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Functional Thinking and Self-Esteem: What Mistakes Do Students Make in Solving Growth Patterns and How Do These Mistakes Occur?

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There is an urgent need to undertake research on identifying the types and patterns of students' functional thinking errors with regard to their self-esteem levels. Functional thinking impacts students' learning success in understanding the concept of function, which is a complex aspect of mathematics that requires appropriate approaches and strategies to help students achieve mastery. The present study aims to analyse the types and patterns of functional thinking errors among students with different levels of self-esteem in solving growth pattern problems. Newman's error analysis was used to analyse students' errors in functional thinking. The study uses a qualitative descriptive design supported by quantitative categorisation of self-esteem levels, involving two research subjects selected from 34 eleventh-grade high school students with diverse backgrounds, genders and levels of academic ability. A task designed to elicit functional thinking skills was developed as a research instrument. Students who answered incorrectly were then grouped based on similar levels of self-esteem and error patterns. In order to clarify the errors made in solving the growth pattern task, one representative was selected to be interviewed from the group with low self-esteem and one from the group with high self-esteem. By integrating functional thinking, Newman's error analysis and affective aspects, the research determined differences in errors between high self-esteem and low self-esteem students. Self-confidence, self-regulation and anxiety are all factors that influence student errors. The findings emphasise the importance of learning that balances cognitive and affective aspects.

Keywords: Newman's error analysis, functional thinking, self-esteem, growth pattern

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Funkcionalno mišljenje in samozavest: katere napake delajo učenci pri reševanju problemov z rastočimi vzorci in kako pride do teh napak?

Suci Yuniati, Nunuk Suryanti in Suparjono

Obstaja nujna potreba po raziskavi, ki bi opredelila vrste in vzorce napak v funkcionalnem mišljenju učencev v povezavi z njihovimi ravnmi samozavesti. Funkcionalno mišljenje vpliva na uspešno učenje pri učencih, kar zadeva razumevanje pojma funkcije, ki je zapleten matematični vidik in ki zahteva ustrezne pristope pa tudi strategije, da bi učencem pomagali doseči obvladovanje te snovi. Namen te študije je analizirati vrste in vzorce napak v funkcionalnem mišljenju med učenci z različnimi ravnmi samozavesti pri reševanju problemov z rastočimi vzorci. Za analizo napak v funkcionalnem mišljenju učencev je bila uporabljena Newmanova analiza napak. Študija uporablja kvalitativno deskriptivno zasnovo, podprto s kvantitativno kategorizacijo ravni samozavesti, v katero sta vključena dva sodelujoča v raziskavi, izbrana med 34 dijaki drugega letnika srednje šole, ki se razlikujeta v ozadju, spolu in v ravni akademskih zmožnosti. Kot raziskovalni instrument je bila razvita naloga oziroma problem, zasnovan za ugotavljanje zmožnosti funkcionalnega mišljenja. Učence, ki so podali napačno rešitev, smo nato razvrstili v skupine na podlagi podobnih ravni samozavesti in vzorcev napak. Da bi razjasnili napake, ki so se pojavile pri reševanju problema z rastočimi vzorci, je bil za intervju izbran po en predstavnik iz skupine z nižjo ravnjo samozavesti in skupine z višjo ravnjo samozavesti. Z združitvijo funkcionalnega mišljenja, Newmanove analize napak in afektivnih vidikov je raziskava opredelila razlike v napakah med učenci z višjimi in nižjimi ravnmi samozavesti. Samozavest, samoregulacija in tesnoba so dejavniki, ki vplivajo na napake učencev. Ugotovitve poudarjajo pomembnost učenja, ki uravnoteženo združuje kognitivne in afektivne vidike.

Ključne besede: Newmanova analiza napak, funkcionalno mišljenje, samozavest, rastoči vzorec

Introduction

Functional thinking plays a crucial role in mathematics education because it provides the foundation for students to understand the relationships between quantities and connect various mathematical representations, which is essential for twenty-first-century learning. From the perspective of representation theory and the development of algebraic reasoning, functional thinking enables an epistemological transition from arithmetic thinking to more abstract structural understanding, and is therefore a prerequisite for mastering advanced concepts such as function models, calculus, data analysis and mathematical modelling (Sun et al., 2023; Levin & Walkoe, 2022; Yuniati et al., 2022). Functional thinking is an important aspect of mathematics learning in schools and universities (Morales & Parra, 2022; Yuniati et al., 2022). However, current challenges indicate that many students still have a limited understanding of functions, experience difficulty connecting representations, and tend to focus on symbolic manipulation (Trujillo et al., 2023; Ayeh, 2025). Furthermore, instructional practices and teacher preparedness do not fully support the development of relational understanding (Oliveira et al., 2021; Morales & Parra, 2022).

Many experts in the field of mathematics education have conducted research on functional thinking through growth patterns. Research has also focused on developing and designing mathematics learning and assignments to improve students' functional thinking (Pang et al., 2022; Pang & Sunwoo, 2022; Deng et al., 2025). This development is part of a comprehensive effort to coordinate curriculum, instruction, assessment and analysis of student learning. This work contributes to the accumulation of empirical evidence regarding the ability of primary school students to think and reason mathematically at a more sophisticated level, particularly when they receive consistent, structured and continuous learning experiences in mathematics instruction. Primary school teacher candidates in Spain and Portugal use different strategies in generalising functional relationships, applying local approaches to interpreting relationships between variables. However, they express difficulties in understanding and connecting different functional representations, indicating a lack of knowledge of functional thinking (Oliveira et al., 2021). Morales and Parra (2022) found that prospective primary school teachers employ a variety of strategies to complete functional thinking tasks, ranging from arithmetic strategies to functional strategies, although their study does not analyse the representation systems used in completing tasks. Other researchers have found that verbal and symbolic representations are utilised in solving functional thinking tasks. Based on the APOS (action, process, object and schema) theory, students' functional thinking processes have been identified as comprising three abilities: partial functional thinking, semi-compositional thinking and compositional thinking (Yuniati et al., 2022). A study by Yuniati et al. (2022) found that the majority of students made errors in completing functional thinking questions, with 28 of the 48 students tested having incorrect answers.

Previous research has focused on development and assessment, while error diagnosis remains underexplored. One tool that can be used to diagnose student errors in solving mathematical problems is Newman's error analysis (NEA) (Sundayana et al., 2023; Astuik & Purwasih, 2023; Kurniati et al., 2021). NEA is considered very appropriate for identifying errors in functional thinking because it provides a systematic framework that traces the cognitive stages in the mathematical problem-solving process. As well as indicating students' incorrect answers, NEA identifies why errors occur and at what cognitive phase obstacles arise. This is very relevant to functional thinking, as students often make errors not because they are unable to calculate, but because they fail to understand the relationship between variables, to generalise patterns or to interpret function representations. According to Dewantara et al. (2024), NEA is an appropriate approach to examining errors in written problems, including story problems and context-based problems. Many researchers use NEA in analysing students' errors in various mathematical concepts, such as geometry concepts (Chiphambo & Mtsi, 2021), word problems (Capane et al., 2021), sets (Noutsara et al., 2021), integral calculus (Angco, 2021) and algebra (Makamure & Jojo, 2022; Msomi & Bansilal, 2022; Thomas & Mahmud, 2021). NEA has also been used in several error analysis studies related to various aspects of students' mathematical abilities, such as mathematical reasoning (Saleh et al., 2022). Thus, NEA is believed to be an effective way to diagnose students' errors in solving mathematical problems. According to Sari et al. (2023), NEA analysis results can help teachers to design and improve the learning process, to select learning methods and strategies, and to minimise student error rates. Student errors in various concepts are also influenced by students' mathematical thinking habits and are suspected to involve affective behaviour.

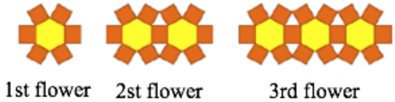
According to Shimizu (2025), students' affective aspects interact dynamically with mathematical reasoning during the problem-solving process, thus directly determining students' success or failure in representing problem situations in mathematical form. Self-esteem is an affective construct that has substantive implications for the emergence of conceptual errors in mathematics learning. Servidio (2023) and Celik et al. (2023) found that self-esteem can make students more confident and motivated, as well as more resilient in dealing with failure. When students have a high level of confidence and a positive self-concept, they tend to behave well in learning situations, leading to improvements in academic achievement (Steinberg et al., 2024; Sainz et al., 2025; Gashlan, 2025). On the other hand, Granello et al. (2025) stated that students' beliefs about mathematics, especially those related to self-efficacy and self-concept, significantly influence the level of student engagement in the learning process and academic achievement. In addition, interventions that focus on strengthening self-efficacy and self-concept have an important role in improving the learning engagement and mathematics learning outcomes of secondary school students.

The present study provides a new contribution by integrating affective (self-esteem) and cognitive (functional thinking and NEA error types) aspects to explore how self-esteem levels influence students' error patterns in solving growth pattern problems. The findings expand the study of the role of affective factors in mathematical reasoning, particularly in the context of functional thinking.

Functional Thinking and Growth Patterns

Functional thinking is the process of describing and generalising about functional material (Yuniati et al., 2022). It involves reasoning about the relationship between two or more varying quantities (Gunster & Weiggand, 2020; Frey et al., 2022; Morales & Parra, 2022). According to Pitta-Pantazi et al. (2020), functional thinking is the process of generalising relationships between varying quantities, reasoning about these relationships, and representing them using words, algebraic symbols, tables and graphs. Pittalis (2023) also defines functional thinking as referring to the understanding of relationships between varying quantities, a concept known as correspondence. Pittalis et al. (2025) provide an example of a functional thinking problem, called "daisy flower growth", which concerns the relationship between the number of flowers and the number of flower petals. The type of function that can be formed is $y = 5x + 1$, where x = number of flowers and y = number of flower petals (Figure 1).

Figure 1
Example of a functional thinking question



Functional thinking can therefore be described as the relationship between two or more quantities that can be generalised into a functional formula based on examples of functional thinking problems. The functional thinking framework consists of: 1) recursive patterns, 2) covariational relationships, and 3) correspondence. The framework is adopted from Morales and Parra (2022), Pittalis et al. (2025), Martins et al. (2023) and Deng et al. (2025). In this instance, a recursive pattern is a method used to identify a number's pattern (Morales & Parra, 2022). Covariational relationships are a thought process that connects two or more quantities (e.g., when x increases by 1, y increases by 5) (Morales & Parra, 2022). Correspondence is a thought process that generalises the relationship between quantities (e.g., y is 5 times x plus 1 or y = 5x + 1). Growth patterns are one of the resources that can be utilised to enhance students' functional thinking. This is in line with the finding that growth patterns can be used as a tool to understand and explore the concept of function (Yuniati et al., 2022; Morales & Parra, 2022; Pang & Sunwoo, 2022; Utami et al., 2023). According to Pittalis et al. (2025), students can gain a conceptual grasp of functional thinking in a new setting by visualising and extrapolating geometric growth patterns, thus providing a solid basis for students to learn mathematics successfully.

NEA

Teachers can utilise the NEA approach to identify students who struggle with mathematics issues, resulting in incorrect answer sheets (Dewantara et al., 2024; Sari et al., 2023). NEA has five rules for analysing types of errors: 1) at the reading stage, students can read questions, symbols and mathematical notation correctly; 2) at the comprehension stage, students are able to explain what they know and what the problem asks, i.e., they comprehend the problem; 3) at the transformation stage, students can develop and explain the formulas and calculations needed to solve the problem; 4) at the process skills stage, students can accurately perform mathematical operations or calculations; and 5) at the encoding stage, students are able to accurately articulate the problem's solution (Sari et al., 2023). The results of NEA have several benefits for teachers: 1) grouping student errors into several error categories, 2) detecting the causes of student errors in solving problems, 3) designing effective interventions, 4) developing learning tools and compiling questions according to student abilities, and 5) providing evaluation tools for measuring classroom learning (Sundayana et al., 2023; Astuik & Purwasih, 2023).

Self-Esteem

Adolescence is a crucial time in determining how self-esteem develops. A person's perception of themselves and the world around them is greatly influenced by their level of self-esteem. Self-esteem is a person's implicit, largely permanent and self-accepted evaluation of themselves, as demonstrated by their actions and attitudes of self-respect awareness (Servidio, 2023; Celik et al., 2023). Self-esteem can influence several aspects of human behaviour, including achieving good performance in school (Knisfsend et al., 2020). It is believed that students who have a high level of self-esteem: 1) have high self-confidence, 2) are able to control stress, 3) can easily interact with the surrounding environment, 4) are motivated in achieving life goals, 5) have a strong fighting spirit, and 6) are motivated to continue to progress (Sakarneh, 2023; Vaughan-Johnston et al., 2020; Isabelle et al., 2021).

Integration of Functional Thinking, NEA and Self-Esteem

Functions are an important topic in the Indonesian mathematics curriculum. Understanding the concept of functions helps students to learn advanced mathematics, such as algebra, calculus and statistics. Furthermore, the concept of functions fosters analytical, reasoning and problem-solving skills, particularly in reading graphs, understanding change and modelling various phenomena. This ability is known as functional thinking, which is the cognitive ability to understand and represent the relationship between two or more variables (Morales & Parra, 2022; Deng et al., 2025). However, many students experience difficulties in solving functional thinking problems. One tool that can be used to diagnose student errors is NEA (Dewantara et al., 2024; Sari et al., 2023), which helps identify specific stages of error experienced by students, such as difficulty recognising number patterns, understanding covariance relationships and generalising function forms. In addition to cognitive factors, affective aspects also influence student success in solving problems. One of the most important affective aspects is self-esteem, which plays a role in shaping students' self-confidence, persistence and self-regulation when facing mathematical tasks that require high-level reasoning (Servidio, 2023). Students with high self-esteem tend to be better able to monitor their understanding, to persist when experiencing difficulties and to correct errors, resulting in relatively fewer NEA errors. Conversely, students with low self-esteem are more prone to anxiety and self-doubt, which can increase NEA errors and hinder the development of functional thinking.

Research Questions

The present study aims to analyse the types and patterns of functional thinking errors among students with different levels of self-esteem in solving growth pattern problems. The following research questions are addressed:

1. What types of errors in functional thinking do students make due to their level of self-esteem when solving problems involving growth patterns?
2. What factors contribute to these errors?

Method

Participants

The present study involved 34 eleventh-grade high school students in Riau, Indonesia. In order to measure their self-esteem, the students answered a Likert-based questionnaire with 30 questions structured around self-esteem indicators. Based on their assessed level of self-esteem, the students were divided into three groups, as shown in Table 1.

Table 1
Student self-esteem data

Score	Description	Number of Students
30–60	Low	5
61–90	Moderate	23
91–120	High	6
Total		**34**

Table 1 shows that most of the students (23) who answered the questionnaire had a moderate level of self-esteem. In order to observe significant differences, only the students with high and low self-esteem were considered as candidates for the interviews that formed part of the study. The final interview participants were selected through purposive sampling (Okoko et al., 2023) based on self-esteem classifications and teacher recommendations in order to ensure a diversity of affective profiles and cognitive representations. The study was exploratory and illustrative in nature, so only two students were interviewed. Based on the grouping results and the teacher's considerations, one student with high self-esteem (HSE) and one student with low self-esteem (LSE) were selected as interview subjects. The types and patterns of student errors in functional thinking were then explored.

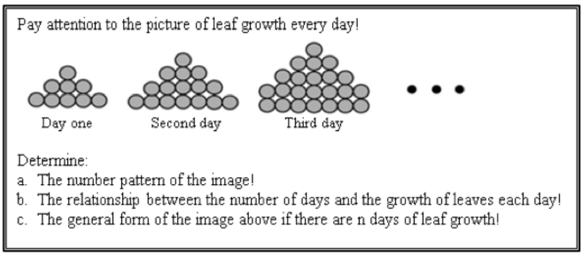
Instruments and Measures

The instruments used were 1) a questionnaire, 2) a written test, 3) an interview guide, 4) a recording device, and 5) field notes. The questionnaire, interview guide and test instruments were validated by three validators (two mathematics education lecturers and one high school mathematics teacher). The validity level was regarded as adequate if all of the validators agreed that the instruments could be used in the research (data collection).

In order to identify student errors in solving growth pattern problems, a test was administered with test questions adapted from Pittalis et al. (2025). The test was designed using a functional thinking framework and consisted of a single question in the form of a description. A test sheet was given to all of the students. After the students completed the test, which took 45 minutes, interviews were conducted with the two selected students to investigate whether the student errors needed to be clarified. Figure 2 shows the test that was administered to the students.

Figure 2

Functional thinking questions



Interview guidelines were developed based on the stages of functional thinking (Morales & Parra, 2022) and the types of student errors. Field notes were used to record important observations that support the main data, and recording tools were used to record the interview process so that no important data was missed. Table 2 lists these phases and the categories of student mistakes.

Table 2

Stages of functional thinking (FT), types of student errors and interview guidelines

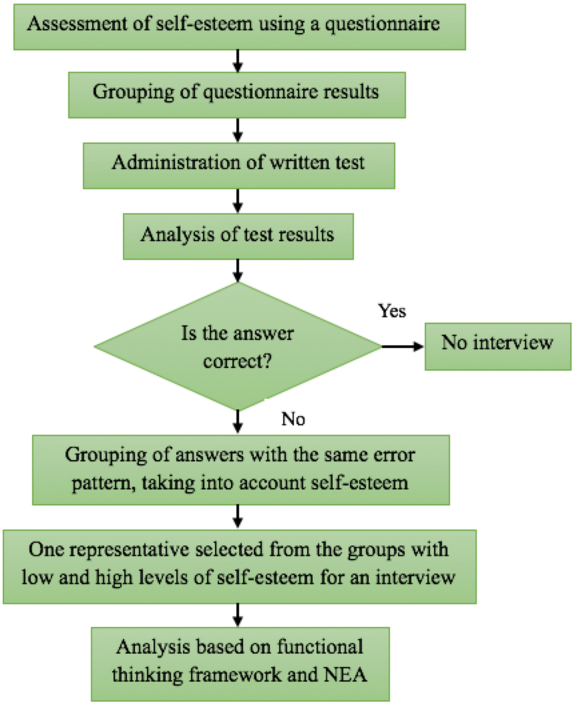
Stage of FT	Description	Interview Guidelines
Recursive Pattern	Students are able to identify number patterns	Can you explain again what the problem in the question is about? (NRr) Can you mention what information you know from the question? (NRc) Can you explain how you determined the pattern from the problem above? (FT)
Covariational Relationship	Students are able to identify the relationship between variables	Based on the image in the question, please describe and show me how the values of x and y change in relation to each other. (FT) (NRr) (NRc)
Correspondence	Students are able to generalise or determine a general formula	What is the general formula for the problem? (FT) Please describe and show how you arrived at that answer. (NRr) (NRc) (NRt) (NRp) What is your conclusion regarding the problem? (NRe)

Key (table 2):
NRr: Newman error reading
NRc: Newman error comprehension
NRt: Newman error transformation
NRp: Newman error process skill
NRe: Newman error Encoding

During data collection, the researchers used a recording device to capture the students' facial expressions while taking the test and during the interviews. Field notes were also taken to record important points. The selection of interview subjects is shown in Diagram 1.

Diagram 1

Selection of interview subjects

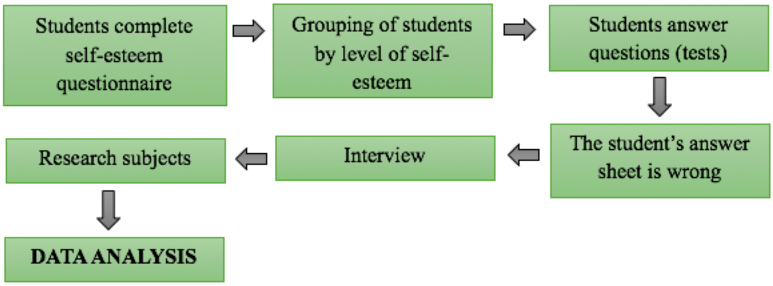


Research Design

The study employed a qualitative descriptive design (Tisdell et al., 2025), supported by quantitative categorisation of self-esteem levels to guide qualitative data selection. This design aimed to provide an in-depth description of the students' errors in functional thinking based on NEA, which examines their self-esteem levels. The study began by administering a self-esteem questionnaire to all of the students in order to categorise them into high, medium and low self-esteem categories. Next, the students were given problem-solving tasks designed to explore their functional thinking abilities. The students who answered correctly played no further part in the study, while those who answered incorrectly were analysed using the NEA stages and grouped based on similar error types and patterns. One representative from the LSE group and one form the HSE groups were selected for interviewing. The goal was to obtain more in-depth information about the students thinking processes when solving problems. The interviews followed the interview guidelines outlined in Table 2 and were conducted in Indonesian outside of class hours. Data analysis was then conducted, adapting the framework of Tisdell et al., (2025). The first stage involved preparing the data for analysis, which included transcribing the interviews, correcting the student answer sheets, processing the questionnaires, grouping the data according to their characteristics and undertaking data reduction. Data reduction involved selection, focusing on relevant information, discarding unnecessary data, and organising the raw data to make it more structured and meaningful. The second stage involved reading all of the data to develop a general understanding of the information obtained, as well as recording key ideas and initial reflections on the meaning of the data. In the third stage, in-depth data analysis was performed through a coding or categorisation process to facilitate interpretation, simplify problems, and clarify the types and kinds of errors made by the research subjects. In this stage, written or visual data were grouped into specific categories and labelled with concepts. The fourth stage involved describing the types and kinds of errors made by the students in functional thinking based on the categorisation results. In the final stage, conclusions were drawn from the analysis results. Triangulation was implemented by integrating the questionnaires, the student response sheets and the interview reflections. Checking and clarification was also performed during follow-up interviews in order to verify the students' intent. This research procedure is outlined in the Diagram 2.

Diagram 2

Research procedure



Results

The correct answer to part a) of the picture test shown in Figure 2 above is the number pattern 9, 16, 23, 30… and so on. The corresponding function table can be seen in Table 3.

Table 3
Recursive pattern

Day	Leaf growth
1	9
2	16
3	23
⋮	⋮
n	…

+ 7
+ 7
+ 7
+ 7

From the perspective of the recursive pattern, an addition of 7 or +7 is obtained. The correct answer to part b) of the picture test regarding the covariational relationship is that for every additional 1 day, there is an addition of 7 leaves. The function table can be seen in Table 4.

Table 4
Covariational relationship

Day	Leaf growth
1	9
2	16
3	23
⋮	⋮
n	…

+ 1, + 1, + 1, + 1
+ 7, + 7, + 7, + 7

Part c) of the picture test concerns correspondence, i.e., generalising the explicit relationship between daily additions and leaf additions, the general formula being $U_n = 7n + 2$.

After grouping the respondents based on their self-esteem levels and administering the test, the students with incorrect answer sheets were analysed. In order to identify significant differences, the researchers selected only two students for analysis: one from the HSE group, representing students with high self-esteem, and one from the LSE group, representing students with low self-esteem. These students were selected as representatives because they demonstrated adequate communication skills and were willing to spend time in the interviews. The interviews were conducted in Indonesian outside of class hours. The results of the interviews with the two students are shown in Table 5.

Table 5

Summary of research results

Student	FT Components	Student responses in interviews	Newman's error types
HSE	Recursive pattern	*"I'm trying to find the result of the number pattern in the image. The first day has 9 and the second day has 16, so 16 minus 9 equals +7. Combine the first, second and third days and subtract them."*	NRc
	Covariational relationship	*"The relationship between the leaves and the number of days is that the difference in leaves per day is influenced by the calculation pattern and the multiplication of the days per day. This pattern is multiplied by the next number to obtain the result."*	NRc
	Correspondence	*"I know the formula $U_n = U_1 + (n - 1)b$, where the difference between the first, second and third days is +7, and it can be applied using the existing formula. However, I don't understand how to apply it, so I can't find the general formula."*	NRc, NRt, NRp, NRe
LSE	Recursive pattern	*"I see the number pattern in the picture is triangular because the picture in the problem is triangular."*	NRr, NRc
	Covariational relationship	*"On the first day there were 9 leaves and on the second day there were 18 leaves because 9 times 2 is 18."*	NRr, NRc
	Correspondence	*"I saw a picture in the shape of a triangle. The formula used is the formula for the area of a triangle L = ½ x a x t."*	NRr, NRc, NRt, NRp, NRe

With the aid of the student responses in the interviews, as shown in Table 5, the students' errors in functional thinking based on self-esteem in solving growth pattern problems can be investigated more deeply. Documentation of the students working on questions and interviews is shown in the Figure 3.

Figure 3

Documentation of students working on questions and interviews

Discussion

The types and patterns of student errors indicate clear differences between the two groups of research subjects (HSE and LSE) in solving growth pattern problems. The HSE students made errors at the comprehension stage (NRc) when identifying patterns and determining covariational relationships, while at the generalisation stage of covariational relationships, they experienced errors in comprehension (NRc), transformation (NRt), process skills (NRp) and coding (NRe). This indicates that the students with HSE were able to maintain fluency in recognising and finding patterns, although they ultimately experienced errors in determining covariational relationships and generalising functional forms. The HSE students had limited errors and the obstacles they encountered were not significant enough to disrupt their ability to think functionally. In contrast, the LSE students showed errors that spanned all stages of the NEA. This indicates that their functional thinking processes were disrupted from the initial stage, from reading the information to constructing solutions. Instability in basic processing will impact difficulties in the functional thinking process. As a result, the LSE students experienced overall failure.

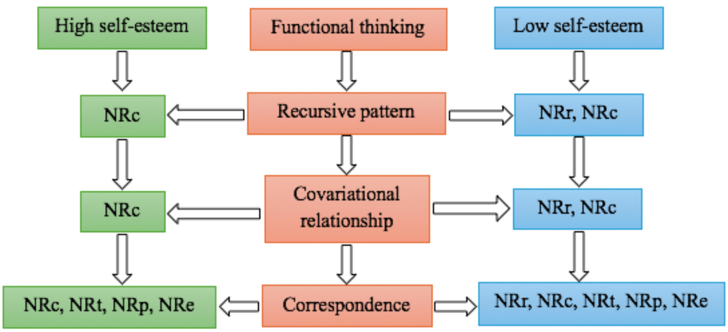
HSE students tend to make fewer cognitive errors because they have better self-regulation and metacognitive skills. During the learning process, HSE students are more confident in reviewing steps or work processes and correcting their answers. According to Acosta-Gonzaga (2023), HSE students are more capable of completing assignments and are more active in the learning process, as well as being quicker to recognise errors. Students' problem-solving skills are positively correlated with academic success and self-esteem. In other words, students will perform better academically if they have high self-esteem. This is supported by the research of Steinberg et al. (2024), who found that self-esteem significantly influences students' academic achievement. Since they are better at solving problems, students with high self-esteem tend to make fewer errors. Moreover, research has shown that students who are able to regulate their thinking and have self-confidence are more proficient at finding and correcting errors early (Halmo et al., 2024; Granello et al., 2025; Shimizu, 2025). Furthermore, students who are able to process their thoughts effectively will become more confident and more careful in cognitive decision-making (Kleka et al., 2024). Therefore, students with good self-regulation, accurate metacognition and stable self-beliefs will be more able to prevent, detect and correct errors before they become serious.

LSE students tend to exhibit a high frequency of fundamental errors in reading and comprehending texts due to the mutually reinforcing interaction between affective and cognitive factors. Affectively, LSE students experience anxiety when reading questions and have doubts about their own abilities. According to Chung et al. (2024), students with negative perceptions of their own abilities process textual information with a lower degree of accuracy. Furthermore, Dodur and Ceylan (2025) suggest that negative emotions can disrupt motivational mechanisms and ultimately decrease comprehension accuracy. Cognitively, anxiety arising from low self-esteem contributes to increased cognitive load and reduced capacity of working memory, which is necessary for decoding words, integrating meaning and establishing global coherence in texts (Shimizu, 2025). This imbalanced cognitive load makes students more susceptible to basic errors, such as misreading terms, failing to grasp relationships between sentences or misinterpreting the intent of instructions. In addition, LSE students are typically more easily influenced by their surroundings and more frequently experience negative feelings such as inferiority, anxiety and low self-confidence (Sakarneh, 2023). Therefore, students who feel less academically capable, are prone to anxiety when reading and have limited thinking skills are more likely to make basic errors when reading and understanding questions.

The present research findings indicate differences in errors between HSE and LSE students when combining functional thinking, NEA and affective aspects. In functional thinking, self-confidence influences the ability of students to determine number patterns, understand covariational relationships and generalise functional forms. HSE students are generally more confident, self-regulated and accustomed to double-checking their work, so errors typically occur during the process or answer-writing stage. In contrast, LSE students more often make errors early on, such as misreading and misunderstand questions, because anxiety and doubt interfere with their concentration and understanding. Judging from the NEA, students' emotional states influence the stage at which errors begin to appear. Positive attitudes and feelings help students to think in a more focused way, to work diligently and to double-check their answers. Conversely, students experiencing negative emotional states easily lose concentration and are less accurate in understanding functional thinking questions. This indicates that functional thinking ability is not only determined by knowledge, but also by students' emotional readiness and self-confidence. In terms of learning, the results of the present study emphasise the importance of developing cognitive and affective abilities simultaneously. Teachers need to create a comfortable and supportive learning environment, use NEA to identify the types of student errors, and present functional learning material in stages with various representations. Furthermore, strategies such as think-aloud, error reflection and self-examination need to be implemented, especially for students with low self-esteem, in order to increase awareness and monitoring of their thinking processes. This approach can help strengthen understanding of functional learning while reducing student errors. The student errors in functional thinking based on self-esteem presented above in Table 5 are shown in Diagram 3.

Diagram 3

Integration of functional thinking, NEA and self-esteem



Conclusion

The present study indicates differences in error types between HSE and LSE students in solving functional thinking problems related to growth patterns. These differences are explained through the integration of functional thinking, NEA and affective states, where students' affective states influence the emergence of errors in the problem-solving process. The study can enrich theoretical understanding of the relationship between cognitive and affective aspects by showing that self-esteem plays a role in influencing the quality of functional thinking processes. Furthermore, the findings confirm that cognitive abilities do not stand alone but interact with affective aspects such as self-confidence, anxiety and self-regulation. The limitations of the study include the limited number of research subjects, which makes it difficult to generalise the findings. Future research should involve a more diverse sample and examine learning interventions specifically focused on strengthening the affective and metacognitive aspects of functional thinking. Pedagogically, the findings emphasise the importance of learning that balances cognitive and affective aspects. Teachers are advised to use NEA as a tool to diagnose student errors, create an emotionally supportive learning environment, and implement metacognitive strategies such as error reflection and self-checking to help students reduce errors and strengthen their understanding of functional concepts.

Ethical Statement

The present research was conducted in accordance with ethical standards for pedagogical research. The study was reviewed and approved by the Universitas Islam Negeri Sultan Syarif Kasim Riau, Indonesia, and Universitas Islam Riau, Indonesia Ethical Research Committee, which confirmed the ethical suitability of the research. All of the procedures followed ethical guidelines to ensure the protection of participants' rights and data privacy.

Data Availability Statement

The datasets generated and/or analysed during the current study are not publicly available due to confidentiality and ethical considerations regarding the research participants, but are available from the corresponding author on reasonable request.

Disclosure Statement

All authors do not have any conflict of interest to declare. No financial or non-financial interests influenced the design, implementation or reporting of this research.

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