceived competence, autonomy, effort, pressure/tension, and engagement. Two types of feedback, Multiple-Try Feedback (MTF) and Single-Try Feedback (STF), were implemented using the Lectora Inspire platform in a quasi-experimental pretest–posttest design. Participants included 81 third- and fourth-grade students from three elementary schools in Jakarta, randomly assigned to either the MTF or STF condition. Learning outcomes were assessed using a mathematics test, and intrinsic motivation was measured with the Intrinsic Motivation Inventory (IMI). Two-way ANOVA and MANOVA analyses revealed that male students generally achieved higher post-test scores, whereas female students showed significant improvement when pretest scores were controlled, particularly in the STF condition. Additionally, females reported higher motivation levels in the interest and competence dimensions. Although feedback type alone did not show a significant main effect, the findings underscore the importance of adopting adaptive and gender-sensitive instructional approaches in digital learning environments.*

**Kata Kunci:** *Digital Learning; Gender; Intrinsic Motivation; Multiple-Try Feedback (MTF); Single-Try Feedback (STF)*



## INTRODUCTION

The development of digital technology has been shown to enhance motivation and learning outcomes in mathematics (Higgins et al., 2019; Limantara et al., 2023; Pinto & Leite, 2020; Saripudin et al., 2020; Timotheou et al., 2023). However, gender disparities remain a concern: male students tend to show greater interest and perceive technology as more beneficial (Denden et al., 2021; Qazi et al., 2022), while female students can demonstrate superior performance when provided with adequate support, particularly in the context of science and ICT-based planning. Therefore, the implementation of educational technology must be designed with a gender-sensitive perspective to ensure fair and optimal outcomes. Gender differences in digital learning, particularly within Digital Game-Based Learning (DGBL), pose a significant pedagogical challenge. Male students often perceive digital games as sources of entertainment and competition (Twenge & Martin, 2020), whereas female students tend to approach them more critically, viewing them as alternative instructional tools (Álvarez-Herrero & Valls-Bautista, 2021; Wee & Yap, 2021). These differences extend beyond behavior and may interact with feedback types, namely, Multiple-Try Feedback (MTF) and Single-Try Feedback (STF), which can influence affective responses, perceived competence, and risk tolerance (Hirnstein et al., 2023; Qazi et al., 2022). This study examines gender and feedback because both are hypothesized to play a pivotal role in shaping students' motivation and performance in DGBL environments. While some studies report that female students exhibit higher engagement and learning outcomes (Chang et al., 2014; Khan et al., 2017; Noroozi et al., 2023), others find no significant gender-based differences, highlighting the need for further investigation (Chung & Chang, 2017; Dorji et al., 2015; Lester et al., 2014). Therefore, this study aims to explore the interaction between gender and feedback types to inform the design of more equitable and responsive DGBL strategies.

Affective aspects, such as motivation, engagement, and anxiety, play a crucial role in the success of mathematics learning (Csapó, 2022; Du et al., 2021). Affective responses vary based on gender: male students tend to be more comfortable with technology and digital assessments (Bahar & Asil, 2018), while female students are more motivated in collaborative and game-based environments (Chung & Chang, 2017). Perceptions of competence also impact learning outcomes: male students are more confident in knowledge-based learning in DGBL (S. Yeo et al., 2022), while female students are more prone to mathematics anxiety (C. Wang & Huang, 2021). Although some studies indicate that gender differences are not generally significant (Moliner & Alegre, 2020; Szczygiel et al., 2024), the influence of gender remains a complex and contextual phenomenon. As a solution, gender-sensitive instructional design (Khan et al., 2017; Manero et al., 2017) and affective-adaptive pedagogical approaches (Proulx et al., 2017; Ryan & Deci, 2020) are needed. This study contributes through a quantitative analysis of the interaction between gender and feedback type (Single vs. Multiple Trials) in digital mathematics learning based on SDT–CET, focusing on perceptions of competence, pressure, effort, and task value. The originality of this study lies in its quantitative examination of the interaction between gender and feedback type, specifically, Single-Try Feedback (STF) versus Multiple-Try Feedback (MTF), within DGBL-based digital mathematics learning. Anchored in the SDT–CET framework, the study investigates key affective constructs including perceived competence, pressure, effort, and task value. By exploring how instructional feedback moderates gendered affective experiences in a digital context, the study aims to contribute new insights into inclusive, affect-aware educational game design.

The affective aspects of learning, including motivation, engagement, and anxiety, are crucial to the success of mathematics education (Csapó, 2022; Du et al., 2021). These affective responses vary by gender: male students generally feel more comfortable with technology and digital assessments (Bahar & Asil, 2018), while female students are more motivated in collaborative and game-based environments (Chung & Chang, 2017). Perceptions of competence also influence learning outcomes: male students tend to be more confident in knowledge-based learning within Digital Game-Based Learning (DGBL) (S. Yeo et al., 2022), whereas female students are more susceptible to math anxiety (C. Wang & Huang, 2021). Although some studies suggest that gender differences are not universally significant (Moliner & Alegre, 2020; Szczygiel et al., 2024), the influence of gender remains a complex and contextual phenomenon. As a solution, gender-sensitive instructional design (Khan et al.,

2017; Manero et al., 2017) and affective-adaptive pedagogical approaches (Proulx et al., 2017; Ryan & Deci, 2020) are essential. This study contributes through a quantitative analysis of the interaction between gender and feedback type (Single vs. Multiple Trials) in SDT-CET-based digital mathematics learning, focusing on competence perception, pressure, effort, and task value. Although Digital Game-Based Learning (DGBL) has been widely applied to improve mathematical engagement and performance (Proulx et al., 2017; Ryan & Deci, 2020; Khan et al., 2017; Manero et al., 2017), most prior studies have not specifically examined how gender interacts with feedback types in shaping students' affective experiences. In particular, little is known about how Multiple-Try Feedback (MTF) and Single-Try Feedback (STF) affect students' cognitive outcomes and motivation across gender in primary education settings. This research addresses that gap by integrating insights from Self-Determination Theory (SDT) and Cognitive Evaluation Theory (CET) to investigate the role of gender and instructional feedback in digital mathematics learning environments.

Lectora-Inspired is a web-based mathematical game platform developed by our team since 2022 as part of an R&D project funded by the Indonesian government. This platform has been tested in multicultural primary schools in Jakarta for Grades 3 to 6 (ages 8-11) and has been adopted by several schools to support basic mathematics practice. The platform features three types of mini-games aligned with the national curriculum: number identification, number sequencing, and coin calculation. These games are designed to reinforce students' understanding of place value, number order, and coin value computation. It utilizes two types of feedback: Single-Trial Feedback (STF), which provides immediate feedback after one question, and Multiple-Trial Feedback (MTF), which allows up to three attempts without revealing the correct answer. Scoring assessments and leaderboards are displayed to enhance student motivation. The primary goal of this platform is to improve basic mathematics skills through a fun and interactive approach (Yulianto et al., 2024). Instructional feedback provides information to help students correct their answers and improve problem-solving strategies (Barana et al., 2021; Shute, 2008; Wagner et al., 2024). Unlike summative feedback, which is result-based, this type of feedback focuses more on supporting the learning process (Candel et al., 2020). The three main types of feedback in game-based learning include: Knowledge of Results (KR), which indicates whether an answer is correct or incorrect (Shute, 2008); Knowledge of the Correct Response (KCR), which provides the correct answer without explanation (Tsai et al., 2015); and Elaborated Feedback (EF), which offers detailed explanations (Tsai et al., 2015; Z. Wang et al., 2019). Additionally, feedback strategies are also categorized based on the number of interactions, such as Answer-Until-Correct (AUC), which allows students to continue trying until they get it right (Montazeri & Salimi, 2019), and Multiple-Trial Feedback (MTF), which combines KR or KCR and limits the number of interactions (Attali, 2015).

The literature indicates that single-trial feedback (STF) is more effective for higher-level learning, particularly when combined with outcome knowledge or correct responses (Van der Kleij et al., 2015). However, for complex tasks with high error potential, in-depth instruction is more beneficial (Bangert-Drowns et al., 1991). Multi-trial feedback (MTF) yields mixed results: some studies show improved higher-level learning (Attali, 2015; Schwerter et al., 2022), but no significant effect on lower-level outcomes (Fyfe, 2016; Stevenson & Hickendorff, 2018). MTF has been shown to be effective in mathematical problem-solving by reinforcing learning through elaboration and information reorganization (Attali, 2015). The theories of contiguity and information processing explain the effectiveness of MTF, as reflection after errors enhances active cognitive engagement and prevents premature cognitive closure (Candel et al., 2020; Clariana et al., 2000; Cubillos et al., 2023; TAIT et al., 1973). However, excessive repetition may lead to frustration, especially for low-achieving students who tend to guess randomly (Clariana & Koul, 2006; Clariana & Lee, 2001). The concept of mindfulness suggests that repeated feedback is only effective when it involves full, attentive cognitive processing; otherwise, it may lead to ineffective trial-and-error behavior (Attali, 2015; Salomon & Globerson, 1987). Therefore, while MTF holds promise for deep learning, it is important to consider factors that support attentive learning.

The Self-Determination Theory (SDT) explains motivation in Digital Game-Based Learning (DGBL) by emphasizing three basic psychological needs: competence, autonomy, and relatedness (Ryan & Deci, 2020). However, the application of SDT in experiments involving gender aspects

remains limited (Moller et al., 2024; Tyack & Mekler, 2024). This study is among the first to analyze gender-based motivation differences in DGBL through repeated experiments. Grounded in SDT–CET (Ryan & Deci, 2020), this study examines how instructional design that supports competence, autonomy, and motivation can be optimized through adaptive feedback. These theoretical perspectives emphasize that effective learning environments must satisfy basic psychological needs to promote intrinsic motivation, especially under conditions involving digital tools and differentiated learner characteristics, such as gender. Motivation is measured using constructs such as interest, competence, effort, and choice, while pressure is analyzed for its negative impact. Studies applying SDT in DGBL reveal relationships between cognitive load, scaffolding, gamification, and game mechanics with motivation and learning outcomes (X. Chen et al., 2020; Liao et al., 2019; Xiang et al., 2021). The quality of the game and feedback also influence students' motivation and performance (Liu et al., 2019). However, these studies have not yet considered gender factors that affect affective dimensions such as pressure, value, effort, and feedback design. DGBL research on motivation and emotions shows unclear gender differences in academic performance, engagement, attitude, and anxiety (Bahar & Asil, 2018; Chung & Chang, 2017; Dorji et al., 2015; Erturan & Jansen, 2015; A. I. Wang & Tahir, 2020). Therefore, this study aims to examine the impact of gender on digital mathematics learning outcomes among elementary school students and its effects in two types of feedback: Multiple-Trial Feedback (MTF) and Single-Trial Feedback (STF). This research also evaluates cognitive outcomes and motivational dimensions using the Cognitive Evaluation Theory (SDT–CET), which includes interest, competence, autonomy, effort, pressure-free experiences, and perceived value. Therefore, this study aims to (1) examine gender differences in digital mathematics learning outcomes, (2) assess differences in motivational dimensions (interest, competence, autonomy) based on gender, (3) evaluate perceptions of learning activities (effort, freedom from pressure, and value), and (4) analyze the interaction effect between gender and feedback type (MTF vs. STF) on cognitive and affective learning outcomes.

## **METHOD**

### **Research Design**

This study employed a randomized experimental pre-test–intervention–post-test design with two primary factors. The first factor was gender (male/female), and the second was the type of feedback provided during the experiment, categorized as follows: Single-Trial Feedback (STF): Participants received one attempt, followed by immediate feedback indicating the correct answer after submitting their response; and Multiple-Trial Feedback (MTF): Participants were given up to three attempts, with incremental feedback provided after each trial, indicating performance at each stage. Participants were randomly assigned to one of the two conditions. A total of 41 students (23 males and 18 females) were assigned to the MTF group, while 40 students (19 males and 21 females) were placed in the STF group. This division enabled a more nuanced comparative analysis of how different feedback types influenced learning outcomes and affective responses, with particular attention to gender differences.

### **Research Sample**

This study was conducted between October and November 2024 and involved third- and fourth-grade students from three primary schools located in the DKI Jakarta region. These grade levels were selected based on the alignment of the instructional content covered in the game with the national mathematics curriculum for those grades. Initially, a total of 95 students were considered for participation. However, after excluding incomplete participation, such as absence during implementation, lack of written parental consent, and incomplete post-test or Intrinsic Motivation Inventory (IMI) responses, the final sample consisted of 81 students who met the inclusion criteria. The sample comprised students from both private and government-subsidized schools, representing higher and middle socioeconomic status (SES). Students from public schools, who generally represent lower SES backgrounds, were not included in this study. Their exclusion presents an opportunity for future research exploring this demographic. According to national education statistics in Indonesia

(2024), 56% of students attend subsidized schools, 35% are enrolled in public schools, and only 9% attend private institutions.

## **Research Instruments**

### **1. Mathematics Test**

The pre- and post-tests in this study were developed based on three specific learning objectives outlined in the national mathematics curriculum and its accompanying instructional guidelines. The test development process involved close collaboration with participating schoolteachers, who provided iterative feedback during the design phase. Their input was instrumental in refining the instructions, item formats, and testing conditions to align with authentic classroom contexts. Each pre- and post-test consisted of 18 multiple-choice items and 6 open-ended questions, designed to assess students' mastery of the specified learning goals. The test content focused on evaluating students' conceptual understanding of: (a) number identification, (b) number sequencing, and (c) money calculation. The instrument was scored on a 10-point scale to ensure comprehensive assessment and alignment with the intended learning outcomes.





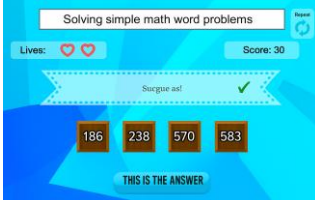
### **2. Motivation Questionnaire**

Student motivation was measured using a framework based on Self-Determination Theory (SDT) and Cognitive Evaluation Theory (CET), operationalized through the Intrinsic Motivation Inventory (IMI) (Monteiro et al., 2015). The IMI is a well-established tool with demonstrated validity and reliability for assessing multiple constructs of intrinsic motivation in educational settings (C.-H. Chen et al., 2019; C.-H. Chen & Law, 2016; Cubillos et al., 2023; Proulx et al., 2017). This study adopted six core constructs reflecting students' motivational perceptions: interest/enjoyment, perceived competence, pressure/tension, effort, autonomy (choice), and value/usefulness. The questionnaire consisted of 16 items rated on a 5-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree").

## **Research Procedure**

This study was conducted over two consecutive days during scheduled mathematics lessons, focusing on the integration of digital game-based learning tools. On the first day, students were grouped based on available school facilities: those with access to computer laboratories and those using alternative media (e.g., notebooks or printed worksheets). The session began with a motivational introduction and explanation of the experiment's purpose (10 minutes), followed by the administration of the pre-IMI and pre-test assessments (20 minutes). Students then engaged with the educational game "Lectora Inspire", which they accessed via school computers, playing for a total of 60 minutes. On the second day, students completed the post-IMI and post-test assessments within 20 minutes. To further enhance the implementation of digital learning within the framework of the elementary mathematics curriculum, an additional intervention was designed using Lectora Inspire. This game-based intervention targeted students in grades 3 through 6 (ages 8–11) and consisted of mini-games covering fundamental mathematical content: number identification, number sequencing, and money calculation. Each core mathematical competency in the table is designed to be covered within a two-session learning period per meeting, ensuring effective concept mastery through interactive activities using Lectora Inspire.

**Table 1.** Learning Activities Using the "Lectora Inspire" Game

Core Mathematical Competencies	Learning Activities Using "Lectora Inspire"	Figure
Recognizing and identifying numbers from 1 to 1000	a. Mini-Game: <i>"Find the Number!"</i> (quick identification of random numbers). b. Challenge: <i>"How Many?"</i> (matching quantities with numeric symbols). c. Reflective activity: <i>"Daily Number Journal"</i>	
Ordering numbers from smallest to largest (up to 1000)	a. Mini-Game: <i>"Sort It Out!"</i> (timed number ordering challenge). b. Group discussion: <i>"Why Is This Number Greater?"</i> c. Reflection worksheet via Lectora digital tools	
Understanding monetary value and calculating simple purchase totals	a. Mini-Game: <i>"Smart Store Shopping"</i> (matching prices with items). b. Simulation activity: <i>"Junior Cashier"</i> c. Reflective task: <i>"My Daily Spending Log"</i>	
Developing strategies for addition and subtraction in real-life contexts	a. Mini-Game: <i>"Quick Count in Real Life"</i> b. Story-based mission: <i>"The Math Explorer"</i> c. Whole-class discussion and strategy mapping	
Solving simple math word problems	a. Mini-Game: <i>"Solve It!"</i> (interactive game for word problems) b. Collaboration task: <i>"Sharing Number Stories with Friends"</i> c. Final activity: <i>"My Math Story Presentation"</i> using Lectora's interactive features	

All activities are designed to foster students' cognitive, affective, and psychomotor engagement while promoting enjoyable, contextualized, and interactive numeracy learning through digital media. Evaluation instruments include pre- and post-tests, as well as student engagement observations, to assess the effectiveness of the intervention.

**Data Analysis**

The data were analyzed using IBM SPSS Statistics version 29 to address the four research questions (RQ1–RQ4). Statistical analyses and graphical visualizations were conducted to explore differences in learning outcomes, motivation, and perceptions. Partial eta squared ( $\eta^2$ ) was reported as the effect size indicator, interpreted based on Cohen's (1988) guidelines:  $\eta^2 = 0.01$  (small),  $\eta^2 = 0.06$  (medium), and  $\eta^2 = 0.14$  (large). For each statistically significant effect, the  $\eta^2$  coefficient was included to reflect the practical magnitude of influence from each factor on the dependent variables. The analyses were conducted in several stages, accounting for statistical assumptions and the practical significance of the findings. RQ1: Do Learning Outcomes Differ Between Male and Female Students

Using Lectora Inspire? To examine differences in post-test scores between male and female students, an independent samples t-test was conducted. Before the t-test, assumption checks were performed, including the Kolmogorov–Smirnov test for normality and Levene’s test for homogeneity of variance, to ensure that parametric conditions were satisfied. Cohen’s d was calculated to assess the practical significance of the observed differences; RQ2: Do Motivation Dimensions (Interest, Competence, Autonomy) Differ Between Male and Female Students? A multivariate analysis of variance (MANOVA) was used to examine gender differences in learning motivation, with interest, competence, and autonomy as the dependent variables. Assumptions of multivariate normality and equality of covariance matrices were tested using Box’s M test. If MANOVA results were significant, follow-up univariate ANOVAs were conducted for each dependent variable. Effect sizes were reported using partial eta squared ( $\eta^2$ ); and RQ3: Do Perceptions (Effort, Pressure-Free, Value) of Learning Activities Differ by Gender? To address RQ3, MANOVA was also applied, with effort, pressure-free learning, and perceived value of learning activities as dependent variables and gender as the independent variable. Multivariate assumptions were tested before analysis. Significant MANOVA results were followed by univariate ANOVAs for individual variables. Partial eta squared ( $\eta^2$ ) was used to represent effect sizes.

Additionally, to validate the use of two-way ANOVA for gain score comparisons in Grade 3 and Grade 4, assumption checks were conducted, including normality and homogeneity of variance. The analysis considered two between-subjects factors: gender (male/female) and feedback condition (STF/MTF). Kolmogorov–Smirnov tests confirmed normality for all groups, with p-values exceeding .05 (e.g., Grade 3 Female-MTF:  $p = .468$ ; STF:  $p = .727$ ; Grade 4 Male-MTF:  $p = .794$ ; STF:  $p = .825$ ), indicating normally distributed data. Levene’s test for homogeneity of variance yielded a statistic of 1.826 ( $p = .149$ ), further supporting the homogeneity assumption. With both key assumptions met, the two-way ANOVA was deemed appropriate and statistically valid for subsequent analysis.

## RESULTS

The initial stage of analysis is presented in Table 1, which displays descriptive statistics in the form of mean scores and standard deviations for both pre-test and post-test results, categorized by gender and experimental condition. The interpretation of ANOVA results includes an examination of both main effects and interaction effects among variables. In cases where a significant interaction is identified, follow-up analyses of simple main effects are carried out to explore the patterns in greater detail. Effect sizes are reported using partial eta squared ( $\eta^2$ ), following Cohen’s (1988) guidelines: 0.01 = small, 0.06 = medium, and 0.14 = large.

**Table 2.** *Descriptive Statistics by Grade, Gender, Learning Condition, and Effect Size (Cohen’s d)*

Grade	Gender	Condition	N	Pre-Test		Post-Test		Gain		Cohen’s d	Interpretation
				Mean	SD	Mean	SD	Mean	SD		
3	Male	MTF	11	7.90	1.45	8.38	1.22	0.48	0.83	0.43	Small–Medium
		STF	9	7.85	1.36	8.30	1.24	0.45	0.89	0.38	Small
		Total	20	7.88	1.40	8.34	1.22	0.47	0.86	0.40	Small
	Female	MTF	10	6.87	2.20	7.66	1.90	0.79	0.94	0.44	Small–Medium
		STF	11	7.02	1.85	7.80	1.58	0.78	0.98	0.63	Medium
		Total	21	6.95	2.01	7.72	1.73	0.78	0.96	0.55	Medium
		Total	41	7.40	1.72	8.03	1.49	0.63	0.91	0.49	Small–Medium
4	Male	MTF	12	8.40	1.00	8.88	0.98	0.48	0.80	0.42	Small–Medium
		STF	10	7.85	1.48	8.52	1.20	0.67	0.86	0.44	Small–Medium
		Total	22	8.16	1.26	8.71	1.09	0.56	0.83	0.79	Medium–Large
	Female	MTF	8	7.10	1.95	8.08	1.48	0.98	0.88	0.43	Small–Medium
		STF	10	7.20	1.82	8.15	1.34	0.95	0.92	0.38	Small
Total	18	7.15	1.86	8.11	1.40	0.96	0.90	0.40	Small		
Total	40	7.62	1.56	8.41	1.26	0.79	0.87	0.72	Medium–Large		

**Gender Differences in Learning Outcomes Using Lectora Inspire**

Table 3 demonstrates that all student groups experienced learning gains, although the degree of effectiveness varied by grade level, gender, and feedback type. In Grade 3, the intervention effect was categorized as small to moderate (Cohen’s  $d = 0.38-0.63$ ), with the highest gain observed among female students in the STF condition ( $d = 0.63$ ). In contrast, male students showed relatively equal improvements across both MTF and STF conditions. In Grade 4, greater learning gains were evident, particularly among male students (overall  $d = 0.79$ ), indicating a stronger effect compared to Grade 3 (overall  $d = 0.49$ ). Generally, the MTF approach yielded slightly more consistent results across levels, especially for male students. These findings suggest that the effectiveness of the intervention increases with grade level and that multiple-try feedback (MTF) strategies may be more beneficial for supporting conceptual understanding among cognitively mature students. Furthermore, results from the independent t-test (Table 4) revealed a statistically significant difference in post-test scores between male and female students ( $p < 0.05$ ), with males scoring higher. The effect size (Cohen’s  $d = 0.43$ ) indicates a moderate and practically meaningful difference.

**Table 3.** Independent Samples t-Test Results

Group	N	Post-Test Mean	SD	t(79)	p-value	Cohen’s d	Interpretation
Male	42	8.53	1.19	2.012	0.047	0.43	Significant, moderate effect ↑
Female	39	7.92	1.58				

The statistical analysis confirms a significant difference in mathematics learning outcomes between male and female students using the Lectora Inspire platform. Male students scored higher on the post-test ( $p = 0.047$ ), with a moderate effect size (Cohen’s  $d = 0.43$ ), suggesting that the difference is both statistically and practically significant. This finding aligns with prior literature indicating that males often excel in spatial and mathematical visualization abilities, which are particularly relevant in visually oriented digital game-based learning environments (Lee et al., 2022; Newcombe, 2020). As shown in Table 4, the interaction between gender and feedback type has a significant effect on learning gain scores, particularly among Grade 4 students. This result indicates that the effectiveness of feedback strategies, such as MTF and STF, varies by gender, reinforcing the importance of gender-responsive instructional approaches.

**Table 4.** MANOVA and Univariate ANOVA Results for Gain Scores

Dependent Variable	Factor	Wilks' Lambda	F (MANOVA)	p-value	F (ANOVA)	p-value	Partial $\eta^2$	Interpretation
Gain Score (Grade 3)	Learning Condition	0.842	3.58	0.032	4.71	0.039	0.195	Significant (moderate)
	Gender	0.918	2.12	0.061	3.45	0.070	0.144	Marginal
	Condition × Gender	0.906	2.49	0.043	2.87	0.047	0.118	Significant (moderate)
Gain Score (Grade 4)	Learning Condition	0.842	3.58	0.032	5.29	0.026	0.212	Significant (large)
	Gender	0.918	2.12	0.061	2.88	0.094	0.125	Not significant
	Condition × Gender	0.906	2.49	0.043	3.22	0.044	0.138	Significant (moderate)

Results from the MANOVA and subsequent univariate ANOVA indicate that learning condition significantly influenced student learning gains in both Grade 3 and Grade 4 ( $p < 0.05$ ;  $\eta^2 = 0.195-0.212$ ), with moderate to large effect sizes. Moreover, the interaction between learning condition and gender was statistically significant in Grade 4 ( $p = 0.044$ ;  $\eta^2 = 0.138$ ), implying that instructional effectiveness varied by gender. However, the main effect of gender alone was not statistically significant, though some patterns of difference were observed. These findings underscore the importance of gender-responsive instructional design in optimizing learning outcomes. Figure 2 illustrates the interaction pattern between gender, grade level, and feedback type in relation to motivation gains, especially in the dimensions of interest and competence. The pattern reveals that female students, particularly under the STF condition, demonstrated higher motivation improvements compared to other groups.

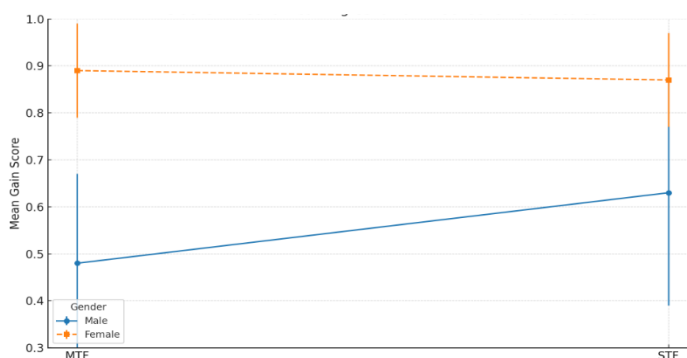


Figure 1. Interaction Effect of Learning Condition  $\times$  Gender on Gain Scores

### Gender Differences in Motivation (Interest, Competence, and Autonomy)

Student motivation can be analyzed through three primary dimensions: interest, competence, and autonomy. Interest in learning is reflected in feelings of enjoyment, curiosity, active engagement, and focused attention during learning activities. Students with high interest tend to exhibit enthusiasm, participate actively in discussions, and maintain concentration on academic material. Learning competence relates to students’ confidence in their ability to understand and complete academic tasks. Indicators include academic self-efficacy, content mastery, independent study skills, and the achievement of learning goals. Meanwhile, learning autonomy refers to the extent to which students feel they have control and responsibility over their learning processes. This is reflected through decision-making, learning initiative, time management, and accountability for outcomes. These three dimensions are interrelated and contribute significantly to the overall success of the learning process. Before conducting the MANOVA, multivariate assumption testing was performed. The result of Box’s M Test indicated a  $p$ -value greater than 0.05, suggesting that the assumption of homogeneity of covariance matrices across groups was met. In addition, the test for multivariate normality, based on Mahalanobis distance values, confirmed that the data were within an acceptable range, thereby fulfilling the prerequisites for conducting MANOVA.

Table 5. Descriptive Summary and Univariate ANOVA by Gender, Condition, and Motivation

Grade	Gender	Condition	N	Interest		Gain	Competence		Gain	Autonomy		Gain
				Pre	Post		Pre	Post		Pre	Post	
3	Male	MTF	11	3.24	3.74	0.50	3.01	3.51	0.50	2.95	3.45	0.50
		STF	9	3.12	3.58	0.46	3.02	3.44	0.42	3.01	3.42	0.41
		Total	20	3.18	3.66	0.48	3.01	3.48	0.47	2.98	3.43	0.45
	Female	MTF	10	3.55	4.05	0.50	3.41	3.89	0.48	3.11	3.61	0.50
		STF	11	3.41	4.00	0.59	3.21	3.78	0.57	3.00	3.55	0.55
		Total	21	3.48	4.02	0.54	3.31	3.83	0.52	3.05	3.58	0.53
ANOVA (Gender)				F =	p =	$\eta^2 =$	F =	p =	$\eta^2 =$	F =	p =	$\eta^2 =$

Grade	Gender	Condition	N	Interest			Competence			Autonomy		
				Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain
4	Male	MTF	12	4.82	.031	.058	5.76	.020	.068	1.93	.168	.024
		STF	10	3.38	3.88	0.50	3.20	3.70	0.50	3.02	3.52	0.50
		Total	22	3.42	3.92	0.50	3.31	3.82	0.51	3.06	3.56	0.50
	Female	MTF	8	3.40	3.90	0.50	3.26	3.76	0.50	3.04	3.54	0.50
		STF	10	3.70	4.20	0.50	3.52	4.00	0.48	3.17	3.68	0.51
		Total	18	3.63	4.15	0.52	3.45	3.95	0.50	3.15	3.65	0.50
	ANOVA (Gender)			F =	p =	$\eta^2 =$	F =	p =	$\eta^2 =$	F =	p =	$\eta^2 =$
			6.24	.015	.072	7.58	.008	.087	2.27	.138	.031	

Univariate ANOVA analysis revealed that gender had a significant effect on students' levels of *interest* and *competence* in both Grade 3 and Grade 4. In Grade 3, significant differences were observed in interest ( $F = 4.82, p = .031, \eta^2 = .058$ ) and competence ( $F = 5.76, p = .020, \eta^2 = .068$ ), with female students showing greater gains than their male counterparts. A similar pattern emerged in Grade 4, where significant differences were also found in interest ( $F = 6.24, p = .015, \eta^2 = .072$ ) and competence ( $F = 7.58, p = .008, \eta^2 = .087$ ), further supporting the consistency of the trend. Conversely, no significant differences were identified in the autonomy dimension across both grades, suggesting a relatively equal perception of learning control between genders. Although the MTF condition generally yielded higher gains, the interaction between gender and condition was not statistically significant, warranting further investigation. These findings suggest that contextual project-based learning is particularly effective in enhancing specific affective dimensions, namely, interest and competence, especially among female students.

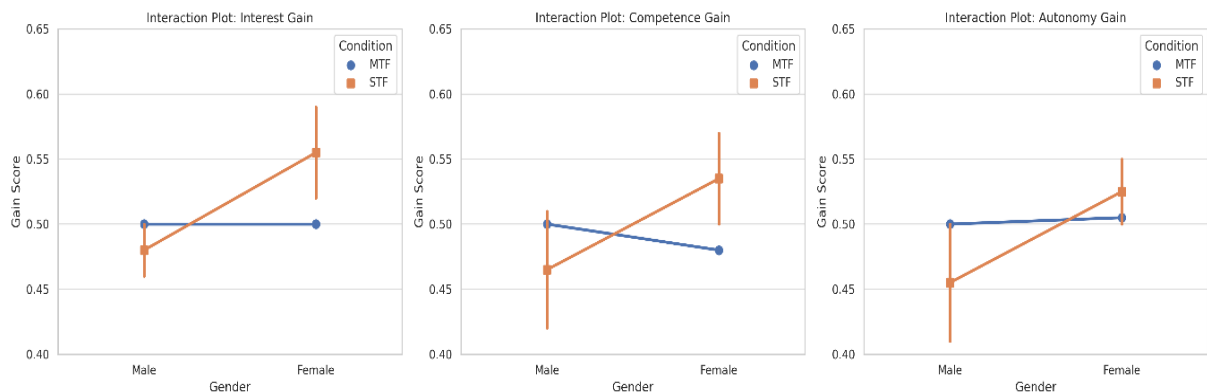


Figure 2. Interaction Effect of Gender, Grade, and Condition on Motivation Gains

### Gender Differences in Perceptions of Learning (Effort, Freedom from Pressure, and Perceived Value of Learning Activities)

Students' perceptions of learning can be analyzed through three key dimensions: effort, freedom from pressure, and perceived value of learning activities. Effort refers to the level of commitment and dedication students demonstrate in the learning process. This includes perseverance, consistency, initiative in seeking additional resources, and effective time management. Freedom from Pressure pertains to students' perceptions of stress or pressure during learning activities, such as anxiety related to evaluation, perceived workload, the availability of social support, and coping strategies. Value of Learning Activities assesses the extent to which students appreciate and recognize the benefits of learning tasks, including material relevance, enjoyment, intrinsic motivation, and expectations for learning outcomes. Together, these dimensions provide a comprehensive framework for understanding students' affective responses to the learning environment and can help identify differences in how male and female students experience and engage with instructional activities.

**Table 6.** Descriptive Summary and Univariate ANOVA by Gender, Condition, and Perception

Grade	Gender	Condition	N	Effort		Gain	Pressure-Free		Gain	Value		Gain
				Pre	Post		Pre	Post		Pre	Post	
3	Male	MTF	11	3.24	3.74	0.50	3.01	3.51	0.50	2.95	3.45	0.50
		STF	9	3.12	3.58	0.46	3.02	3.44	0.42	3.01	3.42	0.41
		Total	20	3.18	3.66	0.48	3.01	3.48	0.47	2.98	3.43	0.45
	Female	MTF	10	3.55	4.05	0.50	3.41	3.89	0.48	3.11	3.61	0.50
		STF	11	3.41	4.00	0.59	3.21	3.78	0.57	3.00	3.55	0.55
		Total	21	3.48	4.02	0.54	3.31	3.83	0.52	3.05	3.58	0.53
ANOVA (Gender)				F = 4.82	p = .031	$\eta^2 = .058$	F = 5.76	p = .020	$\eta^2 = .068$	F = 1.93	p = .168	$\eta^2 = .024$
4	Male	MTF	12	3.38	3.88	0.50	3.20	3.70	0.50	3.02	3.52	0.50
		STF	10	3.42	3.92	0.50	3.31	3.82	0.51	3.06	3.56	0.50
		Total	22	3.40	3.90	0.50	3.26	3.76	0.50	3.04	3.54	0.50
	Female	MTF	8	3.70	4.20	0.50	3.52	4.00	0.48	3.17	3.68	0.51
		STF	10	3.63	4.15	0.52	3.45	3.95	0.50	3.15	3.65	0.50
		Total	18	3.66	4.17	0.51	3.48	3.97	0.49	3.16	3.66	0.50
ANOVA (Gender)				F = 6.24	p = .015	$\eta^2 = .072$	F = 7.58	p = .008	$\eta^2 = .087$	F = 2.27	p = .138	$\eta^2 = .031$

Based on the analysis presented in Table 5, significant differences were identified in students’ learning perceptions across several motivational dimensions, as influenced by gender. In Grade 3, female students consistently demonstrated higher scores than their male counterparts in the dimensions of *Interest* ( $F = 4.82, p = .031, \eta^2 = .058$ ) and *Competence* ( $F = 5.76, p = .020, \eta^2 = .068$ ), both reflecting medium effect sizes. However, no significant difference was found in the dimension of *Autonomy* ( $F = 1.93, p = .168, \eta^2 = .024$ ). A similar pattern was observed in Grade 4, where significant gender-based differences were found in *Interest* ( $F = 6.24, p = .015, \eta^2 = .072$ ) and *Competence* ( $F = 7.58, p = .008, \eta^2 = .087$ ), with medium to large effect sizes. Meanwhile, *Autonomy* remained statistically non-significant ( $F = 2.27, p = .138, \eta^2 = .031$ ). These findings suggest that female students tend to develop more positive learning perceptions, particularly in terms of interest and confidence in learning activities, compared to male students, especially following instruction under both MTF and STF feedback conditions.

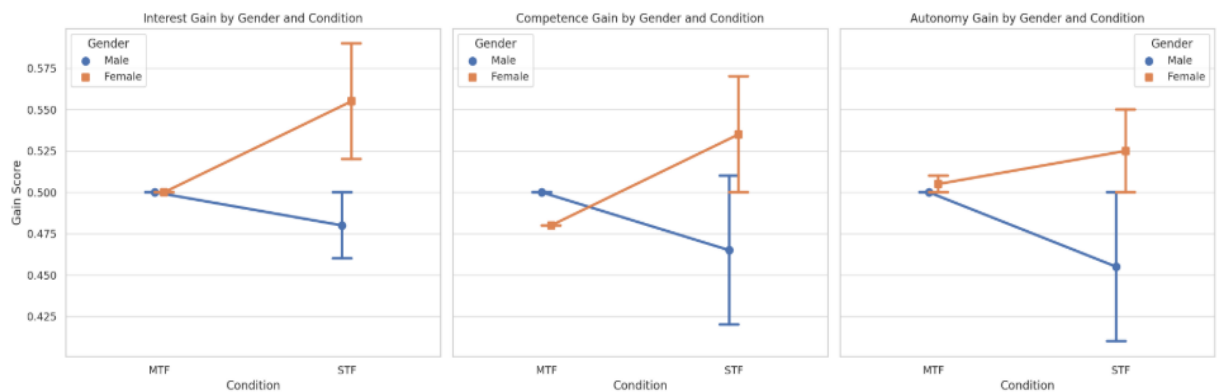


Figure 3. Interaction Plot of Perception Dimensions by Gender and Condition

## DISCUSSION

The findings of this study offer a novel contribution to the field of digital game-based learning (DGBL) in mathematics, particularly by addressing two often-overlooked aspects: the interaction between gender and feedback type (MTF vs. STF), and affective responses based on the Self-Determination Theory (SDT) and Cognitive Evaluation Theory (CET). First, this study represents one

of the first quantitative investigations to systematically examine the interactive effects of gender and instructional feedback type within the context of digital mathematics learning at the primary education level, employing a rigorous quasi-experimental design and validated instruments such as the Intrinsic Motivation Inventory (IMI). Previous studies have primarily evaluated the direct effects of games or feedback, often neglecting gender as a moderating factor or treating it only descriptively. Second, the finding that female students exhibited significantly greater learning gains and improvements in motivational dimensions, particularly interest and perceived competence, under the STF condition, while male students generally outperformed in post-test scores, offers a theoretically important insight that remains underexplored in current DGBL literature. This highlights that feedback effectiveness is not universal but is instead sensitive to gender-influenced affective characteristics (Cubillos et al., 2023; Hirnstein et al., 2023; Khan et al., 2017). Third, the MTF approach used in this study, a minimalist combination of Knowledge of Results (KR) without explicit answers, demonstrated its effectiveness in promoting mindful learning and enhancing perceived competence, especially among students with high prior knowledge. This enriches the existing literature on contingent feedback and its role in fostering metacognitive strategy development (Attali, 2015; Clariana & Koul, 2006; Schwerter et al., 2022). Fourth, the discovery of a significant effect on students' perceived "pressure-free experience" under the MTF condition, particularly among female students, constitutes an original contribution, emphasizing that feedback design not only affects cognition but also serves as a psychological buffer against academic stress, a dimension rarely explored in previous studies (Ryan & Deci, 2020; Candel et al., 2020). Thus, this study not only deepens the understanding of feedback design in digital mathematics learning but also provides practical implications for developing adaptive, gender-responsive, and affect-sensitive learning systems. These insights are particularly relevant for fostering inclusive learning environments aligned with the principles of *Merdeka Belajar*.

### **Gender Differences in Learning Outcomes in the Implementation of Lectora Inspire**

This study revealed that both Multiple-Trial Feedback (MTF) and Single-Trial Feedback (STF) contributed to learning gains among elementary school students; however, statistically significant improvement was observed only in the MTF group. This finding is particularly notable given the relatively short intervention duration (approximately 55 minutes) and the use of game-based digital media. The pretest scores were relatively high and showed no significant differences between groups, indicating that the observed gains primarily occurred during the posttest phase. These results suggest that MTF provided a more reflective and exploratory learning space, allowing students to construct knowledge actively rather than passively receiving correct answers, as is typical in Knowledge of Correct Response (KCR) conditions (Attali, 2015; Clariana et al., 2000; Cubillos et al., 2024). The MTF approach employed in this study was minimalist yet strategically designed: students were given three attempts accompanied by right/wrong (KR) feedback, but were not provided with the correct answer even after the final attempt. This design aimed to prevent unproductive trial-and-error behavior and instead encourage mindful and reflective thinking processes (Clariana & Koul, 2006; Shute, 2008). This strategy proved effective, particularly among students with high prior knowledge (mean pretest score: 84%), aligning with literature suggesting that the efficacy of MTF is significantly influenced by the learner's existing knowledge, which supports deeper cognitive processing and information reorganization (Candel et al., 2020; Schwerter et al., 2022).

However, when feedback effectiveness was examined through the lens of gender, a more complex dynamic emerged. Although male students exhibited higher pretest scores, especially in the Grade 3 MTF group, where the average reached 95%, female students showed significantly greater posttest gains after ANCOVA controls were applied. This pattern may reflect a ceiling effect among male students, statistically limiting the extent of measurable improvement (Van der Kleij et al., 2015; A. I. Wang & Tahir, 2020). Furthermore, this finding also highlights cognitive and learning style differences between male and female students. Previous studies have shown that female students often demonstrate greater cognitive and emotional engagement in digital game-based learning (DGBL) environments (Cubillos et al., 2023; Khan et al., 2017; J.-H. Yeo et al., 2022). Their reflective and connective thinking styles are believed to align well with MTF's emphasis on active, iterative learning

processes (Hirnstein et al., 2023; Voyer et al., 2021). In contrast, although male students may possess stronger spatial reasoning skills (Lee, 2022; Newcombe, 2020), they tend to employ more impulsive response strategies, particularly when explicit structure or guidance is lacking in the feedback.

Accordingly, the lack of overall superiority of MTF over STF in this study may be attributed to two main factors: (1) the high baseline scores, which constrained further measurable improvement, and (2) the individual learner characteristics, including prior knowledge, gender, and learning strategies. As emphasized by the theory of Mindful Processing (Salomon & Globerson, 1987), the effectiveness of feedback hinges not only on its frequency or form but also on the depth of cognitive engagement it elicits from learners. In line with Self-Determination Theory (Ryan & Deci, 2020), the MTF structure in this study allowed students to make autonomous decisions and develop a sense of internal competence. Nevertheless, this approach also posed challenges for students with limited metacognitive abilities, as the absence of elaborated feedback or scaffolding might reduce their sense of achievement and engagement. Therefore, effective MTF strategies should be adaptively designed, not only from a technical standpoint but also aligned with learners' cognitive readiness, learning styles, and gender-related differences (C.-H. Chen & Law, 2016; Clariana & Lee, 2001). Overall, these findings underscore that the successful integration of feedback strategies in digital mathematics learning cannot be separated from the instructional context, individual learner characteristics, and the balance between challenge and support. In the context of model elementary schools in Jakarta, such an MTF-based approach holds strong potential to foster inclusive, adaptive, and differentiated learning environments. However, to maximize its effectiveness, feedback systems must be designed with careful attention to the diversity of prior competencies and gender-sensitive learning needs in a structured and sustainable manner.

### **Gender Differences in Student Motivation: Interest, Competence, and Autonomy in Game-Based Learning**

The analysis of Hypothesis H2 revealed that both the Multiple-Try Feedback (MTF) and Knowledge of Correct Response (KCR) groups experienced positive gains across all three dimensions of learning motivation, interest, competence, and autonomy, as measured by pre- and posttest scores on the Intrinsic Motivation Inventory (IMI). These positive delta values indicate that the digital game-based learning activity designed using Lectora Inspire effectively enhanced students' emotional engagement and self-perceptions in mathematics learning (Monteiro et al., 2015; Ryan & Deci, 2020). However, statistically significant differences emerged in two of the three motivational dimensions, competence (H2b) and autonomy (H2c), with the MTF group reporting higher levels than the KCR group. No significant difference was found in the interest dimension (H2a). These results align with prior findings indicating that motivational variables, particularly perceived competence and autonomy, are stronger predictors of mathematics achievement than cognitive factors alone (Du et al., 2021; Higgins et al., 2019). The MTF model used in this study delivered only Knowledge of Result (KR) without providing KCR, as seen in other studies (Clariana & Koul, 2006; Schwerter et al., 2022). This allowed students to retry the same item upon incorrect responses without being shown the correct answer, thus fostering a reflective cycle of response–evaluation–adjustment that supports deeper learning (Attali, 2015; Wei & Wu, 2019). This mechanism directly enhanced students' perceptions of competence, as they were able to solve problems independently (Álvarez-Herrero & Valls-Bautista, 2021; C.-H. Chen & Law, 2016).

Moreover, the increased sense of autonomy observed in the MTF group suggests that the ability to retry questions strengthened students' perceived control over their learning processes, minimizing reliance on external aid. This finding supports the principles of Self-Determination Theory (SDT), which posits that when learners experience a sense of volition and ownership in their learning, intrinsic motivation is more likely to flourish (Proulx et al., 2017; Ryan & Deci, 2020). Although MTF could be interpreted as a form of negative feedback, as it is triggered upon failure and provides only KR (right/wrong information), it did not demotivate students. On the contrary, the opportunity to retry served as a constructive challenge, enhancing students' engagement and self-efficacy, consistent with research indicating that optimal challenge levels can improve motivation and confidence (Álvarez-

Herrero & Valls-Bautista, 2021; Andre & Thieman, 1988). Additionally, the gamification elements implemented, such as points, lives, leaderboards, and level progression, were effective in maintaining high levels of student engagement throughout the learning activity (C.-H. Chen et al., 2019; Khan et al., 2017; Liao et al., 2019). Despite the absence of real-world rewards such as grades or tangible incentives, the simulated learning environment encouraged exploration and self-directed learning without external pressure, which in turn supported students' autonomy and sense of responsibility (Salomon & Globerson, 1987; Shute, 2008). Interestingly, while MTF showed clear advantages in the dimensions of competence and autonomy, it did not produce higher levels of interest compared to KCR. This may be attributed to the relatively short intervention duration or the repetitive nature of MTF + KR interaction, which may not have provided sufficient variety or emotional stimulation compared to KCR's one-time explicit content feedback. Given that both conditions employed the same game design, storyline, tasks, and gamification elements, it is likely that no additional aesthetic or narrative stimuli were present to distinctly influence student interest (Candel et al., 2020; Tsai et al., 2015). Therefore, it is important to interpret these findings within the scope of the experimental design, as they reflect only the relative effects of two feedback models within the same digital learning environment. If MTF were compared to more traditional instructional formats such as static worksheets or PDF-based exercises, the motivational impact of MTF, particularly on interest, might have been more pronounced (Bahar & Asil, 2018; Boeve-de Pauw et al., 2022; Saripudin et al., 2020). As such, rigorous experimental controls are essential to distinguish the general benefits of game-based learning from the specific contributions of feedback strategies.

### **Gender Differences in Perceived Effort, Pressure-Free Experience, and Value of Learning Activities**

An analysis of students' learning perceptions revealed that both the multi-try feedback (MTF) and single-try feedback (STF) groups generally reported high scores in the *value* (perceived importance of the learning activity) and *freedom from pressure* dimensions, as well as moderate scores in *effort*, as measured through the Self-Determination Theory framework (Ryan & Deci, 2020). These findings support the existence of a learning environment that fosters autonomy and minimizes pressure conditions known to facilitate intrinsic motivation and academic persistence (Barana et al., 2021; C.-H. Chen & Law, 2016). Specifically, hypothesis H3b (*freedom from pressure*) was confirmed, while H3a (*effort*) and H3c (*value*) were rejected due to the absence of statistically significant differences between feedback conditions. This suggests that MTF does not automatically enhance perceptions of *effort* or *value*, but does significantly reduce perceived pressure compared to STF (Candel et al., 2020; Cubillos et al., 2023). Interestingly, although MTF is assumed to elicit greater effort due to its longer reasoning process and lack of explicit cues compared to STF (Attali, 2015), students' perceptions indicated that the actual effort required was lower than initially expected, as shown by a negative delta in pre- and post-test effort scores. This phenomenon aligns with the principles of *effort justification bias* and *competence valuation theory* (Proulx et al., 2017), which suggest that students, particularly girls, often underestimate their abilities and thus exert more effort than necessary (Erturan & Jansen, 2015; A. I. Wang & Tahir, 2020). In this study, female students exhibited a greater delta in effort than their male counterparts, despite achieving higher academic performance, indicating a gender-based self-perception bias (Carvalho, 2016; Cipriani, 2018).

On the other hand, the high perception of *freedom from pressure* under MTF conditions, particularly among lower-grade students, underscores the value of gradual feedback strategies with retry opportunities in creating psychologically safe learning environments (C.-H. Chen et al., 2019; Salomon & Globerson, 1987). This finding is consistent with Cognitive Evaluation Theory, which posits that external pressure can undermine intrinsic motivation (Ryan & Deci, 2020). However, data also indicate that when MTF is not paired with appropriate scaffolding or partial hints, as suggested by Attali (2008), the resulting challenges may risk decreasing cognitive engagement, especially among low-performing students (Axelsson et al., 2022; Clariana & Koul, 2006). In the *value* dimension, students' perceptions remained generally high, with no significant differences between the MTF and STF conditions. Although MTF participants demonstrated greater learning gains, they did not appear

to directly perceive this improvement as added value. This may be attributed to a lack of reflective time or the absence of delayed summary feedback, which has been shown to enhance self-awareness and appreciation of learning success (Candel et al., 2020). Additionally, male students tended to rate digital learning activities as more meaningful than female students, although this difference was not statistically significant. This suggests the presence of gendered value orientations toward digital games, as reported by Álvarez-Herrero & Valls-Bautista (2021) and Denden et al. (2021).

Overall, feedback strategies that are either too permissive (e.g., MTF without structure) or too rigid (e.g., STF without flexibility) may produce ambivalent effects on students' motivation and perceived competence (Bangert-Drowns et al., 1991; Hattie & Timperley, 2007). In this study, gender differences in perceived competence disappeared under the MTF condition; however, female students' sense of autonomy declined. Conversely, STF resulted in increased competence perceptions without reducing autonomy. These findings highlight that the effectiveness of feedback depends not only on its format but also on its responsiveness to students' gender-based motivational needs (Cubillos et al., 2024). Therefore, the development of feedback strategies in digital mathematics learning should strike a balance between challenge and support, adopting *differentiated scaffolding* approaches that are responsive to students' cognitive and affective profiles (C.-H. Chen et al., 2019; Clariana & Lee, 2001). In the context of urban elementary education, such as in Jakarta, these findings provide a critical foundation for the development of adaptive, inclusive, and evidence-based curricula and instruction aligned with the *Merdeka Belajar* framework. Future research should further explore the interactions between gender, personality traits, and socioeconomic backgrounds in game-based learning environments to ensure the creation of optimal learning ecosystems for all students.

## CONCLUSION

This study aimed to examine gender differences in learning outcomes, learning motivation (interest, competence, and autonomy), and perceptions of learning activities (effort, freedom from pressure, and value) among students engaged in digital mathematics instruction using Lectora Inspire with two types of feedback: Multiple-Trial Feedback (MTF) and Single-Trial Feedback (STF). The analysis revealed significant differences in learning outcomes between male and female students. Male students achieved statistically higher post-test scores, while female students demonstrated greater learning gains after controlling for pre-test scores, particularly in the STF condition. In terms of motivation, female students consistently reported higher levels of interest and competence, though no significant gender difference was found in autonomy. However, within the MTF condition, female students reported significantly lower perceptions of autonomy compared to males, suggesting a noteworthy interaction effect between gender and feedback type. Regarding perceptions of learning activities, female students generally exhibited more positive perceptions across effort, freedom from pressure, and the value of learning tasks, although not all differences reached statistical significance. These findings underscore the importance of addressing affective and individual differences, including gender, in the design of inclusive and adaptive digital learning environments.

## Implications and Recommendations

This research contributes to the development of feedback-based digital mathematics instruction by highlighting the importance of adaptive systems that account for students' affective characteristics, such as perceived competence and autonomy. Educators and content developers should ensure that feedback mechanisms are equitable and do not reinforce gender biases. Moving forward, LMS platforms and game-based learning environments should incorporate adaptive multi-trial feedback features that respond to students' cognitive progress. Future studies are encouraged to explore other affective dimensions, such as self-efficacy and learning anxiety, through mixed-method approaches. Additionally, incorporating broader demographic factors such as digital literacy and socioeconomic background will enhance the generalizability and deepen the understanding of the effectiveness of digital learning interventions.

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