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# Mistakes as Missed Takes: Unlocking the Transformational Power of Productive-Failure Strategy in Mathematics Education

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## A B S T R A C T

The Productive-Failure strategy is a transformative instructional method that leverages initial failure as a catalyst for deeper learning. When students grapple with complex problems and activate prior knowledge, this approach fosters resilience and conceptual understanding. It shifts failure from a negative outcome to an integral part of the learning process, empowering students to achieve mastery in mathematics. This study explored how tertiary students' engagement with productive-failure approaches in Mathematics fosters transformative learning experiences and enhances cognitive development and academic success. This study employed transcendental phenomenology to explore how tertiary students engage with productive-failure approaches in Mathematics. This utilized thematic analysis to analyze the qualitative data from the five (5) BSEd Mathematics students via Individual Interviews and Focus-Group Discussion. The emergent themes of the transformational learning experiences of the students on the implementation of the productive-failure approach in teaching mathematics were: *(1) The Fear of Failure; (2) The Stigma of Mistakes; (3) The Importance of Growth Mindset; (4) The Importance of Growth Mindset;* and *(5) The Role of Teacher Support*. An *Unlocked Power Funnel Model of Productive Failure in Mathematics Education* was developed based on the findings. The study reveals that fear of failure and stigma around mistakes hinder learning, while a growth mindset and teacher support are crucial for fostering a more positive and effective mathematics education. To enhance the implementation of the productive-failure approach in mathematics education, it is recommended that educators create supportive, growth-oriented classroom environments and equip teachers with the necessary skills and resources for student support. Integrating productive-failure strategy into the curriculum and conducting further research on its long-term effects can provide deeper insights for improving student learning.

## RESUMO

A estratégia do Fracasso Produtivo é um método de ensino transformador que aproveita o fracasso inicial como um catalisador para uma aprendizagem mais profunda. Quando os alunos se debatem com problemas complexos e ativam conhecimentos prévios, esta abordagem promove a resiliência e a compreensão conceitual. O insucesso deixa de ser um resultado negativo e passa a ser uma parte integrante do processo de aprendizagem, dando aos alunos a possibilidade de dominarem a matemática. Este estudo explorou a forma como o envolvimento dos estudantes do ensino superior com abordagens de fracasso produtivo em Matemática promove experiências de aprendizagem transformadoras e melhora o desenvolvimento cognitivo e o sucesso académico. Este estudo utilizou a fenomenologia transcendental para explorar o modo como os estudantes do ensino superior se envolvem com abordagens de fracasso produtivo em Matemática. Utilizou-se a análise temática para analisar os dados qualitativos dos cinco (5) estudantes de Matemática da BSEd através de entrevistas individuais e discussões em grupos de discussão. Os temas emergentes das experiências de aprendizagem transformacionais dos estudantes sobre a implementação da abordagem produtiva-fracassada no ensino da Matemática foram os seguintes *(1) O medo do fracasso; (2) O estigma dos erros; (3) A importância da mentalidade de crescimento; (4) A importância da mentalidade de crescimento;* e *(5) O papel do apoio do professor*. Com base nas conclusões, foi desenvolvido um modelo de funil de poder desbloqueado do insucesso produtivo no ensino da matemática. O estudo revela que o medo do insucesso e o estigma em torno dos erros dificultam a aprendizagem, ao passo que uma mentalidade de crescimento e o apoio dos professores são cruciais para promover um ensino da matemática mais positivo e eficaz. Para melhorar a aplicação da abordagem do fracasso produtivo no ensino da matemática, recomenda-se que os educadores criem ambientes de sala de aula favoráveis e orientados para o crescimento e que dotem os professores das competências e dos recursos necessários para apoiar os alunos. A integração da estratégia do insucesso produtivo no currículo e a realização de mais investigação sobre os seus efeitos a longo prazo podem fornecer informações mais aprofundadas para melhorar a aprendizagem dos alunos.

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## Introduction

Mathematics teachers shoulder a multifaceted responsibility beyond mere instruction, cultivating foundational skills like number sense and operational fluency (Hussein, Ow, Elaish & Jensen, 2021). They integrate problem-solving, inspiring resilience and perseverance. Their mandate includes instilling a passion for mathematics and equipping students with essential tools for lifelong learning (Zhi-song, 2009).

In mathematics, encountering failure is common, especially when students face unfamiliar problems. Traditionally, teachers introduce concepts through direct instruction, followed by problem-solving (Ling & Mahmud, 2023). In the 21st century, teaching methods must evolve to enhance learning retention. Productive failure flips this sequence, engaging students in problem-solving first, and then teaching concepts and procedures afterward (Kapur, 2010).

The failure-based approach, as described by (Kapur & Bielaczyc, 2012), involves students naturally failing to discover correct solutions, activating their prior knowledge to facilitate learning. This intentional failure, framed as part of the learning process, primes students' brains to grasp new concepts after initial setbacks (Wong & Lim, 2021). By developing tasks that challenge students and necessitate the use of prior knowledge, this approach encourages learning rooted in students' experiences and insights, fostering a deeper understanding of the topics in mathematics.

Productive-failure Approach is not just an adage about persevering through challenges; it is an active and practical teaching approach that empowers students not only do well on short term measures of knowledge but also provides enhanced creative thinking, conceptual understanding, and help students to transfer or utilize learning to real-life situations (Kapur, 2016).

In a productive failure learning approach, the instruction of the new concepts of the lesson is preceded by unguided exploration and inquiry. As learners scarcely know how to decipher the given problems during this exploration phase successfully, they are anticipated to make mistakes. Although failure and errors seem persuasive and are commonly considered undesirable outcomes of the learning process, advocates of the productive failure approach strongly believe that this is not primarily the case (Darabi et al., 2018).

Kapur, Dickson, & Yhing (2009) emphasized that students should receive instruction that is connected to their learning experiences during the lesson. With this proposition, they theorized that failure can be useful and productive when students are facilitated immediately after making mistakes. When the instruction is connected to the experiences of the students, it becomes relevant and meaningful. Consequentially, students learn to recognize the cause of the failure. Additionally, VanLehn, Siler, Murray, Yamauchi, & Baggett (2003) pointed out that

successful learning is associated with failure. This failure permits the students to reach an impasse and are not able to solve the given problem by delaying the instruction.

This approach might seem like frustration to students because of their inability to solve the problem, that is why the teacher must motivate the students in order not to feel bad and instead spike the learners' interest in solving the problem. After students commit mistakes and encounter failure in their own discovery and problem-solving process, the teacher facilitates a discussion that highlights various student attempts and teaches the new concept, consolidating students' understanding of the processes required to complete the task (Perry et al., 2005).

In the Philippine context, Mathematics presents itself as a challenging academic discipline. The researcher has observed a notable deficiency in students' capacity to comprehend and retain mathematical concepts effectively. This trend, if left unaddressed, poses significant obstacles to the cultivation of globally competitive individuals, as evidenced by the outcomes of assessments like the Programme for International Student Assessment (PISA). Motivated by this concern, the researcher utilized the Productive-Failure approach, aiming to stimulate student interest, foster critical thinking skills, and promote long-term retention of mathematical knowledge. Consequently, the researcher seeks to explore students' experiences regarding implementing the Productive-Failure approach in Mathematics.

## Objectives

This study explored how tertiary students engage with productive-failure approaches in Mathematics, focusing on the transformative learning experiences that arise from overcoming challenges and misconceptions. The research highlighted the influence of these approaches on their cognitive development and overall academic success in Mathematics.

## Methods

### Research Design

This study employed transcendental phenomenology to explore how tertiary students engage with productive-failure approaches in Mathematics. The research focused on the transformative learning experiences that emerge when students confront and overcome mathematical challenges and misconceptions. Transcendental phenomenology focuses on uncovering the essence of human experiences by examining subjective perceptions and setting aside preconceived notions. It emphasizes the intentionality of consciousness, where every mental act is directed toward an object, and prioritizes understanding individual lived experiences (Husserl, 2012).

Researchers using this approach practice "bracketing" to avoid bias, aiming to reveal the fundamental structures and meanings of experiences. In educational research, such as examining how students engage with productive-failure approaches in Mathematics, phenomenology provides deep insights into the transformative influence of these experiences

on cognitive development and academic success by capturing the nuanced ways students interact with and reflect on their challenges.

**Research Participants**

The participants of this study were five (5) Bachelor of Secondary Education major in Mathematics students with experience in productive-failure approaches in Mathematics. The researcher selected the participants based on their success and failure stories in learning Mathematics.

**Data Collection and Analysis**

In this study, the researchers acted as the main instrument for data collection. The research employed interviews to gather data. An Interview Guide was created by the researchers and utilized during both face-to-face and virtual interviews.

The collected data were analyzed and organized to identify patterns and underlying meanings. Thematic analysis facilitated the examination of participants' accounts, the development of structural descriptions, and the creation of the model. This study utilized six (6) stages of data analysis by Braun & Clarke (2006) such as: (1) *Familiarization with the Data* includes immersion in the data by transcribing, reading, and noting initial ideas to gain a comprehensive understanding; (2) *Generating Initial Codes* comprises a systematic organization of the data by identifying and labeling significant features through coding; (3) *Searching for Themes* emphasizes the identification and grouping of codes into broader themes that address key aspects of the research question; (4) *Reviewing Themes* refines and validates themes by ensuring they accurately reflect the data and contribute to a coherent narrative; (5) *Defining and Naming Themes* describes and names each theme to articulate its essence and relevance to the research question; and (6) *Writing the Report* compiles and presents the findings in a final report, integrates themes into a coherent narrative, and formulates a model supported by data extracts.

**Delimitations of the Study**

The study is delimited by its focus on how tertiary students engage with productive-failure approaches specifically in the context of Mathematics. The research concentrated on the transformative learning experiences that emerge from overcoming challenges and misconceptions, excluding other subjects or educational strategies. Additionally, the study was limited to exploring the influence of these approaches on cognitive development and academic success, without addressing broader factors such as emotional or social development. The scope was further narrowed to tertiary learners, leaving out primary and secondary education levels.

## Results and Discussion

The emergent themes of the transformational learning experiences of the students on the implementation of the productive-failure approach in teaching mathematics were: *(1) The Fear of Failure*; *(2) The Stigma of Mistakes*; *(3) The Importance of Growth Mindset*; *(4) The Importance of Growth Mindset;* and *(5) The Role of Teacher Support.*

### *The Fear of Failure*

This theme posits a significant barrier for many learners in mathematics. This fear often stems from societal pressures and the educational environment that emphasizes high-stakes testing and performance. Students frequently associate failure with negative self-worth, leading to anxiety and disengagement from mathematics-related tasks. Research indicates that a large percentage of students experience mathematics anxiety, which is closely linked to their fear of failing in this subject as discussed:

*Participant 1: "I've always been scared of math. Like, if I don't get the answer right, it means I'm not smart enough. In our class, we have these big tests, and it's like, if you fail, everyone knows. It's embarrassing, and it makes me feel like I'll never be good at math. I just get stuck sometimes and don't even try because I already know I'll fail."*

*Participant 3: "When the teacher calls on me to solve a math problem on the board, I just freeze. It's like I forget everything I know. It's not that I don't understand; I just get so anxious that I can't think straight. I think it's because we're always told that we need to get it right, and if we make a mistake, it's a big deal. So now, I just avoid putting my hand up or trying too hard. It's easier to just sit back."*

*Participant 4: "Math class makes me feel like I'm always one step away from failing. It's not just about understanding the lessons; it's about feeling like any wrong move will ruin my grade. The system doesn't give you space to mess up and learn. I know I could do better if there wasn't so much pressure. Sometimes, I wish the teachers would let us make mistakes and learn from them instead of making us feel like failures when we get things wrong."*

This fear creates a paralyzing effect, where students may avoid engaging in their mathematics classes. They might feel overwhelmed when faced with mathematics problems, leading to a mental block that prevents them from attempting solutions (Jenifer, Rozek, Levine, & Beilock, 2022). The educational system often reinforces this fear by not allowing room for mistakes, which can stifle creativity and problem-solving skills. As a result, students

may develop a fixed mindset, believing that their abilities are static and that they cannot anymore improve (Yalçın & Erden, 2021).

To combat the fear of failure, educators may create a supportive learning environment that encourages risk-taking and viewing mistakes as part of the learning process. Implementing policies that allow for grade forgiveness and flexible deadlines can help students see failure as an opportunity for growth rather than a definitive end. Lastly, educators can help students build resilience and a more positive relationship with mathematics.

### *The Stigma of Mistakes*

The stigma surrounding mistakes in mathematics can hinder students' willingness to engage with the subject. Many students internalize the belief that making mistakes is unacceptable, leading to a fear of participating in class discussions or attempting challenging problems. This stigma often originates from early educational experiences where incorrect answers were met with negative feedback, reinforcing the idea that mistakes equate to failure as explicated:

*Participant 3: "In math class, I always feel like there's no room for mistakes. Like, if you get something wrong, people look at you differently, or the teacher just moves on without really helping. It makes me not want to answer, even when I think I know how to solve the problem. I'd rather stay quiet than risk getting it wrong and feeling embarrassed."*

*Participant 4: "I remember when I was younger, I got a math question wrong, and the teacher made a big deal out of it. Since then, I've felt like making mistakes means you're not good at math. It's hard to shake that feeling, so now I don't really try when the problems are tough. It feels safer to just avoid it than to try and fail in front of everyone."*

*Participant 5: "Sometimes, I get stuck on a problem and just give up because I don't want anyone to see me struggle. It feels like everyone else knows what they're doing, and if I mess up, it's just going to prove I'm not good enough. I think if we talked more about how making mistakes is part of learning, it wouldn't feel so bad. "*

As students progress in their education, this stigma can lead to avoidance behaviors, where they shy away from mathematics-related activities. They may feel embarrassed or ashamed when they do not understand a concept, further perpetuating their disengagement (Fortune & Spangenberg, 2023). This negative cycle can have long-term effects on their academic performance and self-esteem, making it crucial for educators to address the issue.

To reduce the stigma of mistakes, teachers can foster a classroom culture that values effort and learning over perfection. Encouraging collaborative problem-solving, where students work together and share their thought processes, can help demystify mistakes. By framing mistakes as valuable learning opportunities, educators can help students develop a healthier attitude toward mathematics and cultivate a more inclusive learning environment.

### *The Learning Opportunity in Mistakes*

Mistakes can serve as powerful learning opportunities in mathematics. When students encounter challenges and make errors, they have the chance to reflect on their thought processes and identify areas for improvement. Research shows that allowing students to experience productive failure can lead to deeper understanding and enhanced problem-solving skills as explained:

*Participant 1: "I used to hate making mistakes in math, but now I see it differently. When I get something wrong, it helps me figure out what I didn't understand. My teacher always says it's okay to make mistakes as long as we learn from them, and that's made a big difference for me. It makes me less afraid to try because I know I'll get better the more I practice."*

*Participant 3: "There was this one time I made a mistake on a math problem, and instead of just telling me I was wrong, my teacher asked me why I thought my answer was right. That made me really think about how I got there. Even though I didn't get it right, I felt like I learned more because I had to figure out where I went wrong. Now I don't mind making mistakes because it's helping me understand math better."*

*Participant 4: "I've noticed that when I make a mistake and then fix it, I remember it more than when I just get the right answer the first time. It's like, when you mess up and work through it, the lesson sticks with you longer. It also feels good when the teacher helps us look at mistakes like part of the process, instead of something bad. I think it makes me more confident to try harder problems now."*

Emphasizing the learning potential in mistakes encourages students to take risks and engage more fully with mathematical concepts. Rather than viewing mistakes as setbacks, students can learn to see them as stepping stones toward mastery (Lo & Hew, 2021). This shift in perspective can help reduce anxiety and build confidence, as students realize that their understanding can grow through trial and error.

Educators can facilitate this learning process by providing constructive feedback that focuses on the reasoning behind mistakes rather than merely pointing out errors. Encouraging

students to analyze their mistakes and explore alternative solutions can promote critical thinking and resilience. Finally, teachers can help students develop a more robust understanding of mathematics and a greater willingness to engage with challenging material.

### *The Importance of Growth Mindset*

A growth mindset is crucial for fostering resilience and perseverance in mathematics. Students with a growth mindset believe that their abilities can improve through effort and practice, making them more likely to embrace challenges and learn from mistakes. This mindset contrasts with a fixed mindset, where students view their abilities as static and are more likely to give up in the face of difficulty as mentioned:

*Participant 2: "I used to think I was just bad at math, like no matter how hard I tried, I'd never get better. But then my teacher talked about how it's more about the effort you put in. Now, when I don't understand something, I keep working on it, and it's helping. I've realized I can get better at math if I keep trying, and that made me less afraid of difficult problems."*

*Participant 4: "Before, if I didn't get a problem right away, I would just give up and think, I'm not a math person. But now I know that I can improve by practicing more. My teacher always tells us that it's okay not to get it right the first time, and that has helped me see mistakes as part of learning. I feel like I'm getting better because I'm putting in more effort."*

*Participant 5: "My mindset about math has totally changed. I used to think that if I wasn't good at something right away, it meant I never would be. But now, I set goals for myself and focus on how much I've improved, even if it's just a little. The more I work at it, the more confident I feel. I think the biggest change is that I believe I can get better, and that keeps me motivated."*

Research indicates that promoting a growth mindset can significantly impact students' attitudes toward mathematics (Kim, Schneider, & Yun, 2020). When students understand that effort and persistence lead to improvement, they are more likely to engage with the subject and overcome their fear of failure (Henry, Shorter, Charkoudian, Heemstra, Le, & Corwin, 2021). This shift can lead to increased motivation and a more positive learning experience.

Educators can cultivate a growth mindset by emphasizing the value of effort and progress over innate ability. Celebrating small achievements and encouraging students to set personal goals can help reinforce this mindset. By providing opportunities for self-reflection

and goal-setting, teachers can empower students to take ownership of their learning and develop a more resilient approach to mathematics.

### *The Role of Teacher Support*

Teacher support plays a vital role in shaping students' learning experiences in mathematics. Educators who create a safe and nurturing environment can significantly reduce students' anxiety and fear of failure. When students feel supported, they are more likely to engage with challenging material and take risks in their learning as described:

*Participant 1: "My math teacher is really supportive, and it makes a huge difference. When I don't understand something, she always takes the time to explain it in a different way until I get it. It makes me feel like it's okay not to know everything right away. Knowing I can ask questions without feeling judged has made me more comfortable with math, even when it's hard."*

*Participant 2: "One thing I really appreciate is that my teacher gives us extra resources when we're struggling. I used to be too shy to ask for help, but now I feel like it's okay because she always reminds us that everyone learns differently. I've started to ask more questions, and I don't feel as anxious when I don't get something right away. It feels like she actually cares about us doing well, not just finishing the work."*

*Participant 4: "My teacher always encourages us to keep trying, even when we make mistakes. She says that mistakes are just part of learning, and that helps me not feel so bad when I get something wrong. She even talks to us about how to handle stress and stay confident, which has been really helpful for me. I used to be really nervous in math class, but now I feel like I can handle it because I know she's there to support us."*

Effective teacher support involves recognizing individual students' needs and providing tailored guidance (Ruppar, Kurth, Bubash, & Turner, 2022). This can include offering additional resources, differentiated instruction, and fostering open communication. By being approachable and encouraging, teachers can help students feel comfortable seeking help and expressing their concerns about mathematics. Moreover, teacher support can extend beyond academic guidance. Educators can help students develop coping strategies for managing anxiety and building confidence in their mathematical abilities.

### *Emergent Model*

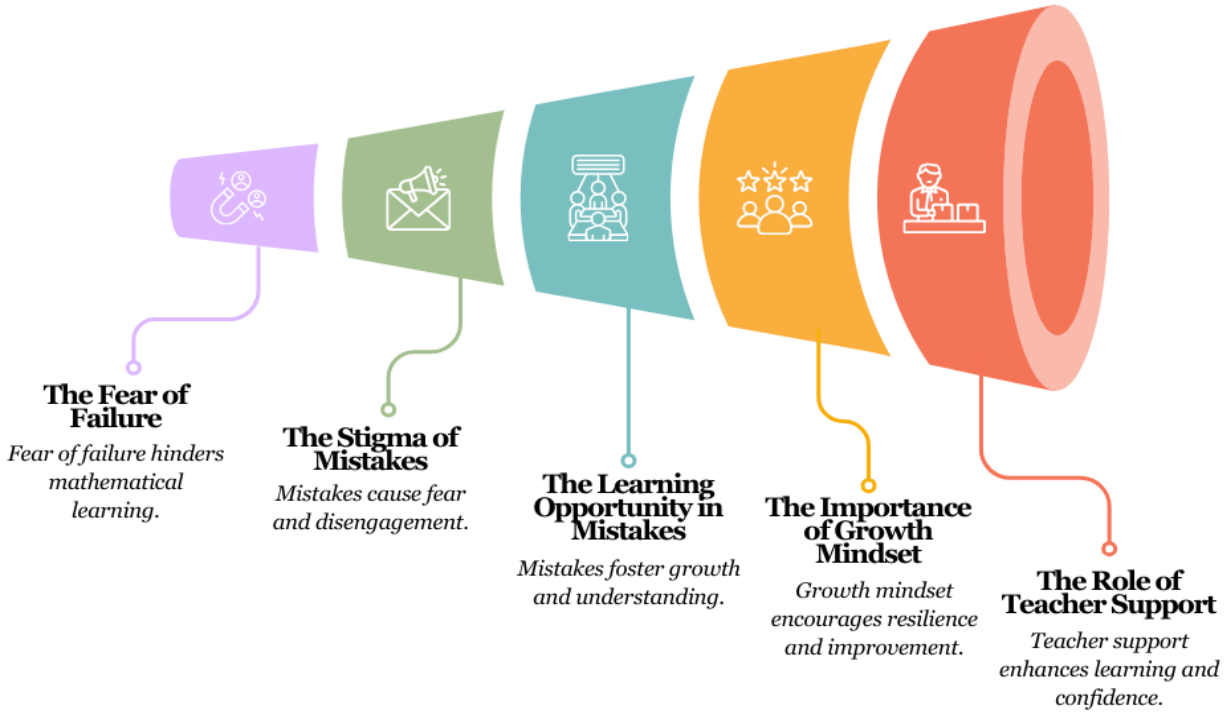
A model emerged that highlights the interplay between fear, stigma, and growth opportunities. At the broadest level, students' fear of failure emerges as a significant barrier to their engagement with mathematics. This fear, fueled by societal pressures and an educational environment that emphasizes high-stakes testing, creates a paralyzing effect on students. They frequently associate failure with a lack of intelligence, leading to heightened anxiety and a tendency to avoid challenging math problems. This aversion is compounded by the educational system's tendency to stigmatize mistakes, reinforcing the notion that errors are unacceptable and a mark of failure. Students internalize this stigma, resulting in avoidance behaviors and a diminished willingness to participate in math-related activities.

As the focus narrows, the stigma surrounding mistakes reveals itself as a critical factor that exacerbates the fear of failure. Students often experience embarrassment and shame when making errors, a sentiment rooted in past negative experiences with incorrect answers. This stigma prevents them from engaging fully in classroom discussions and trying challenging problems. The negative reinforcement received in earlier educational experiences perpetuates a cycle of disengagement and reluctance to take risks. However, when mistakes are framed as learning opportunities rather than failures, students can start to shift their perspectives. This approach encourages them to see errors as valuable feedback rather than personal shortcomings, thereby reducing the fear associated with making mistakes.

At a more focused level, the concept of a growth mindset emerges as a transformative factor in mitigating the negative effects of fear and stigma. Students who embrace a growth mindset view their abilities as malleable and improvable through effort and practice. This perspective fosters resilience and a more positive attitude toward challenges and mistakes. Educators play a pivotal role in nurturing this mindset by creating supportive learning environments that celebrate effort, provide constructive feedback, and encourage students to learn from their errors. By emphasizing the value of perseverance and helping students understand that mistakes are an integral part of the learning process, teachers can empower students to overcome their fear of failure, reduce the stigma surrounding errors, and engage more confidently with mathematics.

**Figure 1.**

*Unlocked Power Funnel Model of Productive Failure in Mathematics Education*




## Conclusion

The findings of this study underscore the significant influence of the productive-failure approach on students' learning experiences in mathematics. The emergent themes—fear of failure, stigma of mistakes, growth mindset, and teacher support—reveal the interconnected nature of these factors in shaping students' attitudes and behaviors. The fear of failure and the stigma of mistakes create significant barriers to learning, while the growth mindset and teacher support can foster a more positive and productive learning environment. These findings highlight the importance of addressing these factors to create a more inclusive and effective mathematics education for all students.

## Recommendation

Based on the results of this study, the following recommendations can be made to improve the implementation of the productive-failure approach in mathematics education:

1. *Create a supportive learning environment:* Educators are encouraged to strive to create a classroom culture that fosters a growth mindset, encourages risk-taking, and values effort over perfection.
2. *Promote a growth mindset:* Teachers can cultivate a growth mindset by emphasizing the role of effort and practice in improving abilities. Teachers need to celebrate small achievements, provide opportunities for self-reflection, empower students to believe in their potential, and persevere in the face of challenges.
3. *Provide effective teacher support:* Teachers need to be equipped with the necessary skills and resources to provide academic support to students. This includes offering additional resources, differentiated instruction, and creating a safe and inclusive classroom environment.
4. *Integrate the productive-failure approach into curriculum and instruction:* The productive-failure approach may be intentionally integrated into curriculum and instruction to ensure that students have ample opportunities to experience failure as a learning opportunity. This can involve designing tasks and activities that promote critical thinking, problem-solving, and resilience.
5. *Conduct further research:* Additional research is needed to explore the long-term effects of the productive-failure approach on students' learning outcomes, attitudes, and beliefs. Investigating the implementation of this approach in different educational contexts can also provide valuable insights for policymakers and educators.

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