THE IMPACT OF PRODUCTIVE FAILURE ON CULTIVATING GROWTH MINDSET IN LEARNERS

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This paper discusses the impact of productive failure (PF) interventions on cultivating a growth mindset among eighty-four second-year learners enrolled in the Diploma in Engineering with Business (DEB) who studied for a 30-hour, creative-focused learning unit during their first semester. The narrative is based on observations that most learners approach problem-solving with a "solution-first" mentality, often prioritising quick solutions and avoiding challenges owing to a fear of failure, which hinders their capacity for creativity. Previous observations indicate that fear of failure is widespread among learners and might lead to fixed mindsets, taking on a risk-averse approach in creative problem-solving. PF interventions, such as individual journals, design thinking methodologies, and collaborative activities, were implemented to motivate learners to embrace challenges and learn from their mistakes. At the end of the learning unit, the learners engaged in a reflective writing exercise employing the PEEL (Point, Evidence, Explanation, and Link) methodology to assess the effectiveness of these interventions. The learners' reflections offered evidence and explanations that highlighted the effectiveness of PF interventions in increasing their self-efficacy, motivation, and willingness to tackle innovative challenges, eventually enhancing their creative problem-solving abilities. These positive outcomes highlight the importance of cultivating a growth mindset in learners by implementing PF interventions, emphasizing the problem-solving process and reframing failure as a learning opportunity. A checklist was used to identify aspects of the learners' reflections that demonstrate the benefits of the various activities in promoting collaborative teamwork among learners with varying abilities, and how user-centric design methodology serves as the primary framework for developing the creative-focused curricula, equipping the learners with essential tools and skills necessary for creativity, as well as fostering a growth mindset crucial for lifelong learning. Future consideration may include investigating the sustained impacts of these interventions and explore their long-term influence on learners' attitudes towards failure, self-efficacy, and motivation over time. Other possibilities include the integration of PF interventions and design thinking methodology with other pedagogical approaches, such as problem-based learning and project-based learning, to uncover potential synergistic effects of combining different instructional strategies in fostering a growth mindset and enhancing creative problem-solving abilities.

Keywords: *productive failure, growth mindset, learning environment, self-efficacy*

Introduction

Singapore's Minister for Education, Mr. Chan Chun Sing, delivered a parliamentary speech in which he stated, "Each and every setback is also a learning opportunity for our children to build resilience. We must retain space for our children to try, fail, take responsibility, and bounce back from setbacks", Sing (2024). This paper closely aligns with the ministry's aim of "Reimagining the Future of Education."

This paper focuses on an Innovation & Enterprise (I&E) learning unit centered on ideation for second-year DEB learners. During the first lesson, it was observed that the majority of learners approach problem-solving with a "solution-first" mentality, often prioritising quick solutions and avoiding challenges. This is a recurring observation in numerous learning units, particularly in units that require learners to address open-ended challenges that lack a singular solution. This inherent tendency of most learners can be attributed to their fear of failure. As expressed by a learner, "Before this module, I felt scared of not finding a suitable solution. This drives my inclination to prioritise finding solutions quickly without fully understanding a problem". This tendency will subsequently impede their preparedness to address ambiguous challenges or to explore other problem-solving approaches. Another learner confirmed this tendency towards seeking for known solutions or easier options, "I went on to find problems that I already knew had a viable solution so I can feel more confident when pursuing the project. However, by doing so I did not understand the problem truly".

Pedagogical interventions were sought to shift this fixed mindset because innovation thrives on experimentation and learning from setbacks. The objectives were not merely to impart I&E competencies

but to cultivate a growth mindset that encourages learners to see challenges as opportunities and failures as integral parts of the learning process. Productive Failure (PF) interventions, where learners are encouraged to tackle challenging issues before receiving direct instruction, emerged as a promising approach. This paper reflects the effect of these interventions, and the qualitative shifts observed in the learners' approaches and reflections.

Literature Review

The challenges observed in learners, as previously described, are well-researched and documented in educational research. Whittle et al. (2020) found that post-secondary education learners frequently experience a fear of failure, which subsequently impedes their learning process. Learners will develop a fixed mindset when they view failures not as opportunities for growth but as personal flaws. They will then define themselves by academic achievement and avoid challenges, which in turn discourages creative thinking and risk-taking, as discussed in several places (e.g., Fishman and Husman, 2017; Arnett, 2022).

Yeager et al. (2019) concluded that in contrast to the expectations of individuals with a fixed mindset, those possessing a growth mindset exhibit a profound desire for self-improvement and continuous learning. They believe that creativity is not an inherent attribute but can be developed by effort. Karwowski (2014) observed that these learners display more commitment to completing creative assignments that usually result in innovative solutions. Dweck and Yeager (2021) found that academic achievements can be improved if the interventions are designed to promote a growth mindset particularly when supported by peer attitudes. Yalçın and Dinler (2022) mentioned that it is important to foster a growth mindset in learners to equip them with vital 21st-century competencies such as flexibility, adaptability, and the ability to view mistakes as learning opportunities.

The interventions aimed to support the learners to understand the process of problem-solving, the tools required to generate multiple ideas, and to explore for possible solutions without providing them with the final solution in advance. This strategy incorporates the findings of Kapur's (2008) work on productive failure, which demonstrate that learning can occur even when learners initially struggle without support structures. Kapur (2016) discussed designing tasks to "activate and elicit their prior knowledge, albeit suboptimal or even incorrect" even if learners haven't formally learned the concept yet. Buseyne et al. (2023) concluded that PF is a great way to "activate learners' prior knowledge" and form new experiences for later reflection.

Materials and Methods

In our approach, the PF-inspired interventions commenced during the initial problem-solving phase and continued through the idea creation, exploration, and solution prototyping stages. These interventions were designed to provide the following key strategies.

Emphasise divergent thinking exploration strategy: The first key strategy underpinning the PF interventions was to actively encourage exploration rather than allowing learners to seek immediate solutions. This was facilitated by providing the learning unit with open-ended challenges derived from the UN's 17 Sustainable Development Goals (SDGs). These SDGs provided an authentic context, presenting real-world issues often outside the learners' direct experience, which inherently lacked simple, pre-defined answers and this aligns with the principles of authentic learning, which argue that learning is most effective in real-world contexts as concluded by Frey et al. (2012).

The learners started their problem-solving approach by conducting exploration works, as the challenges provided by the SDGs were open-ended. The interventions were designed to encourage the learner to explore a variety of approaches rather than settling on a single “correct” one. To further prioritize exploration, the initial weeks of the learning unit deliberately enforced a "no solutions" period using techniques such as brainstorming and the 5W1H Method. This period was designed to specifically conduct broad exploration, encouraging the generation of numerous potential ideas and connections related to the SDG issues. This method requires learners to focus exclusively on comprehending the issues through user research and utilizes divergent thinking tools that encourage investigations prior to attempting to develop solutions. Consequently, the method actively opposes the tendency to converge into a “solution-first” approach.

Provide user-centric investigation tools and reflective practice: The second key strategy is to employ specific design thinking tools, including Empathy Maps, Personas, and How Might We Questions, to guide the learners with a deeper understanding of user's experience and the issues facing the user before they begin to develop solutions. McCurdy et al. (2020) concluded that design thinking activities are effective in fostering empathy and STEM integration in the classroom and that learners are more motivated and engaged in finding solutions that truly address real-world problems that they care about. Consequently, the first few lessons prioritised exploration and understanding the user’s needs, deliberately positioning them as investigation rather than immediate problem-solving approaches.

Complementing these tools, reflective practices were designed to develop the learners’ metacognition ability through learning from the process. They are, as a team, required to document their work, including team discussions and sketches captured from the whiteboard activities which formed a project journal. As individual, the learners are required to maintain a reflective journal that document their weekly progress and setbacks. Dickerson and Clark (2022) concluded that using these reflective interventions contribute to self-regulatory and self-awareness behaviours when practiced regularly because they require the learners to constantly plan, monitor, and assess their understanding and performance.

These requirements ensure that learners actively process their experiences, linking the user-centric investigation and iterative cycles back to their own

learning and mindset development which strongly aligns with the research on reflective practice that assist in developing the learners' metacognition, self-regulation, and motivation. Erickson et al. (2021) concluded that the reflection interventions work well for learners with low individual interest in developing academic motivation.

Create a Supportive Environment for collaborative work: The third key strategy focused on creating learning spaces that supports collaborative learning experiences by providing access to tools and resources for experimentation and prototyping. This is a deliberate act of moving away from traditional teaching environments, where learners are seated in front of a tutor during the lesson. Kariippanon et al. (2019) observed that group work flourishes in flexible and adaptable collaborative learning spaces that allow for ease of movements among the learners to interact and communicate and have easy access to information. Lessons were conducted in Makersnode, utilising its long whitewall. Learners must write and sketch their thoughts, ideas and points of discussion solely on the whiteboard and assess their laptops only to gather information. The whiteboard facilitates verbal and visual communication, and the resulting vigorous discussions fostered a dynamic, engaging, and productive learning environment, promoting shared ownership of ideas even among members who are more reserved. Ritchhart et al. (2011) argued that making thinking visible through writing and sketches can facilitate deeper learning and metacognition.

The learning unit curriculum provides activities that allow the learners to collaboratively identify, develop, and effectively communicate their design solutions using a low-fidelity prototype. These activities were conducted in Makerspace using the necessary tools and resources for hands-on experimentation, allowing teams to integrate personal and interpersonal skills with prototype-building skills. These activities offer learners a variety of design-implement experiences as they are required to refine their solutions iteratively through feedback and testing. In this phase, the tutors acted as facilitators, stepping away from direct instruction and adopted a facilitative role. They provided guidance by asking probing questions and empowering learners to address the challenges themselves. The environment needed for these PF interventions was created by the combination of dedicated collaborative spaces and a facilitative teaching approach.

Results and Discussion

At the end of the learning unit, each learner completed a reflective writing exercise. This exercise is to gather their responses to how they overcame challenges and failures, the crucial lessons they learnt, and their approach to problem-solving during the learning unit. The responses, supplemented by the tutors' observations, indicate that the interventions were effective in cultivating a growth mindset in the learners. They acknowledged the significant role of failure in the learning process by embracing a problem-first, user-centered approach to problem-solving.

The tutors' observations revealed some positive outcomes due to the implemented interventions, and these outcomes were categorised into six primary themes. Based on these themes, a checklist was developed to systematically analyse the learners' responses and validate the impact of the interventions. The objective of the checklist is to identify alignments between the PF intervention experiences and these observable outcomes. The analysis of the outcomes in the first two themes found evidence of shifts in mindset and approach, while the outcomes in the remaining four themes indicated increased learners' cognitive and interpersonal skills.

Reframing Failure to Increase Learner's Self-Efficacy and Motivation: The interventions produced the most significant shift observed when the learners began to reframe failure as a learning opportunity. This mindset change is crucial, as it gave the learners improved confidence and self-efficacy so they could tackle and overcome difficult and ambiguous challenges. They are then able to handle failure better whenever they experience setbacks. The observed mindset shift strongly connects to Dweck (2016) and Yeager et al. (2019) growth mindset theory, which advocates for perseverance and dedication. Crucially, learners began to articulate this value, demonstrating they were embracing failure as intended by the PF strategy.

Most of the problem-solving activities involved iterations, and they inherently involved failures or setbacks. As one learner reflected, "I understand the importance of learning and that failures are ways that we can learn... Failures can help us improve and refine our work." This iteration process provides the best opportunities for learners to use their newly founded perspective of viewing failure as learning opportunities to work towards achieving the best possible solution, as recognised by a learner that "failures provide important insights into what didn't work, allowing us to make better choices for the final solution".

A learner displayed a growth mindset trait when he valued the repetitive process of iteration to improve his potential solution and not just seek to complete the task when he remarked, "...after we found out that the solution doesn't answer the pain points of users, I then proceeded to scrap the idea... As tedious as it might sound, every time I restart, I had a better understanding of what I want in the prototype." Dorland (2023) determined that it is important to provide learners with meaningful and impactful learning experiences that are critical for developing a failure-positive mindset, and the learners' reflective thoughts resonate with Dorland's study. The learner's ability to reframe failure by turning setbacks into motivations to seek better understanding and improvement is strongly linked to increased self-efficacy.

Significant Move Towards a Problem-first Approach: Many teams began discussions regarding potential solutions before fully investigating the problem, leaning towards readily available options or reverse engineering existing solutions. This "solution-first" mentality can lead to trivial solutions that fail to address user needs as they lack the necessary depth to have a substantial influence on the issues. During the first few lessons, a "no solutions" requirement was enforced, and it was

mandatory for learners to use empathy tools in their work. These interventions were effective in fostering a significant change towards a problem-first approach and greater user-centricity. Learners explicitly reflected on this shift: "Compared to the start of the module, understanding the problem and exploring multiple ideas led me to better solutions". The traits of a growth mindset were evidence when the learners expressed understanding and willingness to explore multiple ideas. Another reflected a shift from wanting quick answers to valuing the process of understanding by writing "...it was okay not to be able to solve the complex problems as long as they tried various ways of solving them...".

Some learners demonstrated an appreciation for empathy by mentioning "...sympathising with users is crucial when creating solutions." This heightened appreciation can partly be attributed to the use of design thinking tools like empathy maps and personas. This appreciation enables the learners to have a deeper engagement with the challenges posed by the UN's SDGs, resulting in more meaningful and effective work as they work on tackling the issues. The strategy of encouraging exploration and experimentation exposed learners to an authentic and realistic experience of the design process, where setbacks and failures are common. As pointed out by Frey et al. (2012), the questions, tasks, or problems related to the SDGs have value and interest beyond the classroom and into the real world of learners' values, abilities, and motivations.

Increased Confidence in Critical Thinking and Decision-Making: The PF interventions, as previously discussed, allowed the learners to engage in a systematic problem-solving process that required them to engage deeply with complex problems. Their confidence in critical thinking and decision-making ability was enhanced by their success in collaboratively iterating on solutions. As one learner articulated, "Building a solution via a prototype with my teammates makes me feel more confident in my ability to analyse information, evaluate different options, and make informed decisions." This shift in learners having a growth mindset was built upon the first requirement of engaging in a problem-first approach, and the cycle was completed when they engaged in the impactful iterative process of collaborative prototyping.

This learning unit was designed to empower the learners to engage directly in the learning process via the various active learning methods, such as teamwork, discussions, experimentation, prototyping, and reflection. Ryan and Deci (2000) mentioned that when learners experience autonomy and ownership over their learning, they are likely to be intrinsically motivated, leading to greater engagement and persistence. As reflected by a learner, "If this was an individual project, I would not have been able to open my eyes and see the problems with my initial solutions which were made possible through the discussions with my group members." The evidence suggests the hands-on, team-based PF interventions provided a practical and effective avenue for developing and applying these higher-order thinking skills with growing confidence.

Enhanced Collaboration and Teamwork Skills: The PF intervention required the learners to work in a team where they, at times, struggled to match each other's expectations. They are forced to acquire receptive mindsets to adapt to their teammates' different perspectives. The interventions' collaborative requirements and support from a positive learning environment, like the Makerspace for hands-on work and a whiteboard for shared discussions, enhanced the learners' interpersonal skills. Learners explicitly linked the PF activities to skill development, with one stating, "working in a team and iteratively on our prototype has helped me develop valuable collaboration and problem-solving skills."

It was observed that the requirements and experience of doing collaborative iterations and problem-solving enable the teams to develop their own constructive team processes. Many teams practised different approaches when navigating challenges or when they faced negative feedback or disagreement, as reflected by one learner, "...we come together to discuss how whether to keep it or how we can work it out. This approach helped us to better understand each other." This reflection demonstrates how the PF interventions strengthened both teamwork capabilities and mutual understanding.

Improved Communication and Conflict Resolution: Ritchhart et al. (2011) concluded that the need to articulate ideas and reasoning during discussions and whiteboard use aligns with visible thinking strategies promoting more profound understanding, which in turn reduces possibilities of conflicts. Kapur (2016) mentioned that providing opportunities for explanation and elaboration is also a core principle of PF design. The PF interventions had fostered essential interpersonal skills for effective teamwork, such as active listening and constructive conflict resolution, with an increase in openness and patience in managing team dynamics. One learner highlighted this development, "A significant learning opportunity was handling my classmate's recurring ideas... I learned to value not disregarding anyone immediately. From this situation, I enhanced my skill in actively listening... This experience showed me the importance of being patient and open-minded when communicating." This mindset supported constructive approaches to disagreements, with teams learning the value of dialogue, as reflected by another learner: "...when there is bad feedback, as in someone disagrees... we come together to discuss... This approach helped us to better understand each other…."

Appreciation for Diverse Skills and Perspectives: McCrae and Costa (1997) suggested that learners in teams that work together with a high level of openness and acceptance are more willing to explore new ideas and experiences that engage their intellectual curiosity, aesthetic sensitivity, and emotional engagement. The PF interventions require learners to work together in teams with members of different abilities, perspectives and motivations. To successfully create a solution to the challenges posed by the UN's SDGs, the learners must learn from others and not just rely on their own innate ability. The successful teams were those who recognised the value diverse inputs bring to the innovation process,

which enhanced both collaboration and critical thinking and illustrated a growth mindset.

The teams learned to value the need to adapt to their peer's input and to recognise the value of different viewpoints within their team, as reflected by one learner when he wrote, "...when my teammates elaborated on why my idea may not be useful, and I heard their ideas which were more logical... it made me realise there are many ways of interpreting the problem."

Conclusions

This paper records the significant outcomes of implementing Productive Failure (PF) interventions within a creative-focused learning unit, designed to overcome the learners' "solution-first" mentality approach while working on a challenge due to their fear of failure . The learners' end of learning unit reflective writing offer valuable qualitative evidence to strongly conclude that the implemented interventions were effective in fostering a growth mindset. These interventions involve employing user-centric Design Thinking tools to prioritise exploration in addressing authentic SDGs challenges, coupled with reflective practices such as maintaining project journal, and conducting lessons in a supportive, collaborative environment with tutors acting as facilitators.

The most significant outcome of the interventions is the learners' positive shift in their attitudes towards failures and setbacks, perceiving them not as obstacles to be feared but as valuable and productive learning opportunities that enhanced their self-efficacy and motivation. This new mindset results in a significant shift in their problem-solving approach, when learners value deep understanding of the issues prior to the ideation stage. The learners worked through setbacks by conducting several iterations through the process, with the conviction that failures provide important insights. The learners also attributed their increased confidence in analytical and decision-making abilities to the various collaborative learning experiences that foster communication and conflict resolution, and appreciating diverse perspectives.

These outcomes, as documented in the learners' reflective writings, emphasize the value of PF-inspired pedagogy. The learning unit provides the learners with a safe learning environment for exploration, challenges, struggle, and reflection. The lessons learnt show that educators can move beyond traditional teaching methods to create educational practices that empower learners to embrace challenges, learn from mistakes, and develop the essential skills that align with the broader educational goals centred on lifelong learning and resilience. While future research may investigate the implementation of these interventions and assess their long-term effects on learners' mindsets and creative problem-solving abilities, this paper offers strong qualitative evidence for the significant positive effect of Productive Failure in transforming the learning experience.

Acknowledgements

The author would like to express gratitude to the management of the School of Engineering for their unwavering support and valuable feedback throughout this project. Additionally, heartfelt thanks are extended to the colleagues from the Centre for Innovation & Life Skills for the use of the facilities in Makerspace and Makersnode. Their collaboration and resources established a crucial foundation for the practical aspects of this work.

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