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Exploring Factors Influencing Students' Affective Engagement with Systems Thinking

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Increasing complexity in today's world requires skills to analyze ideas, identify connections, and view concepts holistically. Systems thinking addresses this need by focusing on the interactions and relationships among various elements. However, developing this skill requires explicit and scaffolded activities for effective learning. To explore how this can be achieved, a descriptive survey was conducted to determine whether significant differences exist in students' affective learning of systems thinking based on gender, academic grade, and birth order. These factors were examined as they relate to emotional responses, engagement, and motivation, which are critical to developing students' ability to apply systems thinking effectively. The study involved 380 junior high school students from a public high school in the Philippines. Findings revealed significant differences in how male and female students applied systems thinking. Students with higher academic grades showed greater appreciation for its application, while birth order had minimal influence on perspectives regarding systems thinking capabilities. These findings highlight the importance of strategies that consider individual differences, such as gender-related variations and cognitive diversity, in enhancing systems thinking development. By incorporating these insights, educators can design targeted interventions, and researchers can develop strategies to foster systems thinking skills essential for addressing real-world challenges.

Keywords: systems thinking, affective aspect, gender, academic grade, birth order, educational intervention

INTRODUCTION

Complex interconnected systems constitute the natural world. With the advent of technology, new systems are continuously created, amplifying the interdependence among their elements. In this context, systems thinking has emerged as an essential skill for navigating complexity and interconnectedness (Arnold & Wade, 2015). This approach promotes a holistic problem-solving perspective, encouraging learners to

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analyze the dynamic interactions among various system components. Moreover, systems thinking fosters higher-order thinking skills, compelling both students and teachers to recognize the value of school-acquired knowledge as a critical resource for addressing intricate, multi-faceted challenges in today's world (Fowler et al., 2019; Koral Kordova et al., 2018). This skill also facilitates critical thinking and problem-solving by enabling students to draw both intra- and interdisciplinary connections between diverse concepts (Orgill et al., 2019; York et al., 2019). This growing emphasis on systems thinking aligns with the evolving education policies and practices, highlighting the need to equip learners with the skills and mindset necessary to tackle modern challenges.

In response to these educational needs, policymakers and educators have cautioned that traditional linear methods of thinking are insufficient for tackling the complexity of global challenges (Ndaruhutse et al., 2019). This has led to the increased promotion of systems thinking in educational settings, especially within STEM disciplines, where interrelated scientific concepts require a systems-oriented approach (York et al., 2019)). Many scientific concepts are interconnected, making systems thinking crucial for understanding how individual elements function within broader processes. For instance, Tripto et al. (2018) argue that meaningful biological understanding necessitates perceiving systems, recognizing interactions among components, and comprehending the system's overall function. Furthermore, systems thinking equips students to solve complex problems beyond traditional, linear approaches. By fostering a holistic view that considers interrelated factors, systems thinking helps mitigate barriers such as biased reasoning and offers a strong foundation for critical thinking and problem-solving (Dwyer, 2023; Monat & Gannon, 2015). These perspectives highlight the importance of deliberate efforts to cultivate systems thinking through scaffolded guidance and structured activities (York et al., 2019).

However, despite its growing importance, Verhoeff et al. (2018) noted that the varied definitions and approaches to systems thinking have led to ambiguity in its conceptualization and the assessment of related interventions. Commonly regarded as a critical cognitive skill, systems thinking involves analyzing and understanding the interconnections, structures, and behaviors within systems, enabling individuals to predict outcomes, identify areas for improvement, and implement effective modifications (Arnold & Wade, 2015). It relies on higher-order cognitive processes such as analysis, synthesis, and evaluation (Verhoeff et al., 2018). Effective systems thinking is also further supported by other mental abilities, including the identification and analysis of relationships among system components, adoption of a holistic perspective to develop comprehensive solutions, and strategizing dynamic processes that reveal interconnected system behaviors (Henning et al., 2012; Miller et al., 2023).

While cognitive aspects of systems thinking are widely acknowledged and recognized, it is equally crucial to consider its affective dimensions, which remain underexplored. The affective dimension of systems thinking encompasses students' emotional responses, attitudes, and values associated with learning and using its principles (Camelia et al., 2018). It plays a pivotal role in fostering the internalization of systems thinking concepts, enhancing cognitive understanding, and ensuring meaningful application in real-world contexts. While the cognitive dimension of systems thinking is necessary for assessing ideas, its affective aspect ensures that these skills are consistently applied, particularly when addressing complex, interconnected issues. As a holistic approach to problem-solving, systems thinking inherently integrates an affective component, drawing on values that shape how students perceive and engage with the world (Dastgeer et al., 2022). This affective aspect motivates persistence in applying systems thinking, even under challenging conditions (Camelia et al., 2018). Such internalization is essential for forming coherent and meaningful understandings of complex ideas (Verhoeff et al., 2018).

Despite the critical role of the affective aspect of learning, particularly in relation to systems thinking, this dimension is often overlooked in instructional strategies that prioritize cognitive development. This neglect stems from concerns about indoctrination, skepticism regarding the assessment of attitudes or character development, and the perception that beliefs and values are private matters. This proves to be limiting, as the full potential of instructional system design to achieve societal impact often remains unrealized due to insufficient attention to the affective domain (Price, 1998). Such a perspective hinders the integration of affective elements into both general educational contexts and systems thinking, limiting meaningful engagement and long-term application of learned concepts. Therefore, exploring and addressing students' affective engagement with systems thinking is crucial not only for enhancing their cognitive development but also for ensuring the lasting relevance and impact of the knowledge they gain. Research suggests that demographic factors, such as personality (Roslan et al., 2021) gender, age, and cultural background (Palmberg et al., 2017), influence how students emotionally connect with and internalize systems thinking principles. By addressing these and other relevant factors in a holistic manner, educators can promote a deeper and more sustained application of systems thinking, ensuring that educational interventions achieve their intended impact.

Building on this, the current study investigates the affective aspects of systems thinking among junior high school students, focusing on their perceptions and emotional engagement with systems thinking activities. The research is guided by Kolb's (1984) experiential learning theory, which emphasizes how personal experience and reflection foster both cognitive and emotional engagement. Empirical research supports this framework, demonstrating that students construct meaning through active participation, reflection, and the integration of their experiences (Hulaikah et al., 2020; Pherson-Geyser et al., 2020). These findings underscore the significance of emotional engagement in deepening learning and fostering meaningful connections with complex concepts. Thus, the study explores students' emotional engagement with systems thinking across various demographic factors, such as gender, academic grade, and birth order, by posing the following research questions: (1) Is there a significant difference between male and female students' affective learning of systems thinking? (2) Is there a significant difference in students' affective learning of systems thinking based on their academic grades? (3) Is there a significant difference in affective learning of systems thinking among students of different birth orders? (4) Is students' affective learning of systems thinking correlated with gender, academic grade, and birth order?

While this study offers valuable insights for educational practice and policy, it presents certain limitations, including a sample confined to junior high school students from a single public school in the Philippines, which may limit the generalizability of the findings. Additionally, while the research considers factors such as gender, academic grade, and birth order, it does not account for other influential variables, such as socio-economic status and cultural background. The cross-sectional design also limits the ability to establish causal relationships. Despite these constraints, the study emphasizes the critical role of emotional engagement in systems thinking, illustrating how affective dimensions can deepen interactions with complex concepts. By exploring these aspects within diverse contexts and demographic factors, the study provides important insights that can inform the development of curricula and educational strategies that prioritize emotional engagement and affective development. As the affective aspect of systems thinking is integral to fostering meaningful learning experiences, findings from the study also offer valuable guidance for preparing learners with the critical thinking and problem-solving skills necessary to navigate an increasingly complex world.

METHOD

Research Design

This study used a descriptive survey design to examine the affective aspects of systems thinking, focusing on students' values, emotions, and attitudes toward systems thinking activities. Descriptive research was chosen for its suitability in identifying patterns and relationships (Creswell & Creswell, 2017). Surveys were the primary tool for collecting data on demographic factors such as gender, academic grades, and birth order, as well as for assessing students' systems thinking engagement using a scale. This approach enabled a systematic exploration of how these characteristics influence their engagement.

Research Participants

The participants in this study were 380 junior high school students, aged 12 to 15, from a public high school in Quezon City, Philippines. A voluntary response sampling method was employed, wherein questionnaires were distributed to all class sections, but only students who opted to participate were included. This approach addressed practical constraints such as accessibility, time limitations, and ethical considerations, ensuring voluntary participation. Although this non-probabilistic sampling method can introduce self-selection bias, it enabled efficient data collection from a large sample. To mitigate this bias, a priori power analysis using G*Power, based on a significance level (α) of 0.05, power ($1-\beta$) of 0.80, and medium effect sizes, was conducted to determine the recommended sample size for the statistical analyses required to achieve the research objectives. The calculation indicated a required sample size of 159–290 participants, which informed the minimum sample size for the study. The final sample of 380 exceeded this range, ensuring sufficient statistical power for all analyses. Ethical compliance also further strengthened the validity and reliability of participant selection. Informed consent was obtained from all participants and their parents or guardians, and the study's objectives were clearly communicated, ensuring transparency. These measures upheld ethical research standards and reinforced the voluntary nature of participation.

Research Instrument

The study adapted a survey instrument originally developed by Camelia et al. (2018) based on Frank's Capacity of Engineering Systems Thinking (CEST) inventory. The instrument was simplified and translated into Filipino to suit junior high school students while retaining its original 22 items on a seven-point Likert scale. Three experienced teachers reviewed the adapted version for content validity before pilot testing it on 100 students. The pilot test confirmed strong construct validity, with all items exceeding a critical correlation threshold of 0.1129. Reliability analysis showed a Cronbach's alpha of 0.894, indicating good internal consistency. The finalized Systems Thinking Affective Aspect Survey (STAAS) was used to collect data on students' affective responses, with results analyzed based on the scale's interpretation and values. Table 1 presents the scale interpretation and corresponding values for data analysis.

Table 1
Systems thinking affective aspect assessment scale

Level	Scale Range	Value
Very True of Me	6.0 - 6.9	6
True of Me	5.0 – 5.9	5
Somewhat True of Me	4.0 – 4.9	4
Neutral	3.0 – 3.9	3
Somewhat Untrue of Me	2.0 – 2.9	2
Untrue of Me	1.0 – 1.9	1
Very Untrue of Me	0 – 0.9	0

Data Collection Procedure

The data collection strictly adhered to ethical standards. Approval was obtained from the Schools Division Superintendent and the school principal to comply with institutional protocols. Informed assent and consent were secured from students and their parents, who were provided with detailed information about the study's objectives, procedures, and voluntary participation. They were reminded of their right to withdraw at any time without repercussions. The survey was conducted online with 380 junior high school students from Grades 7 to 9. Clear instructions were given, and the researcher was available to address technical concerns. The procedure ensured transparency, clear communication, and ethical compliance while evaluating students' emotional engagement with systems thinking.

Data Analysis Procedure

Although the affective aspect of systems thinking is ordinal, as assessed using a 7-point Likert scale, the mean scores were treated as interval data in this study. Likert (1932) supported the use of composite scores, and Norman (2010) demonstrated the robustness of parametric methods for such data when sample sizes are large and distributions approximate normality. Given that the sample size in this study is sufficient, the normality of the affective aspect of systems thinking scores was evaluated using the Shapiro-Wilk test, which confirmed that the data were normally distributed (Shapiro-Wilk statistic = 0.995, p = 0.233). This satisfies the assumption of normality required for parametric tests. Normality testing was not conducted for gender, academic grades, or birth order, as gender and birth order are nominal variables, while academic grades are ordinal variables that do not require the assumption of normality. Instead, Levene's test for homogeneity of variances, applied to the affective aspect of systems thinking scores across these demographic factors revealed no significant differences in variances (gender: $F = 1.093$, $p = 0.297$; academic grade: $F = 1.590$, $p = 0.205$; birth order: $F = 1.514$, $p = 0.211$), further supporting the appropriateness of using parametric tests.

With these assumptions met, an independent samples *t*-test was employed to compare male and female students' affective engagement with systems thinking, while a One-Way ANOVA was used to analyze differences based on academic grades and birth order. Meanwhile, the type of variable was considered in selecting the appropriate correlation methods: Point-Biserial Correlation for gender (binary), Spearman's Rank Correlation for academic grade (ordinal), and dummy-coded Point-Biserial Correlation for birth order, treated as a nominal variable due to the inclusion of the 'only child' category, which precludes the formation of a true ordinal relationship. Linearity was not assessed as it is not a required assumption for these methods, given the nature of the variables involved.

FINDINGS

Students' demographic information, including gender, academic grade, and birth order, was used for comparison and to identify relationships with the affective aspect of systems thinking. The following are the results of the statistical analyses conducted to interpret the collected data:

Comparison of Students' Affective Engagement with Systems Thinking by Gender

A two-tailed independent samples t-test compared male and female students' affective engagement with systems thinking. The results (Table 2) show that female students perceive themselves as applying systems thinking to a greater extent than males. Male students had a neutral average score ($M = 3.88$, $SD = 0.868$), while female students showed partial agreement on engagement with systems thinking activities ($M = 4.11$, $SD = 0.833$), with a mean difference of -0.22.

The *t*-test yielded a *t*-value of -2.56 and a *p*-value of .010, indicating a statistically significant difference at the .05 level, with female students scoring higher. The effect size, measured using Cohen's *d*, was 0.27, suggesting a small but meaningful difference. Meanwhile, the low standard deviations for males ($SD = 0.868$) and females ($SD = 0.833$) imply minimal variation within each group, indicating consistent perceptions of systems thinking application among students of the same gender.

Table 2
Independent samples T-test comparing students' affective learning of systems Thinking based on gender (n=380)

Gender	N	M (SD)	*t(df)*	*p*	*Mean Difference*	Effect Size (Cohen's *d)*
Male	175	3.88 (0.868)	$t(378) = -.265$	.010*	-0.22	0.27
Female	205	4.11 (0.833)				

*Note: *p* < .05

Comparison of Students' Affective Engagement with Systems Thinking based on Academic Grades

Meanwhile, to group students based on their academic grades, the Philippines' grading scale as outlined in DepEd Order No. 8, s. 2015 (Department of Education, 2015) was applied. While students' academic performance is categorized into five levels—Outstanding, Very Satisfactory, Satisfactory, Fairly Satisfactory, and Did Not Meet Expectations—the students in this study had average grades ranging from 80 to 95. These students were therefore categorized into three groups: Outstanding (90–100), Very Satisfactory (85–89), and Satisfactory (80–84). A One-Way Analysis of Variance (ANOVA) was then conducted to examine differences in students' affective engagement with systems thinking across these groups.

Results on Table 3 showed that students with Outstanding grades had the highest mean score for affective engagement (M = 4.32, SD = 0.738), reflecting partial agreement with systems thinking application statements. Very Satisfactory students followed with slightly lower scores (M = 4.10, SD = 0.832), while Satisfactory students displayed a more neutral stance (M = 3.72, SD = 0.859). Furthermore, the standard deviations across all groups (below 1) indicate minimal variability within each grade category, suggesting consistent responses among students with similar academic performance. The ANOVA also revealed a statistically significant difference among the groups, $F(2, 377) = 18.37$, $p < .001$, with an eta squared value of 0.09, suggesting a moderate effect size and indicating that academic performance is strongly associated with affective engagement in systems thinking. The significant F-value and low p-value indicate that the differences in affective systems thinking mean scores across academic performance categories are unlikely to have occurred by chance.

Table 3
ANOVA comparing students' affective learning of systems thinking based on Academic grade (n=380)

Grading Scale	N	M (SD)	*F(df* between, *df* within*)*	*p*	*η2*
90-100 (Outstanding)	107	4.32 (0.738)	F(2,377) = 18.37	<.001***	0.09
85-89 (Very Satisfactory)	111	4.10 (0.832)			
80-84 (Satisfactory)	162	3.72 (0.859)			

*Note: ***p* <.001

Given the significant differences in affective engagement with systems thinking among students grouped by academic grades, a Bonferroni Test was conducted for further analysis. Table 4 indicates that students with Satisfactory grades (80–84) had significantly lower engagement compared to those in the Very Satisfactory (85–89) and Outstanding (90–100) groups. The confidence intervals for these comparisons were: Satisfactory vs. Very Satisfactory, -0.5852 to -0.1337; Satisfactory vs. Outstanding, -0.7826 to -0.3261; and Very Satisfactory vs. Outstanding, -0.4431 to 0.0533. These intervals confirm significant differences for the group of students with Satisfactory grades but suggest no significant difference between groups of students with Very Satisfactory and Outstanding grades. This indicates that while lower-performing students differ significantly from higher-performing peers, the distinction between Very Satisfactory and Outstanding learners is minimal.

Table 4
Multiple Comparison of Groups based on Grades (Bonferroni Test)

Group Comparison	Mean Difference	95% Confidence Interval	*p*-value	Significance
80–84 vs. 85–89	-0.375	-0.5852 to -0.1337	< 0.001	**
80–84 vs. 90–100	-0.600	-0.7826 to -0.3261	< 0.001	***
85–89 vs. 90–100	-0.225	-0.4431 to 0.0533	0.106	—

*Note. ***p*** < 0.001 = highly significant; **p** < 0.01 = significant.*

Comparison of Students' Affective Engagement with Systems Thinking Based on Birth Order

The study also explored the relationship between birth order and students' affective engagement with systems thinking. A One-Way ANOVA was conducted to analyze differences in affective engagement across birth order groups. As shown in Table 5, all groups generally shared similar perspectives, with each group agreeing that statements about the application of systems thinking were "somewhat true" of them. Among the groups, only children had the highest mean score (M = 4.08, SD = 0.938), suggesting slightly greater confidence in their ability to apply systems thinking compared to others. Last-born students followed with a mean score of 4.01 (SD = 0.769), while first-born students reported a comparable mean score of 4.00 (SD = 0.866), indicating similar perceptions of systems-based activities between these two groups. Middle-born students had the lowest mean score (M = 3.98, SD = 0.906), reflecting a slightly lower perception of their systems thinking skills. Despite these reported variations, the analysis revealed no significant differences ($F(3,376) = 0.08$, $p = 0.973$, $\eta^2 = 0.0006$), indicating that birth order does not have a significant impact on students' affective engagement with systems thinking.

Table 5
ANOVA comparing Students' Affective Learning of Systems Thinking based on Birth Order (n=380)

Birth Order	N	M (SD)	*F(df* between, *df* within*)*	*p*	*η2*
Only Child	28	4.08 (0.938)			
First Born	129	4.00 (0.866)	F(3,376) = 0.08	.973	0.0006
Middle Born	117	3.98 (0.906)			
Last Born	106	4.01 (0.769)			

*Note: *p < .05*

Relationship of the Affective Aspect of Systems Thinking to Gender, Academic Grade, and Birth Order

Lastly, the study examined the influence of personal and demographic factors, such as gender, academic grade, and birth order, on students' attitudes, beliefs, and values related to the application of systems thinking skills. To investigate these relationships, appropriate correlation methods, including Point-Biserial and Spearman's Rank correlations, were employed to assess the strength and direction of these connections. Table 6 presents the correlations between students' affective dimension of systems thinking and their gender, academic grade, and birth order. The analysis identified a weak but statistically significant positive correlation between gender and the affective dimension (r = .135, p = .008), indicating slight differences based on gender. Similarly, a statistically significant weak positive correlation was also found between academic grade and the affective aspect ($r = .295$, $p < .001$), suggesting that students with higher academic grades tend to exhibit more favorable attitudes, emotional responses, and values toward systems thinking. In contrast, birth order categories (e.g., only child, firstborn, middle born, and last born) showed no significant associations, with correlation coefficients ranging from $r = .005$ to $r = -.011$ and p-values well above .05. These findings highlight that while gender and academic grade may modestly influence the affective aspect of systems thinking, birth order does not appear to play a meaningful role in shaping students' emotional responses to this skill.

Table 6
Correlation of Affective Learning of Systems Thinking to Gender, Academic Grade, and Birth Order (n=380)

Variable (Category)	Correlation Type	Correlation Coefficient	*p-value*
Gender	Point-Biserial	.135**	.008
Academic Grades	Spearman's Rank	.295**	<.001
Birth Order (Only Child)	Point-Biserial	0.23	.661
Birth Order (First Born)	Point-Biserial	0.005	.921
Birth Oder (Middle Born)	Point-Biserial	-.008	.883
Birth Order (Last Born)	Point-Biserial	-.011	.835

Note: Birth order categories are treated as separate groups in point-biserial correlations with systems thinking. $p < .01$** indicates statistical significance at the 0.01 level.

DISCUSSION

The study provides valuable insights into students' affective engagement with systems thinking, focusing on their emotional responses, attitudes, and values toward understanding complex systems. It examines how these aspects relate to gender, academic performance, and birth order. Notably, one of the key findings revealed that female students demonstrated significantly higher emotional responsiveness to systems thinking activities compared to their male peers. This suggests that female students may form a deeper emotional connection to understanding interrelationships within systems, potentially influencing their motivation and approach to systems-based learning. Based on their self-reported assessments, female students demonstrated higher engagement, often avoiding neutral responses, while male students frequently opted for neutral options. This trend aligns with Rose's (2012) findings, which noted that female students typically provide more detailed and reflective self-assessments, whereas male students often respond more reservedly. These differences in response patterns may reflect varying ways in which male and female learners express engagement, view learning experiences, and perceive their roles within educational settings.

However, these gendered tendencies are not static and may evolve as students mature and gain broader educational experiences. Adolescence, as Erikson (1968) emphasizes, is a critical period of identity formation, where cognitive and emotional development intersect with social and academic influences. For students aged 12–18, this stage is particularly crucial, as they begin refining their ability to engage with abstract concepts like systems thinking. During this time, the interplay of emotional sensitivity, motivational dynamics, and emerging cognitive control becomes crucial (Alarcón et al., 2018; Yoon et al., 2023). Steinberg's (2008) Dual Systems Model further explains these patterns, noting that the socio-emotional system, which matures earlier, often drives heightened emotional engagement in early adolescence. Meanwhile, the cognitive control system matures later, gradually enabling students to regulate emotions and engage in complex reasoning. This developmental trajectory helps clarify why younger adolescents show greater gender differences, with these differences diminishing as cognitive maturity progresses. Evidence of this is seen in college students, where minimal gender disparities in systems thinking emerge, likely due to broader exposure to diverse learning environments (Camelia et al., 2018).

These developmental shifts provide valuable context for understanding the engagement patterns observed in junior high school students involved in the study. At this stage, gender differences in emotional responses or confidence toward systems thinking may significantly influence early engagement. However, as students' cognitive and emotional systems mature, coupled with increased academic experience, these differences tend to narrow. Motivational shifts during adolescence, shaped by peer dynamics and the development of cognitive control, also contribute to this process (Somerville, 2013; Steinberg, 2008). This highlights the need to create inclusive and supportive environments that cater to the developmental needs of adolescents. For example, teacher encouragement has been found to significantly boost the confidence and engagement of female students in system-based learning, especially in classrooms with female teachers or peers (Dasgupta et al., 2015; Wang et al., 2023). Likewise, male students thrive in environments that are seen as supportive of their participation (Aguillon et al., 2020). Nevertheless, despite the statistically significant gender differences identified in the study, the small effect size suggests their practical significance is modest, highlighting that although gender is a contributing factor, other influences may play a more substantial role in shaping students' emotional engagement with systems thinking.

Thus, the study also examined students' perceptions of their ability to apply systems thinking in relation to other demographic factors, such as academic performance. The findings revealed a significant influence of academic performance on students' perceptions of their ability to apply systems thinking. This connection is evident in the varying levels of engagement and perceptions among students from different academic categories (Outstanding, Very Satisfactory, and Satisfactory) regarding the execution of systems-based activities. Students with higher grades tended to view their application of systems thinking more positively, while those with lower grades exhibited less confidence in their abilities. This association can be attributed to the interdependence between cognitive abilities and the effective application of systems thinking (Vachliotis et al., 2014). High academic achievers are better equipped to internalize and comprehend information, enabling them to perceive themselves as more capable of employing systems thinking strategies to complete tasks.

As students develop their systems thinking skills and apply them to process information or accomplish tasks, their confidence in these abilities increases. Successfully navigating complex tasks, such as systems-based activities, not only strengthens their skills but also enhances their sense of competence and self-efficacy. This growing confidence positively influences their emotions, motivation, and engagement in systems thinking activities, fostering both personal and academic growth. This dynamic can also be explained through the expectancy-value theory, which posits that students' motivation and engagement are shaped by their expectations of success and the value they assign to tasks (Wigfield & Eccles, 2000). Students with higher academic performance are more likely to perceive systems thinking as valuable and anticipate positive outcomes from its application, which reinforces their confidence and engagement. Furthermore, significant differences among students with varying academic performances are also often linked to deeper task engagement, which is driven by intrinsic motivation. According to Deci and Ryan's (2000) self-determination theory, intrinsic motivation arises from the fulfillment of autonomy, competence, and relatedness. These elements can be cultivated through student engagement in complex activities, which strengthen their ability to analyze, synthesize, and understand information (Barlow et al., 2020; Xie & Kuo, 2021). While sustained engagement may benefit all learners, students with higher academic performance are often better positioned to excel in systems-based tasks, thereby boosting their confidence and perception of their ability to apply systems thinking. In contrast, students with lower academic performance may face greater challenges in achieving similar outcomes.

Considering these findings, the observed connections and differences among students with varying levels of academic performance underscore the significant interplay between cognitive and affective dimensions, which should be regarded as essential in designing effective classroom lesson plans and activities. In fact, numerous studies have already emphasized the need to consider and integrate both dimensions, highlighting their critical role in improving learning outcomes. (Agnoli et al., 2023; Eichler & Gradwohl, 2021; Kustyarini, 2020; Li et al., 2023; Loon & Bell, 2018). While cognitive factors are well-documented, affective aspects, such as motivation, confidence, and self-perception, remain underexplored (Getie, 2020; Trujillo & Tanner, 2014). The current study contributes to this gap by further highlighting the critical role of affective engagement in shaping students' application of skills, such as systems thinking, in real-world tasks. As the findings suggest, academic performance, influenced by both cognitive and affective factors, shapes how students emotionally engage with applying systems thinking. This aligns with Richmond’s (1993) work, which emphasizes that cognitive processes, along with affective factors, are essential for fostering systems thinking skills. This understanding can be applied to the design of lessons and learning materials, ensuring they effectively integrate affective engagement alongside cognitive processes to foster deeper learning and enhance problem-solving abilities.

Lastly, the present study also explored the connection between birth order and the affective aspect of systems thinking. The findings reveal that students across different birth-order groups generally share similar perspectives on activities involving systems thinking skills, suggesting that birth order does not significantly impact students’ confidence or attitudes toward systems thinking. Nevertheless, a slight difference was still observed, with ‘only children’ reporting the highest self-ratings regarding their systems thinking abilities. This could be attributed to receiving greater individual attention from parents or developing a strong sense of independence in learning (Cerino, 2023; Susiani et al., 2022). Similarly, Lehmann et al. (2018) observed that ‘only children’ and ‘firstborns’ often benefit from increased parental attention and resources, fostering independence and enhancing their confidence in applying systems thinking skills. Meanwhile, 'middle-born' students were reported to exhibit lower engagement and self-perception (Aloka, 2023; Fukuya et al., 2021), a finding consistent with the present study regarding affective engagement with systems thinking skills. This tendency may have stemmed from their inclination to compare themselves with their siblings or adopt a more reserved self-assessment. In contrast, Largado et al. (2024) offered an alternative perspective, suggesting that 'firstborns' and 'middle-borns' receive more parental attention than 'only children', fostering greater confidence and emotional stability. Their findings also highlighted that only children may experience heightened anxiety, which could undermine their confidence in systems thinking. On the other hand, students who are born last in their family may often interact with older siblings, providing opportunities to develop emotional regulation and conflict resolution skills, thereby enhancing their affective learning processes (Howe & Recchia, 2006). This might explain why 'last-born' students showed high affective engagement with systems thinking in the study.

It can be surmised from the findings of the present study and relevant literature that there are differing patterns of engagement across birth-order groups, which may have been influenced by the interplay of various contextual factors. This notion is supported by Luo et al. (2022), who emphasized that the impact of birth order on skill development, including systems thinking, varies across ecological contexts. Variations in parental involvement and sibling dynamics, which are often linked to birth order and, consequently, to skill development and engagement, may be shaped by factors such as family dynamics, socio-economic conditions, and cultural expectations. For instance, Tause (2024) highlighted the critical role of supportive family environments, characterized by warmth and responsiveness, in fostering student engagement and motivation. Family dynamics, influenced by the number and birth order of siblings, likely affect affective engagement with systems thinking through collaborative and reflective interactions within the family. Additionally, socio-economic status, often tied to family size and birth order, may also influence students' emotional well-being and engagement. Students from lower socio-economic backgrounds often face heightened emotional challenges, such as increased anxiety and depression (Hermawan, 2023; Li et al., 2020), which may affect their affective engagement with learning, including those related to systems thinking applications. Cultural expectations and societal norms may also further shape the relationship between birth order and affective engagement with systems thinking. Riquelme et al. (2024) noted that cultural diversity significantly impacts students' emotional dynamics, influencing their motivation and engagement. Societal expectations surrounding individuals of different birth orders vary across cultures, potentially affecting attitudes toward systems thinking. In fact, students who feel culturally validated are more likely to engage both emotionally and cognitively in learning processes (Anyichie & Butler, 2023; Suardana et al., 2018). Such insights underscore the importance of recognizing contextual factors in fostering positive affective skills, as these elements are crucial for promoting meaningful engagement with systems thinking.

In essence, the findings of the study highlight the importance of considering gender and academic performance in developing systems thinking skills. Gender-sensitive and responsive teaching approaches that address emotional aspects can create inclusive environments and materials, engaging students emotionally while effectively leveraging their strengths. Recognizing gender disparities and the diverse emotional responses associated with them enables educators to bridge engagement gaps, fostering both cognitive and affective involvement. This understanding can guide educators in creating more collaborative and equitable learning experiences that cater to the unique needs and emotional dynamics of all students. Additionally, recognizing how academic performance shapes emotional engagement is crucial. Implementing educational strategies and materials that cater to all students, regardless of academic standing, while integrating opportunities for problem-solving and fostering self-efficacy, is essential for encouraging meaningful engagement with systems-based activities. While birth order was not found to significantly influence students' engagement with systems-based activities, addressing factors such as family dynamics, socio-economic status, and culture is crucial for fostering equitable and inclusive learning environments. Tailored support and resources can help all students, regardless of background, develop the cognitive and affective skills essential for systems thinking. In an era of complex challenges, educators must provide scaffolded guidance and design activities that engage students both cognitively and emotionally. By understanding the diverse factors shaping students' emotional responses and self-perceptions, teachers can implement targeted strategies to nurture systems thinking across diverse learner groups.

CONCLUSIONS AND RECOMMENDATIONS

This study explored student differences to identify factors influencing systems thinking development. Significant variations were observed between male and female students, as well as among students with differing academic performance levels. Gender differences were evident in how students approached systems thinking, reflecting varying priorities and interests, particularly in engaging with system components. High-performing students exhibited greater confidence in applying systems thinking compared to their peers, suggesting a link between academic performance and self-perception of these abilities. Although no significant differences were found based on birth order, future research could investigate its subtler effects by considering factors such as family dynamics, socio-economic status, and cultural influences that may shape emotional engagement in systems thinking tasks.

Addressing these differences through targeted interventions can enhance systems thinking instruction. For instance, collaborative learning could help reduce gender disparities by fostering emotional engagement and inclusivity, encouraging all students to participate actively in team-based problem-solving. Similarly, problem-solving tasks could be tailored to build confidence in students with lower academic performance by providing scaffolding or offering incremental challenges. Real-world examples aligned with students' interests and prior experiences may further engage students across genders and performance levels. To implement these strategies effectively, professional development programs should equip educators with tools and techniques to adapt systems thinking instruction to diverse student needs. Future research should expand to include broader participant bases and diverse school settings to validate these approaches and explore how instructional strategies can address nuanced factors like self-perception and family dynamics. By refining teaching practices, educators can cultivate systems thinking skills that enhance critical thinking and problem-solving, empowering students to address real-world challenges and contribute to a sustainable future.

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