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The STAR Reflective Growth Cycle: An Integrative Framework Linking Growth Mindset, Mathematics Anxiety, and Fraction Numeracy in Elementary Teacher Education

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ABSTRACT

Mathematics anxiety and limited understanding of fractions remain persistent challenges in elementary teacher education, often constraining conceptual learning and instructional confidence. Addressing these challenges requires learning frameworks that integrate cognitive, affective, and reflective processes. This study examines the relationships among growth mindset, mathematics anxiety, and fraction numeracy within the framework of the STAR Reflective Growth Cycle, an integrative reflective learning framework for pre-service elementary teachers. An explanatory sequential mixed-methods design was employed involving 71 pre-service teachers. Quantitative data were collected using a growth mindset scale, a mathematics anxiety scale, and a fraction numeracy test. Qualitative data were obtained through structured self-assessment reflections aligned with the four-STAR phases: self-awareness, take action, analysis and self-assessment, and rise and growth. The results indicate that a growth mindset is positively associated with fraction numeracy and negatively associated with mathematics anxiety. Regression analysis further shows that a growth mindset significantly predicts fraction numeracy performance, accounting for 35.9% of the variance. These relationships should be interpreted as associative rather than causal, consistent with the correlational design of the study. Qualitative findings reveal a gradual shift from anxiety and avoidance toward reflective persistence, strategic engagement, and increased confidence across the STAR phases. These findings provide interpretive insight into

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participants' experiences rather than evidence of causal impact. Overall, the findings suggest the potential relevance of structured reflective learning frameworks that integrate belief, emotion, and self-assessment in understanding numeracy development within elementary teacher education.

Keywords: Elementary teacher education, fraction numeracy, growth mindset, mathematics anxiety, reflective self-assessment,

INTRODUCTION

Mathematics education remains a major challenge in teacher education programmes, especially in elementary education. Many pre-service teachers begin their learning with high levels of mathematics anxiety and limited understanding of basic topics such as fractions, ratios, and proportional reasoning (Nasiruddin & Hayati, 2019; Nasiruddin & Basri, 2020; Zahra Nasiruddin et al., 2024). These problems are not only cognitive in nature but are also closely connected to emotional and motivational factors, which affect how future educators learn and later teach mathematics to their students (Ashcraft et al., 2007; D. Park et al., 2014). Therefore, developing instructional frameworks that address both cognitive and affective dimensions of mathematics learning has become a critical priority in improving teacher education.

Therefore, the need to integrate emotional and cognitive aspects of mathematics learning has been widely emphasised in recent research (Carey et al., 2017). For many pre-service educators, their fear of mathematics originates from prior negative learning experiences, which often leads them to avoid mathematics, feel less confident, and doubt their ability to teach it (Yunus & Nasiruddin, 2022). At the same time, many of them demonstrate fragmented or procedural understanding of fractions, even though fractions are one of the most crucial and difficult concepts in early mathematics learning (Siegler & Lortie-Forgues, 2015). The combination of emotional difficulties and limited conceptual understanding creates a cycle of low confidence and surface-level learning, which may affect both their own achievement and their future students learning outcomes.

In the past few decades, the concept of a growth mindset has been introduced to address this problem (Dweck, 2017; Yunus & Nasiruddin, 2022) and has emerged as a promising approach to mitigating these challenges. A growth mindset refers to the belief that intelligence and ability can be developed through effort, effective strategies, and persistence. This perspective has been associated with greater resilience, adaptive help-seeking, and persistence in the face of difficulty (Yeager et al., 2022). However, empirical evidence suggests that holding a growth mindset alone is insufficient to produce meaningful changes in learning behaviour or academic outcomes. Many students exhibit what is described as a "false growth mindset," where they express positive beliefs but do not engage in reflective or effortful learning practices

(Memari et al., 2024). This discrepancy between belief and action indicates that meaningful cognitive and emotional change requires structured support through self-assessment and self-regulation, rather than motivational beliefs alone.

Parallel developments in reflective learning theory (Gibbs, 1988; Schön, 1983; Nusantara, 2016a) and self-regulated learning (SRL) (Zimmerman, 2002; Matitaputty et al., 2024) emphasise that metacognitive awareness, self-monitoring, and feedback processes are essential mechanisms for learning and development. Reflective learning frameworks enable learners to examine their thoughts, emotions, and strategies when encountering difficulties. This process can transform failure into insight and frustration into improved planning. However, in mathematics teacher education, self-assessment is often implemented in a limited and disconnected manner, focusing more on teaching methods rather than helping students deeply understand mathematical concepts or regulate their emotions during problem solving (Hutajulu & Minarti, 2024). As a result, pre-service educators rarely perceive self-assessment as an integrated mechanism that supports both cognitive and emotional aspects of mathematics learning.

This study addresses this conceptual and practical gap by introducing the STAR Reflective Growth Cycle, an integrative framework that combines the principles of growth mindset (Stohlmann & Yang, 2024), reflective practice, and self-regulated learning into a coherent model of emotional-cognitive development. The STAR framework consists of four iterative stages: Self-Awareness, Take Action, Analysis & Self-Assessment, and Rise & Growth. Within this framework, self-assessment is not treated as a final step but as a central mechanism for supporting adaptive learning processes. As learners move through each stage, they first become aware of their thoughts and emotions (Self-Awareness), apply strategies (Take Action), evaluate their performance (Analysis & Self-Assessment), and reconstruct their understanding and confidence (Rise & Growth). This cycle aligns with Zimmerman's model of self-regulated learning while also incorporating the emotional and motivational dimensions highlighted in Dweck's and Gibbs's theories.

Importantly, this study does not aim to establish the causal effectiveness of the STAR framework. Instead, it seeks to explore the associations between growth mindset, mathematics anxiety, numeracy, and reflective experiences among pre-service teachers. By linking theory with empirical observations, this study positions the STAR framework as a conceptual and exploratory model that may support understanding of how cognitive and affective processes interact in mathematics learning. Rather than eliminating difficulty, the framework encourages learners to interpret challenges as opportunities for reflection and development, transforming failure into feedback and anxiety into adaptive learning responses.

LITERATURE REVIEW

Growth Mindset in Mathematics Learning

Growth mindset theory conceptualises intelligence and ability as malleable attributes that can be developed through effort, effective strategies, and persistence (Dweck, 2017; Dweck & Yeager, 2019). A substantial body of empirical research demonstrates that learners who endorse growth mindset beliefs are more likely to persist when facing difficulty, interpret errors as learning opportunities, and engage in adaptive help-seeking behaviours (Yeager et al., 2022; Rahayuningsih et al., 2023). In mathematics education, growth mindset has been associated with improved achievement, increased strategy use, and reduced fear of failure, particularly in learning contexts that require sustained cognitive effort (Boaler et al., 2022; Lunardon et al., 2022; Yunus & Nasiruddin, 2022).

Despite these positive associations, recent empirical studies have highlighted important limitations of growth mindset interventions when implemented as isolated belief-based messages. Barger et al. (2022) describe the phenomenon of false growth mindset, in which learners verbally endorse growth-oriented beliefs without engaging in reflective or effortful learning behaviours. Similarly, Dweck and Yeager (2020) argue that mindset interventions are most effective when embedded within learning environments that provide explicit opportunities for strategy use, feedback, and self-monitoring.

In mathematics learning, particularly in conceptually demanding domains such as fractions, effort without reflection may reinforce misconceptions rather than promote understanding (Brewster & Miller, 2023; Muzaini et al., 2023). Therefore, a growth mindset should be understood not only as a belief system but also as a practice enacted through structured cognitive and metacognitive processes. Without mechanisms that guide learners to reflect on errors, regulate emotions, and adapt strategies, a growth mindset risks remaining motivational rather than instructional in nature.

Mathematics Anxiety and Emotional Regulation

Mathematics anxiety is commonly defined as a feeling of tension or apprehension that interferes with numerical manipulation and mathematical reasoning (Ramirez et al., 2013). Extensive empirical evidence indicates that mathematics anxiety negatively affects working memory, attentional control, and problem-solving performance (Chuderski & Necka, 2012; Cipora et al., 2022). In fraction learning, where tasks require multi-step reasoning and conceptual coordination, anxiety can significantly constrain learners' ability to engage productively with mathematical content (Chang, 2023). Within teacher education, mathematics anxiety presents a dual challenge. First, it limits pre-service teachers' own conceptual development and learning engagement. Second, it may influence future instructional practices, as anxious teachers tend to avoid mathematics-rich activities or convey negative attitudes toward mathematics to their students (Chamberlain, 2023; Seo & Lee, 2021; Peterman & Ewing, 2019). Empirical studies further demonstrate that reducing mathematics anxiety requires more than repeated exposure to mathematical tasks; it necessitates explicit support for emotional regulation and metacognitive awareness (O'Leary & Fletcher, 2024; Aydin et al, 2022; Seo & Lee, 2021). Research on emotional regulation in mathematics learning emphasises the role of awareness, monitoring, and reflective interpretation of emotional experiences. Learners who recognise anxiety as a temporary and manageable response are more likely to persist and engage in adaptive problem-solving strategies (O'Leary & Fletcher, 2024). These findings suggest that effective mathematics learning environments must integrate emotional regulation with cognitive engagement, rather than treating affective factors as secondary or peripheral.

Reflective Learning and Self-Assessment

Reflective learning theory emphasises deliberate reflection on experience as a mechanism for professional and cognitive growth. Schön (1983) distinguishes between reflection-in-action and reflection-on-action, both of which enable learners to examine their thinking, emotions, and decisions during and after learning activities. Gibbs (1988) further operationalises reflective learning through structured cycles that guide learners from experience to evaluation and action planning. Empirical studies in mathematics teacher education demonstrate that reflective practices support metacognitive awareness, error diagnosis, and conceptual change. Structured self-assessment activities, in particular, have been shown to help pre-service teachers identify misconceptions, regulate emotional responses to errors, and refine learning strategies (Erdemir & Yeşilçınar, 2021; Font et al., 2024; Ashiddiqi et al., 2024). By making tacit cognitive and emotional processes explicit, reflective self-assessment facilitates deeper learning and adaptive strategy use. Despite its documented benefits, self-assessment in teacher education is often implemented superficially, functioning primarily as a summative evaluation of performance rather than as an ongoing learning mechanism (Markkanen et al., 2020). When self-assessment is not explicitly linked to emotional regulation and strategy adaptation, its potential to support both conceptual understanding and growth mindset enactment remains limited.

Self-Regulated Learning as an Integrative Framework

Self-regulated learning (SRL) provides a comprehensive framework for understanding how learners actively manage cognition, motivation, and emotion during learning. Zimmerman (2002) conceptualises SRL as a cyclical process involving forethought (goal setting and motivation), performance (strategy use and monitoring), and self-reflection (evaluation and adaptation).

A robust body of empirical research demonstrates that learners who engage in SRL processes achieve higher academic performance, show greater persistence, and respond more adaptively to academic challenges (Graham et al., 2024; Heyder et al., 2023; Matitaputty et al., 2024). In mathematics education, SRL has been shown to mediate the relationship between beliefs, emotions, and performance. Learners who monitor their understanding, evaluate errors, and adjust strategies are better able to manage anxiety and sustain engagement with complex mathematical tasks (Aydın & Özgeldi, 2024; Muslim et al., 2024). However, SRL processes are not automatically acquired; they require explicit scaffolding and structured opportunities for practice, particularly in teacher education contexts where learners are developing both mathematical knowledge and pedagogical identity. This highlights the need for integrative instructional frameworks that make SRL processes explicit and operational within domain-specific learning contexts such as mathematics.

Positioning the STAR Reflective Growth Cycle

Although growth mindset, reflective learning, and self-regulated learning have each been extensively studied, existing approaches frequently address these constructs in isolation. Growth mindset interventions often emphasise belief change without sufficient guidance for enactment. Reflective practices may focus on teaching methods rather than on learners' emotional and cognitive experiences with mathematical content. SRL frameworks, while theoretically comprehensive, are frequently presented in abstract terms and lack explicit integration with affective regulation in mathematics learning. The STAR Reflective Growth Cycle is positioned as an integrative framework that addresses these limitations by explicitly linking belief, emotion, reflection, and strategy within a single cyclical learning process (Aka et al., 2025; Zayyadi et al., 2020). The four phases (self-awareness, act, analysis and self-assessment, and rise and growth) align with core SRL processes while foregrounding emotional regulation and reflective meaning-making. Unlike traditional growth mindset approaches that emphasise belief endorsement, STAR conceptualises growth mindset as a reflective practice enacted through self-assessment and strategic adaptation. Self-assessment functions as the central mechanism connecting emotional awareness, cognitive strategy use, and conceptual reconstruction. Importantly, this framework is proposed as a conceptual and exploratory model rather than as evidence of established instructional effectiveness, aligning with the non-experimental design of the present study. In this way, STAR extends existing frameworks by operationalising how growth mindset beliefs are translated into observable learning behaviours during mathematically challenging tasks such as fraction problem solving. By positioning STAR at the intersection of growth mindset theory, reflective learning, and self-regulated learning, this study contributes a theoretically grounded and contextually responsive framework for mathematics teacher education (Hanafi et al., 2025; Rahayungsih et al., 2025a; Rahayungsih et al., 2025b). The framework addresses a critical gap in literature by offering a structured mechanism through which pre-service teachers can regulate emotions, engage reflectively with errors, and develop a deeper conceptual understanding of mathematics.

Table 1 illustrates the conceptual alignment between the STAR Reflective Growth Cycle and key elements of reflective learning, self-regulated learning, and growth mindset theory.

The STAR Reflective Growth Cycle integrates cognitive, affective, metacognitive, and belief-related dimensions within a structured reflective learning framework (Table 2).

Table 1
Theoretical integration underpinning the STAR reflective growth cycle

STAR Phase	Reflective Learning (Gibbs, 1988)	Self-regulated Learning (Zimmerman, 2002)	Growth Mindset Perspective (Dweck, 2017)	Key Learning Outcome
Self-Awareness	Reviewing experience	Forethought (goal setting, motivation)	Belief in the malleability of ability	Metacognitive awareness
Take Action	Exploring feelings and thoughts	Performance (strategy use)	Effortful engagement	Deliberate persistence
Analysis and Self-Assessment	Evaluating experience	Self-reflection (monitoring and evaluation)	Learning from errors	Conceptual understanding
Rise and Growth	Action planning	Adaptive regulation	Adaptive and growth-oriented mindset	Resilience and growth-oriented identity

Table 2
Conceptual structure of the STAR reflective growth cycle

Dimension	Focus of Enhancement	Operationalisation in STAR	Expected Learning Outcome
Cognitive	Conceptual understanding and numeracy reasoning	Take Action; Analysis and Self-Assessment	Improved problem-solving and fraction numeracy
Affective	Emotional regulation and anxiety management	Self-Awareness: Rise and Growth	Reduced mathematics anxiety and increased confidence
Metacognitive	Self-monitoring and self-evaluation	Analysis and Self-Assessment	Enhanced reflective awareness and adaptive thinking
Belief System	Growth-oriented beliefs and effort attribution	Rise and Growth	Increased motivation, persistence, and resilience

Unlike generic self-regulated learning models that emphasise cognitive regulation in broad academic contexts, the STAR Reflective Growth Cycle explicitly foregrounds emotional awareness and structured self-assessment as central mechanisms through which growth mindset beliefs are enacted during mathematically demanding tasks. Rather than treating reflection as a peripheral or post-hoc activity, STAR positions self-assessment as an ongoing regulatory process that links emotion, strategy use, and conceptual understanding. In this way, STAR extends existing reflective and self-regulated learning frameworks by providing a domain-sensitive structure for examining how growth-oriented beliefs translate into observable learning behaviours in mathematics teacher education.

METHODOLOGY

Research Design

This study employed an explanatory sequential mixed-methods design, in which quantitative data collection and analysis were followed by qualitative exploration to elaborate and contextualise the statistical findings. This design was selected to examine not only the relationships among growth mindset, mathematics anxiety, and fraction numeracy but also to explore how reflective self-assessment processes shape learners' emotional and cognitive experiences during mathematics learning.

The quantitative phase focused on examining associative and non-causal relationships among the study variables, whereas the qualitative phase provided insight into the reflective mechanisms underlying the observed patterns. Importantly, this design does not permit causal inference but is intended to explore patterns of association and meaning-making processes. Integration occurred at the interpretation stage through triangulation of quantitative results and qualitative themes, consistent with best practices in mixed-methods research.

Participants and Context

Participants were 71 pre-service elementary teachers enrolled in the third semester of an elementary teacher education programme at a public university in Indonesia. The sample consisted predominantly of female students (approximately 88%), with ages ranging from 18 to 21 years. All participants were enrolled in a compulsory mathematics course focusing on foundational topics, including fractions. This cohort was selected because early-stage pre-service teachers are in a critical period for developing mathematical self-efficacy, emotional dispositions toward mathematics, and foundational conceptual understanding prior to teaching practicum experiences (Bani et al., 2022; Berg et al., 2025; Rahayungsih et al., 2025a; Rahayungsih et al., 2025b). Participation was voluntary, and informed consent was obtained before data collection. However, the use of a single institutional sample and a relatively small sample size may limit the generalisability of the findings.

Instruments

All questionnaire instruments employed a 4-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). The use of a four-point scale was intended to reduce central tendency bias and encourage participants to express clear positions regarding their beliefs and emotional experiences.

Growth Mindset Scale

Growth mindset was measured using a 15-item questionnaire adapted from established mindset instruments (Barger et al., 2022; Dweck, 2017). The items assessed beliefs about the malleability of mathematical ability, effort, and learning strategies. Reliability analysis demonstrated high internal consistency (Cronbach's α = .88), exceeding recommended thresholds for psychological measurement. The instrument was used to capture perceived beliefs rather than direct behavioural enactment, and therefore should be interpreted within the limits of self-reported data.

Mathematics Anxiety Scale

Mathematics anxiety was assessed using an 8-item scale adapted from Carey et al. (2017), measuring emotional, cognitive, and physiological responses to mathematical tasks. The instrument demonstrated strong internal consistency in the present study (Cronbach's α = .85), supporting its suitability for examining affective dimensions of mathematics learning. This measure reflects perceived anxiety levels and does not capture real-time emotional fluctuations during task performance.

Fraction Numeracy Test

Fraction numeracy was measured using a 10-item diagnostic test designed to assess conceptual understanding, procedural reasoning, and applied problem-solving involving fractions. Test items were aligned with international numeracy frameworks and national assessment indicators, covering three cognitive domains: knowing, applying, and reasoning. Content validity was established through expert review by mathematics education specialists to ensure alignment with instructional objectives and conceptual demands. Reliability analysis indicated satisfactory internal consistency (Cronbach's α = .86), supporting the use of the instrument for inferential analysis.

Qualitative Data Source

Structured Self-Assessment Reflections

Qualitative data were collected through written self-assessment reflections guided by the STAR Reflective Growth Cycle. Participants completed structured reflection prompts corresponding to the four-STAR phases: (1) Self-Awareness, (2) Take Action, (3) Analysis and Self-Assessment, and (4) Rise and Growth. The prompts encouraged participants to reflect on emotional responses, learning strategies, errors, and changes in understanding during fraction learning activities. This approach aligns with reflective practice research emphasising the use of structured prompts to support analytic depth and metacognitive engagement (Erdemir & Yeşilçınar, 2021; Gibbs, 1988; Schön, 1983).

Data Collection Procedure

Data collection was conducted over a six-week instructional period. Quantitative instruments were administered after participants completed instructional units on fractions. Qualitative self-assessment reflections were collected subsequently, allowing participants to reflect on their learning experiences informed by the prior quantitative assessment results. This sequential procedure ensured alignment with the explanatory mixed-methods design, enabling qualitative data to elaborate on and contextualise observed quantitative relationships. No experimental manipulation or control group was employed in this study.

Data Analysis

Quantitative Analysis

Quantitative data were analysed using SPSS. Descriptive statistics were computed to examine central tendencies and variability. Pearson correlation analyses were conducted to examine relationships among growth mindset, mathematics anxiety, and fraction numeracy. A simple linear regression analysis was performed to assess the predictive role of growth mindset on fraction numeracy performance. Mathematics anxiety was not included as a predictor in the regression model, as the primary purpose of the analysis was to examine the direct predictive contribution of growth mindset prior to qualitative exploration of emotional regulation and reflective processes. Assumptions of regression analysis, including normality, linearity, and homoscedasticity, were examined prior to inferential testing. Statistical significance was determined at the .05 level. The regression results are interpreted as indicative of statistical association rather than causal influence.

Qualitative Analysis

Qualitative data were analysed using thematic analysis following a systematic coding process. Initial open coding was conducted to identify emotional, cognitive, and strategic patterns within participants' reflections. Codes were subsequently organised into themes corresponding to the STAR phases. To enhance trustworthiness, themes were reviewed iteratively across participants to identify convergence and divergence in experiences. Reflexive memoing was employed throughout the analytic process to support analytic transparency and reduce researcher bias. This approach enabled qualitative findings to function not merely as illustrative examples but as interpretive evidence explaining how reflective self-assessment mediated emotional regulation and learning processes. Researcher subjectivity was acknowledged as part of the interpretive process and managed through iterative validation of themes.

Integration of Quantitative and Qualitative Data

Integration occurred at the interpretation stage through joint display analysis, linking statistical relationships with qualitative themes across the STAR phases. This integration aimed to provide explanatory insight rather than causal confirmation of relationships among variables.

Ethical Considerations

Ethical approval was obtained from the institutional review board. Participants were informed of the voluntary nature of participation, confidentiality of responses, and their right to withdraw at any time without academic consequences.

RESULTS

Quantitative Results

Descriptive Statistics

Descriptive analyses were conducted to examine participants' profiles in terms of growth mindset, mathematics anxiety, and fraction numeracy. The results show that pre-service teachers demonstrated a moderately high level of growth mindset ($M = 48.1$, $SD = 6.4$; possible range = 15-60). Mathematics anxiety scores were in the moderate range ($M = 21.3$, $SD = 5.9$). Fraction numeracy performance also fell within a moderate range ($M = 39.7$, $SD = 7.8$).

Correlation Analysis

Pearson correlation analyses were conducted to examine the relationships between growth mindset, mathematics anxiety, and fraction numeracy. The results revealed a significant positive correlation between growth mindset and fraction numeracy ($r = 0.631$, $p < .01$). In contrast, mathematics anxiety was significantly and negatively correlated with fraction numeracy ($r = -0.482$, $p < .01$). These results indicate moderate to strong statistical associations among the variables; however, they do not imply causal relationships.

Regression Analysis

A simple linear regression analysis was conducted to examine whether growth mindset significantly predicted fraction numeracy performance. The model was statistically significant, $F(1, 69) = 18.47$, $p < .001$. Growth mindset was found to be a significant statistical predictor of fraction numeracy within the regression model ($\beta = 0.598$, $p < .001$); however, this relationship should be interpreted as associative rather than causal. The model explained 35.9% of the variance in fraction numeracy as indicated by the adjusted coefficient of determination (adjusted $R^2 = 0.359$), while the corresponding zero-order correlation between growth mindset and fraction numeracy was $r = 0.631$. This proportion of explained variance indicates a moderate level of statistical association rather than a definitive explanatory effect. Mathematics anxiety was not included as a predictor in the regression model, as the analysis was designed to examine the direct predictive role of growth mindset before qualitative exploration.

Taking together, these quantitative patterns indicate that cognitive beliefs and affective responses are statistically associated and may interact in shaping fraction learning outcomes; however, these relationships should not be interpreted as causal.

Qualitative Results

The qualitative findings are presented as interpretive insights into participants' experiences rather than as evidence of causal impact. Qualitative analysis of structured self-assessment reflections identified four interrelated themes corresponding to the phases of the STAR Reflective Growth Cycle. These themes capture recurring emotional, cognitive, and strategic patterns reported by participants during fraction learning.

Theme 1: Self-Awareness: Recognition of Emotional and Cognitive Barriers

In the initial phase, participants frequently reported heightened emotional responses when engaging with fraction tasks, including anxiety, confusion, and fear of making mistakes. Many reflections described emotional reactions as barriers to engagement, often accompanied by hesitation or avoidance behaviours. Participants commonly expressed uncertainty prior to attempting problem solving, as illustrated by statements such as, "I panic when I see fraction problems with many steps", and "I feel unsure even before I start solving." Across reflections, participants demonstrated increasing awareness of emotional triggers and maladaptive thought patterns that interfered with mathematical engagement (Muzaini et al., 2023). Emotional responses were often explicitly linked to perceived cognitive difficulty, indicating early recognition of the interaction between affective states and learning processes.

Theme 2: Take Action: Strategic and Effortful Engagement

Following heightened self-awareness, participants reported deliberate efforts to adopt new learning strategies. Common strategies included breaking fraction problems into smaller steps, writing down reasoning processes, and reframing mistakes as part of the learning process rather than as indicators of failure. Participants consistently described intentional effort and strategic action as contributing to increased engagement with fraction tasks. Reflections such as "When I slow down and follow the steps, I feel more in control" and "Trying again after mistakes made me less afraid" illustrate a recurring shift from emotional reactivity toward active and effortful engagement (Rahayuningsih, 2022; Yunus & Nasiruddin, 2022).

Theme 3: Analysis and Self-Assessment: Linking Emotions, Strategies, and Outcomes

In the analysis phase, participants engaged in evaluative reflection that connected emotional experiences, applied strategies, and learning outcomes. Many reflections demonstrated increased metacognitive awareness, as participants identified which strategies were effective and examined the sources of their errors. Participants frequently reported recognising conceptual misunderstandings related to fraction equivalence and operations. Statements such as "I realised my mistake came from using rules without understanding" and "Checking my steps helped me see where I was wrong" illustrate analytic engagement with both cognitive processes and learning outcomes. Self-assessment reflections commonly function as a mechanism for examining the alignment between emotional responses, strategic choices, and conceptual understanding (Kholid et al., 2020).

Theme 4: Rise and Growth: Reflective Persistence and Emerging Confidence

In the final phase, participants described increased confidence, reduced anxiety, and greater willingness to engage with challenging fraction problems. Reflections indicated a shift from avoidance toward persistence, with participants emphasising gradual improvement and sustained effort. Statements such as "I no longer avoid difficult questions" and "I believe I can improve if I keep practising" were recurrent across reflections. Participants frequently described a more adaptive orientation toward mathematical challenges, viewing difficulty as manageable rather than threatening. This theme captures a pattern of reflective persistence and increased self-efficacy emerging through continued engagement with the STAR cycle.

DISCUSSION

The present study examined the relationships among growth mindset, mathematics anxiety, and fraction numeracy within the framework of the STAR Reflective Growth Cycle. Consistent with the quantitative results summarised in Table 3, the findings indicate that a growth mindset is positively associated with fraction numeracy, whereas mathematics anxiety shows a negative association with numeracy performance. Together, these results highlight the interconnected roles of cognitive beliefs and affective factors in shaping mathematical learning outcomes among pre-service elementary teachers.

Table 3
Summary of reliability, descriptive statistics, correlations, and regression results

Variable	Cronbach's α	Mean (SD)	Correlation with Fraction Numeracy (r)	Regression (β)	Sig. (p)
Growth mindset	0.881	48.1 (6.4)	0.631	0.598	< .001
Math Anxiety	0.854	21.3 (5.9)	-0.482	-	< .01
Fraction Numeracy	0.862	39.7 (7.8)	-	-	-

These relationships should be understood as associative patterns rather than causal effects, consistent with the correlational design of the study.

The observed positive association between growth mindset and fraction numeracy ($r = 0.631$), along with the significant regression coefficient ($\beta = 0.598$), suggests that pre-service teachers who report stronger beliefs in the malleability of mathematical ability tend to demonstrate higher levels of fraction understanding. However, this pattern reflects a statistical association and does not imply that a growth mindset directly causes improvements in numeracy performance. This pattern aligns with prior empirical research linking growth mindset to persistence, adaptive strategy use, and engagement in mathematics learning (Purnomo et al., 2022; Lunardon et al., 2022; Yeager et al., 2022). Importantly, the present findings extend this literature by situating growth mindset within a structured reflective learning framework rather than treating it solely as a belief construct.

As illustrated in Figure 1, the integration of quantitative and qualitative findings provides interpretive insights into how these relationships are experienced and reflected during the learning processes. The positive association between growth mindset and numeracy corresponds to reflective processes observed in the Take Action and Analysis and Self-Assessment phases, where participants described deliberate strategy use, effortful engagement, and systematic error analysis. Conversely, the negative association between mathematics anxiety and fraction numeracy aligns with emotional challenges identified in the Self-

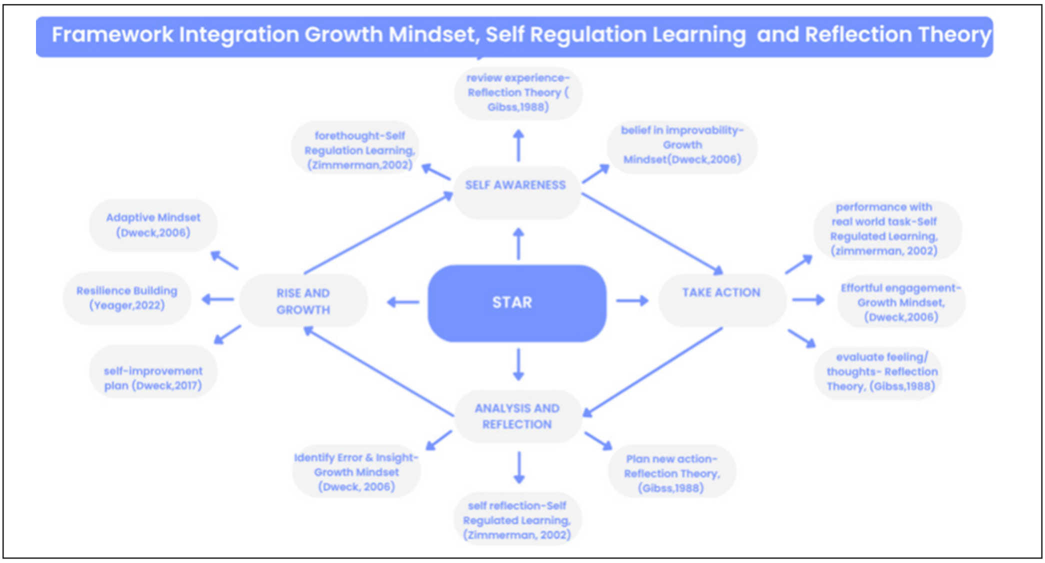

Figure 1. Integration of growth mindset, mathematics anxiety, and fraction numeracy across the phases of the STAR reflective growth cycle

Awareness phase, including fear of error and avoidance. These patterns suggest that each STAR phase functions as an interconnected cognitive-affective checkpoint within the reflective learning cycle, without implying a deterministic or causal sequence of effects.

In parallel, the negative association between mathematics anxiety and fraction numeracy ($r = -0.482$) is consistent with extensive evidence indicating that anxiety constrains mathematical performance by taxing cognitive resources and disrupting problem-solving processes (Chang, 2023; Cipora et al., 2022; Ramirez et al., 2013). Although participants reported moderate levels of anxiety, the findings indicate that emotional discomfort remains a salient factor even among future teachers, with potential implications for both learning and future instructional practice (Chamberlain, 2023; Seo & Lee, 2021; Peterman & Ewing, 2019). These findings should be interpreted as indicative of relational patterns rather than causal influence.

The qualitative findings provide explanatory depth by illustrating how growth-oriented beliefs were enacted through reflective and self-regulated learning processes. Participants' reflections revealed a progression across the STAR phases, moving from emotional awareness to strategic engagement, analytic self-assessment, and increased confidence. This progression offers a possible interpretive account of why the growth mindset was statistically associated with numeracy performance, rather than serving as a causal explanation. Its influence appeared depend on the presence of structured reflection and self-assessment that supported emotional regulation and strategic adjustment.

This interpretation aligns with contemporary critiques of isolated growth mindset interventions, which emphasise that belief endorsement alone is insufficient to produce durable learning gains (Dweck & Yeager, 2020; Memari et al., 2024). Within the STAR Reflective Growth Cycle, self-assessment emerged as a central mechanism linking emotional regulation, strategy refinement, and conceptual monitoring. This finding is consistent with research on reflective learning and self-regulated learning that highlights self-monitoring and evaluative judgment as core processes underlying adaptive learning (Erdemir & Yeşilçınar, 2021; Schön, 1983; Zimmerman, 2002). However, this mechanism should be understood as a theoretically grounded interpretation rather than an empirically verified causal pathway.

The study also contributes to the literature on fraction learning in teacher education. Prior research has shown that pre-service teachers often rely on procedural rules without a deep conceptual understanding of fractions (Nasiruddin & Hayati, 2019; Rahayungsih et al., 2025a; Siegler & Lortie-Forgues, 2015). The present findings suggest that reflective engagement with errors and strategies may support the identification and revision of such misconceptions. While the study does not claim broad effectiveness, it provides empirical support for the relevance of a reflective learning framework such as STAR in cognitively demanding mathematical domains.

Several limitations should be acknowledged. The study involved a relatively small sample from a single institution, limiting generalisability, and employed a correlational design that precludes causal inference. Additionally, mathematics anxiety was not included as a predictor in the regression model. These limitations underscore the need for cautious interpretation and align with recommendations in the broader literature (Cipora et al., 2022; Yeager et al., 2022).

Despite these limitations, the study offers an integrative perspective on how belief, emotion, and reflection interact during mathematical learning in teacher education. Rather than positioning growth mindset as a universal solution, the findings suggest that its educational value depends on structured reflective processes that enable learners to regulate emotions and adapt strategies. The STAR Reflective Growth Cycle provides a theoretically grounded framework for conceptualising this integration and informs the design of reflective learning experiences in mathematics teacher education. Overall, these interpretations are intended as exploratory and should be understood within the limits of a correlational design rather than as evidence of causal relationships.

CONCLUSION

This study examined the relationships among growth mindset, mathematics anxiety, and fraction numeracy within the framework of the STAR Reflective Growth Cycle among pre-service elementary teachers. The findings indicate that a growth mindset is positively associated with fraction numeracy, whereas mathematics anxiety is negatively related to numeracy outcomes, highlighting the intertwined roles of cognitive beliefs and affective factors in mathematics learning. These relationships should be understood as associative rather than causal, consistent with the correlational design of the study. Beyond these associations, the qualitative findings suggest that a growth mindset is most productively enacted when embedded within structured reflective and self-regulated learning processes rather than treated as a standalone belief. This interpretation should be understood as an exploratory and context-specific insight rather than as evidence of a causal mechanism. The STAR Reflective Growth Cycle offers a conceptual lens for understanding how emotional awareness, strategic engagement, and self-assessment interact within learning processes to support mathematical engagement. This framework is presented as a conceptual and interpretive model rather than a validated causal intervention. Rather than claiming broad effectiveness, this study provides context-specific evidence that integrating mindset, reflection, and self-assessment may be relevant for supporting fraction learning in teacher education contexts. Such relevance should be interpreted cautiously as indicative of potential rather than definitive effectiveness (Rahayungsih et al., 2025a; Rahayungsih et al., 2025b).

IMPLICATION OF THE STUDY

Pedagogical Implications

The findings suggest that mathematics instruction in teacher education programmes may benefit from moving beyond the transmission of growth mindset messages toward the integration of structured reflective self-assessment within learning activities. Reflection that supports learners in recognising emotional responses, analysing errors, and adapting strategies can contribute to both emotional regulation and conceptual engagement. However, these contributions should be interpreted as potential and context-dependent rather than guaranteed outcomes. In this regard, the STAR Reflective Growth Cycle may serve as a guiding framework for designing reflective learning experiences in mathematics courses, particularly in conceptually demanding domains such as fractions. This framework is intended as a flexible conceptual guide rather than a prescriptive instructional model (Aka et al., 2025; Matitaputty et al., 2024; Zayyadi et al., 2020).

Implications for Curriculum and Assessment

From a curricular perspective, self-assessment may be positioned as an ongoing formative process rather than as a terminal evaluation of performance. The use of structured reflection prompts aligned with the STAR phases can support pre-service teachers in connecting beliefs, emotions, and learning strategies coherently. Such support should be understood as a potential facilitative condition rather than a direct causal influence on learning outcomes. Such alignment may foster reflective learning habits that are essential not only for mathematical understanding but also for future instructional practice. These implications are presented as theoretically informed and exploratory rather than empirically conclusive (Hima et al., 2019).

Implications for Future Research

Future research is needed to examine the STAR Reflective Growth Cycle across diverse institutional contexts and with larger samples to explore the robustness and transferability of the observed relationships. Longitudinal and experimental designs could further clarify how reflective, growth-oriented processes develop over time and how they interact with mathematics anxiety. Additional studies may also investigate how the STAR framework can be adapted to other mathematical domains or integrated into digital and collaborative learning environments (Hanafi et al., 2025; Khotimah et al., 2026; Suwandi, 2022).

By clarifying how belief, emotion, and reflection interact during learning, this study contributes to ongoing efforts to design theoretically grounded and emotionally responsive mathematics teacher education. These contributions should be interpreted as exploratory and situated within the limitations of correlational design (Nusantara, 2016b).

LIMITATION AND FUTURE RESEARCH

Limitations

Several limitations of this study should be acknowledged. The sample was relatively small and drawn from a single teacher education institution, which limits the generalisability of the findings. As a result, the conclusions should be interpreted as context-specific rather than representative of all pre-service teacher populations. In addition, the correlational and predictive design does not permit causal inference, and the observed relationships may have been influenced by unmeasured factors such as prior mathematical achievement or instructional context. Accordingly, all findings should be interpreted as associative rather than causal.

Furthermore, mathematics anxiety was not included as a predictor in the regression model, and its potential mediating or moderating role within the STAR framework was not examined. The fraction numeracy assessment, while demonstrating acceptable reliability, captured a limited range of fraction-related competencies. Finally, the qualitative findings were based on written self-assessment reflections, which rely on participants' self-reports and may not fully reflect real-time cognitive and emotional processes during mathematical problem solving (Cipora et al., 2022; Yeager et al., 2022).

Future Research

Future studies could extend the present findings by employing larger and more diverse samples across multiple institutions to examine the robustness and transferability of the observed relationships. Longitudinal and experimental designs may further clarify how growth mindset, mathematics anxiety, and reflective self-assessment develop over time and interact within instructional contexts. Additional research may also explore the role of mathematics anxiety as a mediator or moderator within the STAR Reflective Growth Cycle, as well as examine the applicability of the framework across different mathematical domains and learning environments, including digital and collaborative settings (Indrawati, 2021).

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