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# Enhancing teachers' design thinking mindsets through reflective practice: Cultivating innovation in an upskilling STEAM training program

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**Abstract**

Promoting innovation in education through enhanced design thinking (DT) mindsets among teachers is a central goal. This study examines the use of reflective practice within an upskilling STEAM training program to achieve this enhancement. The upskilling training initiative examined in this research encompasses a ten-week instructional session characterized by a hybrid learning methodology under the guidance of an instructor. An explanatory mixed method design is employed, starting with a quantitative method (teachers' survey) followed by a qualitative method (focus group discussion). The participants were in-service K-12 teachers (n = 55) from charity schools across Northern Emirates in the United Arab Emirates. The main results demonstrate that reflective practice significantly contributed to developing teachers' DT mindsets, fostering empathy, creative confidence, and the ability to navigate uncertainty. Teachers reported increased confidence in guiding students through open-ended problem-solving tasks and adapting their instructional strategies to address feedback from students and peers. This research highlights reflective practice's transformative potential in elevating teachers' DT mindsets. For example, through iterative reflection, teachers were better equipped to design STEAM challenges that connect with real-world problems, allowing students to apply creativity and critical thinking. It demonstrates the link between the upskilling STEAM program and the cultivation of innovative teaching methods, equipping educators to nurture creativity and problem-solving skills in students, thereby enriching education.

**Keywords:** social psychology, design thinking mindsets, reflective practice, innovation process

## INTRODUCTION

The education system reform in the United Arab Emirates (UAE) is one of the main goals of the country's national agenda 2030 (UAE, 2017). Accordingly, goals and objectives for a new transformation in education were stated. The UAE government allocates a significant share of the federal budget to develop the education system annually to provide quality education (UAE, 2017), where focusing on building a high-quality education and training system became essential to ensure that the youth of the UAE receive the best education possible (McKnight et al., 2016). However, the teaching profession in the UAE is characterized as a "backup plan" for those who cannot attain high-skill level employment, which in turn leads to a shortage of qualified teachers (McKnight et al., 2016). Various teaching training programs were available in the UAE to cater to the growing demand for quality teachers and provide a better understanding of the learning needs. In particular, charitable schools in the UAE face unique challenges, often due to limited resources and funding, which distinguish them from public schools. These schools, primarily serving underprivileged communities in different Emirates across UAE, including Dubai, Sharjah, and Ajman, have fewer opportunities for professional development and access to advanced teaching tools, especially when implementing STEAM education. Teachers in charitable schools are often required to innovate with fewer resources, making it more challenging to integrate STEAM effectively than their public school counterparts. This distinction highlights the critical need for tailored training programs like the one explored in this study to address


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**Contribution to the literature**

- This paper highlights the role of reflective practice in enhancing teachers' design thinking (DT) mindsets, especially in resource-limited educational settings.
- It provides insights into how an upskilling STEAM training program can foster essential Design Thinking Mindsets among in-service teachers, demonstrating the transformative potential of reflective practice for both teacher development and classroom innovation.
- The study offers scalable strategies tailored for under-resourced schools, helping educators build the skills needed to engage students in critical, real-world problem-solving activities.

these challenges and support these teachers in implementing STEAM pedagogy.

Importantly, there is a notable requirement to enhance the professional growth of educators, utilizing an approach that aligns more closely with constructivist principles. Moreover, proficient teachers who prioritize pedagogical elements enabling their professional advancement are of significant import (Fernández-Batanero et al., 2020). As a result, the integration of these pedagogical concepts into practical propositions suitable for integration into teacher training or upskilling programs emerges as crucial (Fernández-Batanero et al., 2020). In reference to the current study's program, the term "upskilling" was specifically chosen to differentiate it from the concept of "reskilling." The objective of the upskilling training program is to cultivate an elevated level of expertise across a defined spectrum of competencies encompassing skills, attitudes, and knowledge. This approach facilitates the enhancement of educators' capabilities, fostering both personal and professional growth (Cedefop, 2020). In contrast, reskilling focuses on equipping employees with the specific skills required for new roles, limiting the scope of training to addressing immediate skill demands (Cedefop, 2020). ElSayary (2023) stated that the teachers' upskilling training program could enhance teachers' growth mindsets when they are provided with opportunities to reflect on their practices, receive constructive feedback, collaborate, and develop innovative solutions for their challenges. Design thinking (DT) is a complex and continuous innovation-led process requiring individual and organizational creativity. This approach places a central emphasis on human-centered methodologies, aiming to energize, stimulate, conceptualize, and actualize novel concepts that uphold the principles of enduring progress (Dosi et al., 2018). Reflective practice significantly influences the trajectory of DT, ensuring its seamless progression and propelling individuals and entities toward the pinnacle of innovation referred to as "transformation." The underlying principle of DT involves actively involving individuals in the identification of real-world predicaments, experimental trials, impact assessment, and collaborative product development, all geared toward devising effective solutions (Androutsos & Binia, 2019).

The significance of this study lies in its potential contribution to both teacher education and STEAM education. By addressing the research questions, this study provides insight into how reflective practice can foster DT mindsets among teachers, a key element in promoting innovation in classrooms. The outcomes of this research will help fill a gap in the literature regarding professional development programs tailored for teachers in under-resourced educational environments, like charitable schools in the UAE. Furthermore, it highlights how STEAM training programs can be adapted to such contexts, providing scalable strategies for other schools facing similar challenges. Ultimately, the study contributes to a better understanding of how teacher training programs can be designed to cultivate innovative, reflective educators capable of nurturing creativity and problem-solving skills in students, thereby enriching education as a whole.

Accordingly, this study aims to enhance teachers' DT mindsets through reflective practice in order to cultivate innovation in an upskilling STEAM training program. This study seeks to answer the following questions that would fulfill the study's main purpose: To what extent does cultivating a DT mindset through reflective practice contribute to teachers' ability to generate innovative ideas in the context of an upskilling STEAM training program?

1. How does incorporating reflective practice in an upskilling STEAM training program impact teachers' DT mindset?
2. What are the best practices and strategies for effectively integrating reflective practice and DT mindset development in an upskilling STEAM training program for teachers?

According to the research questions, the following hypotheses were proposed:

**$H_1$.** The participants' mean score was above average after the training, $m > 4$.

**$H_0$.** The participants' mean score was not above average after the training, $m \leq 4$.

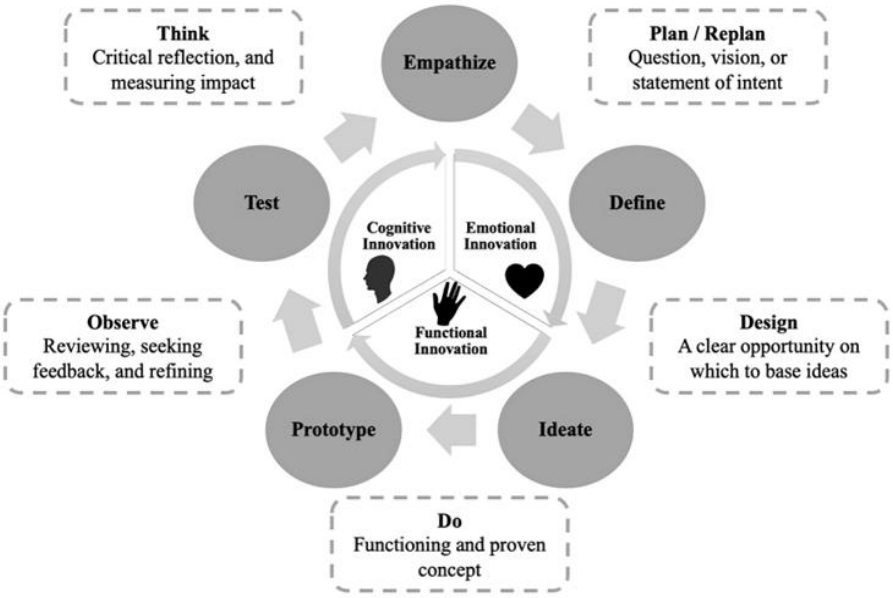


**Figure 3.** A proposed model of innovation-led DT integrated with a reflective practice model adapted from ElSayary (2021)

## LITERATURE REVIEW

### Conceptual Framework

*Social psychology*, the backbone of this study, can explain the strengths and limitations of individuals' thoughts, feelings, and attitudes to approach the process of innovation or change and develop growth mindsets. Spencer and Myers (2006) defined *social psychology* as the "scientific study of how people think about, influence, and relate to one another." In 1954, Gordon Allport stated that *social psychology* understands and explains how people's thoughts, feelings, and behaviors are influenced by other individuals' actual, imagined, or presence (Thompson & Schonthal, 2020). Finally, Baron et al. (2006) defined *social psychology* as the scientific method to understand the cause-and-effect of individuals' behavior and thought in social situations. The social psychology principles influence how to design thinkers approach the process of innovation and influence how users respond through reflective practice and systematic reasoning. Based on the literature presented, **Figure 1** shows the framework proposed and used to guide this study.

The model focuses on a human-centered approach where the emotional, cognitive, and functional innovations are interconnected and presented at the center. Emotional innovation presents the individuals' motivation, collaboration, and communication. Individuals should understand the current education landscape in consultation with the educational organization. Cognitive innovation presents critical reflection, reviewing, analyzing, and seeking feedback to measure the impact. The individuals identify needs, challenges, and constraints in the current system. Functional innovation presents the creation and testing of ideas. This could include reimagining new roles in the current context and for the future, where considerations of the different groups' roles and the use of technology enhance educational opportunities.

The second stratum is the DT process (empathize, define, ideate, prototype, and test), influenced by a cycle of reflective practice that ensures the continuity of the DT process. The reflective practice is adapted from a study by ElSayary (2021) to include five main steps: plan/replan, design, do, observe, and think. This process is considered the checking point for individual reflections during the design process. In other words, it is integrated with the design process, where reflection and improvement occur after each step to ensure the sustainable development of the ideas. In the following section, the literature review of the model is explained in more detail.

### Design Thinking as Reflective Practice

DT is an interdisciplinary approach to innovation that places humans at the center. It draws inspiration from the methods designers employ to comprehend human needs, engage in rapid prototyping, and generate inventive concepts that can potentially transform the development of products, services, processes, and entire organizations (Johansson-Sköldberg et al., 2013). In recent years, the application of DT has gained momentum in teacher education, where it has been used to promote creativity, problem-solving, and student-centered pedagogies (Hubbard & Datnow, 2020; Naseem & Crichton, 2022). However, despite its growing use, limited empirical research critically examines its long-term effectiveness in educational settings. Critics argue that DT is sometimes viewed as a "one-size-fits-all" approach that may oversimplify complex educational challenges (VanGronigen et al., 2022), particularly when applied to deeply entrenched systemic issues (Markula & Aksela, 2022).

Those who adopt DT and their respective organizations can utilize insights derived from social psychology to inform and strengthen the DT process. This approach is founded on four fundamental principles: observation and perception, framing and reevaluation, envisioning and creation, and realization and experimentation (Klenner et al., 2021). The initial principle of observing and perceiving involves a cognitive strategy that prompts design thinkers to undertake three mental actions: relinquishing preexisting cognitive perspectives, inductively learning through inferences, and identifying patterns. Framing and reframing involve setting social and emotional goals that highly motivate individuals to develop and experiment with the products that meet people's needs. Imagining and designing are the heart and soul of the DT process that involves examining the practice of group brainstorming (Klenner et al., 2021). This creative process requires social interactions in designing and imagining several ideas (Razali et al., 2022). Finally, Making and experimenting is the final step in narrowing the ideas. This step involves the practical application of designing the most useful ideas. Reflection is considered an essential part of the process that helps in understanding the strengths and limitations of the products and the individuals' influence on the success of the projects (ElSayary, 2021; Klenner et al., 2021; You, 2022).

However, potential limitations of DT in education should be considered. Critics have noted that while DT emphasizes iteration and creativity, it can be resource-intensive, requiring considerable time and effort to train educators, develop prototypes, and refine ideas (Naseem & Crichton, 2022; Parker et al., 2020). Furthermore, the ambiguity and openness of the design process can be overwhelming for educators who are more accustomed to traditional, structured approaches to problem-solving (Reigeluth & Honebein, 2020). Without sufficient support and training, some teachers may struggle to implement DT effectively in the classroom (Razali et al., 2022).

DT seeks to go beyond the immediate confines of a problem in order to guarantee the proper interrogation of pertinent questions. This approach employs divergent thinking to generate many potential solutions and convergent thinking to refine the scope toward the optimal solution (You, 2022). The advantages associated with DT encompass the ability to examine an issue from various angles, delve into its depths, harness innovative thought and inventive means of solving problems, ensure that outcomes align with objectives and stipulations, and promote the iterative process of refining and redeveloping. While these advantages are often celebrated, some critics caution that the highly iterative nature of DT may lead to a lack of focus or direction in projects, particularly if clear goals are not established early in the process (Wardrip & Herman, 2020). In the context of teacher education, educators may require additional scaffolding to manage this ambiguity and translate it into actionable outcomes for their students.

In essence, DT epitomizes an exceptionally innovative approach to problem-solving, contingent upon a distinct frame of mind. You (2022) mentioned that DT could be part of the innovation drill through the following steps:

(1) involving design thinkers from different qualifications,
(2) following the human-centered approach,
(3) creating an expectation of rapid testing, experimenting and prototyping and measuring progress,
(4) looking for opportunities to create web networks,
(5) managing short-term ideas and long-term ideas,
(6) rethinking the funding approach,
(7) finding talents and hiring from interdisciplinary programs, and
(8) planning assignments and designing for an innovation cycle.

Despite these promising steps, it is important to remain cautious about over-reliance on DT to solve all educational challenges, as the approach may not fully address systemic inequities or deeply entrenched institutional barriers (Wardrip & Herman, 2020). In addition to DT, redesigning the education workforce must be considered to shift the focus from improvement toward innovation (Ladachart et al., 2022).

The DT mindset elements include *uncertainty, empathy, mindfulness, collaboration with others, orientation toward learning,* and *creative confidence*. *Uncertainty* is essential to the DT mindset, as it encourages individuals to embrace ambiguity and take risks. *Empathy* is another critical element of the DT mindset, as it involves understanding and empathizing with the needs and experiences of others. *Mindfulness* is also a crucial element of the DT mindset, as it involves being present and aware of one's thoughts and feelings. *Collaboration* with others is another essential element of the DT mindset, as it involves working with others to generate new ideas and perspectives. *Orientation toward learning i*s also a key element of the DT mindset, as it involves a willingness to learn from failure and continually improve. Finally, *creative confidence* is an essential element of the DT mindset, as it involves having the confidence to take risks and to believe in one's ability to generate new and innovative ideas (Ladachart et al., 2022).

Incorporating DT into diverse aspects of the organization's activities has become widespread, embraced by major corporations spanning different industries (Carlgren et al., 2014). It was also used in

educational sectors and shown to have a significant positive impact on teachers and students (Calavia et al., 2023; Panke, 2019; Razali et al., 2022). A study by Razali et al. (2022) stated how DT could be used and integrated into education and discussed the challenges teachers face in using this method, such as lack of experience and misunderstandings. Another study by Calavia et al. (2023) emphasized the effectiveness of DT education in allowing teachers to face complex challenges in their day-to-day work, where the study focus is on training teachers to address practice challenges. In addition, Razali et al. (2022) emphasized the importance of DT in creating a new education paradigm for higher student engagement and success. Furthermore, Calavia et al. (2023) and Razali et al. (2022) emphasized the importance of adopting DT and its potential to transform teaching and learning strategies in the classroom.

### Reflective Practice in STEAM Education

Reflective practice has long been recognized as a key component of teacher education, offering a systematic approach to self-assessment and continuous professional growth (Schön, 1987). In STEAM education, reflective practice enables educators to critically examine their teaching strategies, student engagement, and the integration of interdisciplinary content (Bassachs et al., 2020). While reflective practice is widely regarded as beneficial for fostering teacher development, it has limitations. Some critics argue that reflective practice can be overly focused on individual reflection without sufficiently addressing broader, systemic challenges in educational settings (Suaib, 2022). Moreover, without proper support and guidance, educators may find reflective practice challenging to sustain over time, particularly in fast-paced teaching environments (Campbell & Rogers, 2022; Machost & Stains, 2023).

Incorporating reflective practice into STEAM education is especially relevant due to the interdisciplinary and hands-on nature of the subject matter. Teachers who regularly engage in reflective practice can adapt their teaching methods to meet the evolving needs of their students, particularly in project-based learning environments where flexibility and creativity are essential (Markula & Aksela, 2022; Mohamed et al., 2022). Furthermore, reflective practice can help teachers align their instructional strategies with DT principles, ensuring that each iteration of a STEAM project is refined based on previous experience and feedback (Chung et al., 2020).

Despite these advantages, reflective practice faces several challenges in implementation. Some studies have highlighted that reflective practice can sometimes become superficial, where teachers may only reflect on surface-level aspects of their teaching rather than deeply engaging with underlying pedagogical challenges (Imran et al., 2020). In STEAM education, this issue can be exacerbated by the complexity of integrating multiple disciplines, which may overwhelm teachers if they are not adequately supported in their reflective practices. Therefore, ensuring that reflective practice is meaningful and embedded within a supportive professional development framework is crucial for its success (Mohamed et al., 2022).

Reflective practice and DT emphasize iterative learning, critical thinking, and the ability to adapt to new challenges. When integrated, these approaches can transform STEAM education by equipping teachers with the tools to foster their students' innovation, creativity, and problem-solving skills (Bassachs et al., 2020). However, it is essential to recognize that both approaches require significant time, resources, and professional development support to be fully effective. Without adequate investment in these areas, the potential benefits of reflective practice and DT may not be fully realized (McKenney & Reeves, 2020).

### Upskilling Training as Innovation

The majority of educational programs for teachers do not succeed in adequately equipping them with vital skills. This is attributed to the fact that, despite experienced educators playing a crucial part in the educational process, they still require guidance to proficiently utilize these activities (ElSayary, 2023). Developing teachers' teaching skills requires integrating complex and different strategies to act as role models and provide learners with opportunities to reflect, collaborate, and have authentic experiences (Howard et al., 2022). These goals can be achieved with proper planning of upskilling training programs that meet teachers' needs and help them enhance their mindsets. Hence, in this research, the term "upskilling" was employed instead of "reskilling". While "reskilling" involves providing training or retraining to employees for new job roles, the term "upskilling" focuses on enhancing competencies to a higher level and cultivating a mindset that enables employees to excel in their existing or prospective positions (Cedefop, 2020). It is how to cope with the many changes in education, such as the shift toward online learning due to the pandemic, the use of ChatGPT in teaching and learning, and many more changes that might occur.

STEM education is an educational transformation where students learn in an authentic learning environment to solve real-life and complex problems. Adding the "A" to STEM promotes students' creative learning to be STEAM (ElSayary, 2021). As with any new ideas or initiatives, there is resistance toward change and a need for understanding how to implement proper ways of teaching and learning STEM problems, challenges, etc. So, achieving innovation requires processes and actions where a proper way of thinking, planning, and teaching is introduced. Greenhill et al. (2018) introduce a category of innovation called "transformation," which is the highest level that

**Table 1.** The weekly outline of the upskilling teacher training program

| Weeks/topics | Descriptions | DT (design-folio) |
|---|---|---|
| 1. History of the STEM movement | An overview of the background, importance, and history of the STEM movement emphasizes its importance in fostering the development of skills and competencies for college, career, and life. Also, understanding the differences between multidisciplinary, interdisciplinary, and transdisciplinary strategies. | *Empathize & define* During the first three weeks, teachers will work on empathizing with the needs and defining the challenge or the problems they can use to teach STEM. |
| 2. Content knowledge and skills | Aiming to refine and integrate the STEM content knowledge and skills necessary in a learner-centered environment to become successful teachers. It also covers discussions about the best practices of instructional and assessment strategies that support student learning and development. | |
| 3. Planning and preparing a project | Helping teachers plan and prepare projects effectively by using the curriculum wheel, understanding the engineering design process and project-based learning, and developing a theme for the project. | |
| 4. Pedagogical strategies | Equipping teachers with effective pedagogical strategies to enhance STEM education and engage students in active learning. The topics covered include the use of theme-based, problem-based, and project-based learning, as well as active learning and engagement strategies. | *Ideate & prototype* In the weeks from 4-6, teachers collaborate with other teachers from different specializations to generate ideas for the STEM challenge or project. |
| 5. STEM design & UAE-STI policy | Helping teachers develop STEM challenges using the UAE Science, Technology, and Innovation (STI) policy themes and understanding the relationship between standards and engineering to develop curriculum. | |
| 6. Developing integrative STEM challenge | Emphasizing the importance of STEM challenges that encourage critical thinking and innovation while building student understanding. Teachers are guided to examine problems from all angles by questioning, and students use hands-on, practical applications of content to solve their challenges. | |
| 7. The power and promise of STEM education | Highlighting the value and power of the constructive alignment curriculum and how to co-plan with students STEM challenges using Drake's KDB model and 5Es strategy. | *Test & reflect* In weeks 6-9, teachers test their ideas and try to find areas for integration and smooth transition between subjects. They reflect together on what works and what need improvement. |
| 8. Teaching and assessing integrative STEM | Developing teachers' competence in teaching and assessing integrative STEM education. It also includes the development of STEM rubrics according to the challenge designed. | |
| 9. Bring project to life | Helping teachers develop and implement engaging and effective STEM challenges for their students. The training may cover strategies for presenting projects to students, outlining what students will do during the project, and reflecting on the process to improve future projects. | |
| 10. Revise and reflect | Promoting teachers to reflect on their experiences in developing the STEM challenge and the design-folio. They reflect on the main important experience gained from the training, challenges faced, and future plans to follow. | In the last week, teachers reflect on the whole process and identify goals for their future plans. They reflect on their habits and ways of thinking. |

considers human values at the center with its components of cognitive, emotional, and functional innovation, using technology to enhance the DT process in the digital era, leading to producing and generating new creative products. Using DT and reflective practice in an upskilling STEAM training program is considered a way of transforming education, as the teachers' values, motivation, and development are at the core of enhancing their DT mindsets.

A federal university organized an upskilling program for teachers, aimed at enhancing their skills. The program was conducted for a set of national charity schools located across the UAE. The training's timeline spanned ten consecutive weeks (as outlined in **Table 1**), and the participants were assigned weekly assignments encompassing both reflective exercises and practical implementations of building a "design-folio," which as portfolio teachers build throughout the training duration to include designing a STEM challenge, teaching and learning activities and ways to assess students' learning. Teachers applied what they learned to create STEM challenges that target real-world problems for their students.

## METHODOLOGY

The study aims to enhance teachers' DT mindsets through reflective practice in order to cultivate innovation in an upskilling STEAM training program. An explanatory mixed method design is employed, starting with a quantitative method (teachers' survey) followed by a qualitative method (focus group discussion).

## Participants

The study participants are in-service teachers (n = 55) from charity schools across Northern Emirates in the UAE. The sample was selected randomly from the schools, and criteria were set for participants to be engaged in the upskilling training program. The criteria are defined, as follows:

(1) should be specialized in science, technology, mathematics, or social studies,

(2) have basic information about STEM education, and

(3) willing to participate in the study.

Of the participants, 43.64% (24) were males, and 56.36% (31) were females. The majority of teachers were 35-44 years old to form 50.91% (28), followed by teachers aged 25-35 to form 34.55% (19), and 12.73% (7) aged above 45 years old. Teachers participated with different specializations, including 43.64% (24) science, 7.27% (4) technology, 34.55% (19) mathematics, and 14.55% (8) social studies teachers. Regarding experiences, 7.27% (4) had 0-5, 49.9% (27) had 6-10, 21.82% (12) had 11-15, 9.09% (5) had 16-20, and 14.55% (8) had more than 20 years of experiences.

## Instruments

### *Teachers' survey*

The teachers' survey was used to collect quantitative data to address the first question of the study (*How does incorporating reflective practice in an upskilling STEAM training program impact teachers' DT mindset*?) The survey consisted of demographic information and DT mindsets items. The demographic information included multiple choice questions to ask participants about their age, gender, years of experience, and specialization. The second section is the DT mindsets (36 items), adapted from Dosi et al. (2018) and distributed in sub-categories, as follows: uncertainty (6 items), empathy (6 items), mindfulness (6 items), creative confidence (6 items), collaboration (6 items), and learning orientation (6 items). The validity and reliability of the survey were measured before sending it to the participants.

The internal consistency coefficient (Cronbach's alpha [a]) was used regarding reliability. The reliability coefficient for all the survey sections was a = 0.973, with the following values in each category: uncertainty (a = 0.901), empathy with students' needs (a = 0.865), mindfulness in designing STEAM projects (a = 0.930), collaborative work with colleagues (a = 0.866), orientation towards learning (a = 0.899), and creative confidence (a = 0.875), which are considered suitable for the study. After assuring the instrument's reliability, the survey was administered to the teachers through a web survey.

Regarding construct validity, the exploratory factor analysis, a statistical analysis method, identified the underlying relationship between measured variables. For teachers' *uncertainty*, the value of Kaiser-Meyer-Olkin (KMO) is 0.845, and the Bartlett Chi-square approximation is 244.876 with $p < 0.001$. For *empathy*, the value of KMO is 0.792, and the Bartlett Chi-square approximation is 273.437. For *mindfulness* the value of KMO is .866, and the Bartlett Chi-square approximation is 312.830 with $p < 0.001$. For *collaborative work with colleagues*, the value of KMO is 0.813, and the Bartlett Chi-square approximation is 270.714 with $p < 0.001$. For *orientation toward learning*, the value of KMO is 0.862, and the Bartlett Chi-square approximation is 306.265 with $p < 0.001$. For *creative confidence*, the value of KMO is 0.834, and the Bartlett Chi-square approximation is 289.523 with $p < 0.001$. A KMO value close to 1 indicated that the correlation pattern was compact enough to produce different and reliable factors.

Additional analyses were conducted to evaluate indicator reliability and validity, focusing on convergent validity, composite reliability (CR), and discriminant validity using partial least squares.

Convergent validity was established by examining CR, average variance extracted (AVE), and Cronbach's alpha (CA) for each construct. All variables' CR and CA values were above the recommended threshold of 0.70, indicating strong internal consistency across the six constructs: collaboration, creative confidence, empathy, mindfulness, orientation toward learning, and uncertainty. Each construct's AVE exceeded 0.50, indicating that the constructs explained more than half of the variance in their respective indicators, supporting the convergent validity of the instrument. Since all CR values were higher than 0.70 and AVE values exceeded 0.50, the overall construct validity of the instrument was confirmed.

Discriminant validity was evaluated using the Heterotrait-Monotrait ratio (HTMT). Most constructs demonstrated satisfactory discriminant validity, with HTMT ratios falling below the acceptable limit of 0.90. However, the correlation between empathy and mindfulness (HTMT = 0.946) and between empathy and orientation toward learning (HTMT = 0.938) was close to or slightly above the 0.90 threshold, suggesting some overlap between these constructs. Despite this, discriminant validity remains acceptable overall.

### *Focus group discussion*

The second research question (*What are the teachers' best practices and experiences for effectively integrating reflective practice and DT mindset development in an upskilling STEAM training program*?) was explored during a focus group discussion at the conclusion of the ten-week upskilling training program. Seven participants were selected from the larger sample based

on their active involvement and consistent attendance throughout the program, as well as their diverse backgrounds and subject areas. This purposive sampling aimed to gather a wide range of perspectives. However, it is essential to acknowledge that potential bias may have arisen by selecting the most engaged individuals, which could influence the representation of experiences within the group. All participants expressed willingness to engage in the focus group discussion, sharing their insights openly. Their contributors provided a deeper understanding of the perceived impact and effectiveness of the training program, illuminating both the successes and challenges encountered.

In this phase, the selected group of participants (n = 7) engaged in the discussion, responding to open-ended inquiries designed to delve into their perspectives. To facilitate this exchange, a virtual focus group session was conducted via Zoom video conferencing and lasted for a duration of 45 minutes. The formulation of three open-ended questions was adapted from Rolfe et al. (2001), and these questions underwent scrutiny for face validity and clarity. Two educational experts were consulted to ensure the alignment of the questions with the study's objectives. Their assessment resulted in an endorsement of the questions' appropriateness. The questions employed in this context are outlined, as follows:

1. What was the most important experience you gained from this training?
2. So what did you learn? List 2-3 things you learned from this training.
3. Now what challenges have you faced, and what changes will you apply in your practices?

## Procedure

To obtain ethical approval, the study received the endorsement of the institutional review board. The Research Ethical Committee of a federal university in UAE has approved this study. Participants received consent forms at the beginning of the training program, and a full explanation of the study's purpose was given. The data was collected sequentially, where the quantitative approach (web survey) was used to address question 1 (*How does incorporating reflective practice in an upskilling STEAM training program impact teachers' DT mindset*?), employing a one-sample t-test administered among K-12 educators, a web-based survey link was distributed to participants ensuring anonymity. Participants were explicitly informed about the voluntary nature of their involvement and were given the option to refrain from contributing to the research. Subsequently, to address the study's second query, a qualitative method involving focus group discussions was employed (*What are the teachers' best practices and experiences for effectively integrating reflective practice and DT mindset development in an upskilling STEAM training program?)*.

**Table 2.** Handal et al.'s (2013) questionnaire score range

| Score range | Description |
|---|---|
| $1.0 < x < 1.5$ | Very low |
| $1.5 < x < 2.0$ | Low |
| $2.0 < x < 2.5$ | Moderately low |
| $2.5 < x < 3.0$ | Slightly below average |
| 3.0 | Average |
| $3.0 < x < 3.5$ | Slightly above average |
| $3.5 < x < 4.0$ | Moderately high |
| $4.0 < x < 4.5$ | High |
| $4.5 < x < 5.0$ | Very high |

The survey results were analyzed using descriptive and inferential statistics using the statistical package of social sciences. Descriptive statistics measured the mean, standard deviation, frequency, and z-scores. The inferential statistics addressed the one-sample t-test to compare the mean scores of the DT mindset with established benchmarks (above average; m = 4). As per the report from the World Bank (2021), it was highlighted that primary and secondary school educators should possess an intermediate level of competence along with a growth mindset in their development. Consequently, the expected value postulated in this research, which was subject to examination through a one-sample t-test, was the above-average score (m = 4) as presented by Handal et al. (2013) (refer to **Table 2**). This score was anticipated to surpass the intermediate benchmark established by the World Bank (2021). The objective was to ascertain if there existed a significant increase in the mean scores of the participants after undergoing the upskilling training.

A single focus group took place after the completion of the upskilling training initiative, involving seven K-12 educators. The interaction transpired via Zoom and spanned a 45-minute period. The participants' input was deciphered to furnish in-depth textual elucidation, aligned with the queries posed during the focus group discussion. The primary aim was to provide participants with an unfettered platform for articulating their perspectives and reflecting on their experiences. The findings underwent analysis, and their amalgamation with the quantitative outcomes served to mitigate potential bias arising from relying solely on one data modality.

Thematic analysis was employed, which involved identifying and analyzing patterns or themes within the data. Following the steps outlined by Braun and Clarke (2006), the first phase involved familiarizing ourselves with the data, where the focus group recordings were transcribed verbatim, and the researcher thoroughly read the transcripts to gain a deep understanding of the content. After familiarization, initial codes were generated by systematically coding the dataset. These codes represented key aspects of the data that were relevant to the research questions.

**Table 3.** The one-sample t-test for the DT mindsets elements

| | t | df | Significance | | Mean difference | 95% CI of the difference | |
|---|---|---|---|---|---|---|---|
| | | | One-sided p | Two-sided p | | Lower | Upper |
| Uncertainty | 2.713 | 54 | .004 | .009 | .22424 | .0585 | .3900 |
| Empathy | 4.418 | 54 | < .001 | < .001 | .34545 | .1887 | .5022 |
| Mindfulness | 3.657 | 54 | < .001 | < .001 | .29091 | .1314 | .4504 |
| Collaborative work with colleagues | 3.098 | 54 | .002 | .003 | .24848 | .0877 | .4093 |
| Orientation towards learning | 5.087 | 54 | < .001 | < .001 | .39697 | .2405 | .5534 |

Note. Test value = 4 & CI: Confidence interval

In the next phase, codes were examined to identify broader themes. Codes were grouped based on their commonalities, and themes such as "collaborative learning," "DT mindset development," "reflective practice," and "challenges in STEAM education" emerged. Once potential themes were identified, they were reviewed and refined to ensure they accurately captured the essence of the data. This included checking whether enough data supported the themes and whether they provided meaningful insights into the participants' experiences.

After reviewing the themes, they were defined and named to reflect their content, ensuring each theme had a clear focus. Finally, the themes were integrated into the report, where specific quotes from the focus group discussion were used to illustrate key points and link the themes to the overall research questions. The thematic analysis enabled the research team to gain deeper insights into the teachers' reflections and experiences regarding the upskilling program and their DT mindset development. This qualitative approach enabled us to gain deep insights into teachers' reflections, experiences, and challenges while integrating DT mindsets and reflective practice into their teaching.

## RESULTS

### Survey Analysis

#### *Z-score*

In order to avoid biases such as non-response bias or the influence of the outliers of the results, the Z-score is measured for the variables as common univariate outlier identification techniques (Mowbray et al., 2019). When data are normally distributed, 95% of the responses fall between the z-scores of ±1.96, and 99% of cases fall between z-scores of ±2.58 (Mowbray et al., 2019). The z-scores were calculated for the DT mindsets, where 100% of the responses fall between z-scores ±1.99 for uncertainty, ±2.3 for empathy, ±2.18 for mindfulness, ±2.09 for collaboration with others, ±2.4 for an orientation toward learning, and ±2.2 for creative confidence.

#### *One-sample t-test*

The one-sample t-test was run to compare the participants' mean in the DT mindset categories to the average mean (m = 4) that Handal et al. (2013) determined. As presented in **Table 3**, the mean of participants' *uncertainty* (mean [M] = 4.22, standard deviation [SD] = 0.612) was significantly higher than the mean set (m = 4), $t(54) = 2.713$, $p < .05$ ($\eta^2 = 0.612$); the mean of *empathy* (M = 4.345, SD = 0.579) was significantly higher than the percentage set (m = 4), $t(54) = 4.418$, $p < .05$ ($\eta^2 = 0.579$); the mean of *mindfulness* (M = 4.291, SD = 0.589) was significantly higher than the percentage set (m = 4), $t(54) = 3.657$, $p < .05$ ($\eta^2 = 0.59$); the mean of *collaborative work with colleagues* (M = 4.248, SD = 0.594) was significantly higher than the percentage set (m = 4), $t(54) = 3.098$, $p < .05$ ($\eta^2 = 0.59$); the mean of *orientation toward learning* (M = 4.397, SD = 0.578) was significantly higher than the percentage set (m = 4), $t(54) = 5.087$, $p < .05$ ($\eta^2 = 0.57$); and the mean *creative confidence* (M = 4.318, SD = 0.597) was significantly higher than the percentage set (m = 4), $t(54) = 3.948$, $p < .05$ ($\eta^2 = 0.59$). Thus, the results support the conclusion that the participants' mean range was higher than the above-average demonstrated by Handal et al. (2013).

In summary, a noteworthy rise in the average scores of the participants was observed ($p < .001$). The mean scores of the participants across all aspects of the DT mindset exceeded 4. Consequently, the null hypothesis was invalidated, affirming the alternative hypothesis that the mean scores of participants were notably greater than 4.

### Focus Group Discussion

#### *Q1. What was the main important experience you gained from this training?*

All the teachers agreed that the most important experience they gained from the training is understanding how to use the DT process. They mentioned their collaboration facilitated learning and reached the "AHA" moment. They were satisfied with implementing the DT process. Some of the responses are stated below:

For *uncertainty*, Teachers acknowledged how the open-ended nature of the DT process pushed them out of their comfort zones.

***Participant 3*** said,

> "It was a wonderful experience.. I benefited and tried to apply what I learned in school and even

personally. I feel like my way of thinking about other problems has changed … like to be more open-minded."

This illustrates how they learned to embrace uncertainty, understanding that innovation often requires stepping into the unknown.

***Participant 6*** mentioned,

"At first, it was hard to proceed without a clear solution in mind, but I realized that uncertainty actually fostered my creativity and pushed me to try new approaches."

For *empathy*, teachers noted how working with students and colleagues required them to understand different perspectives better.

***Participant 2*** said,

"This is the first time to understand the other subjects' perspectives about the same problem … We sometimes had conflicts in how we taught the projects, but when collaborating in designing the challenge, we understand others' perspectives."

***Participant 7*** shared,

"By empathizing with my students, I realized they weren't just struggling with the content but also the way it was delivered, which made me redesign my approach."

Regarding *mindfulness*, teachers became more aware of their teaching methods and their influence on students.

***Participant 1*** said,

"We had a useful experience from which we learned new ways of teaching students and new ways of thinking and approaching problems … we gained many skills in developing ourselves and the ability to relate to other subjects."

***Participant 4*** added,

"Being mindful in the classroom allowed me to pick up on subtle cues from my students, like when they were disengaged, and I could adjust my teaching immediately."

In *collaboration with others*, working together was vital to the success of the training.

***Participant 5*** noted,

"A very interesting experience … in which we gained many skills to develop ourselves and relate to others. We became more motivated to understand more and complete our challenge … We even communicated through our WhatsApp group to think of the challenge we designed after our working hours."

***Participant 3*** said,

"Collaboration helped me understand that my peers have different insights, and their contributions made the challenge more comprehensive than if I had done it alone."

Regarding *orientation toward learning*, teachers expressed their commitment to lifelong learning.

***Participant 4*** shared,

"It is useful and excellent, and I hope that everyone who has not been fortunate enough to participate in it … we need to be updated with all new strategies to help us cope with this changing world."

***Participant 7*** added,

"This training reminded me that education is always evolving, and I must keep learning new methods and technologies to stay relevant."

For *creative confidence*, teachers gained confidence in their ability to design and implement innovative STEM challenges.

***Participant 3*** said,

"I wasn't sure about my ability to come up with creative solutions at first, but by the end of the training, I felt much more confident in taking risks and trying new ideas."

### *Q2. So what did you learn? List 2-3 things you learned from this training.*

All teachers mentioned positive experiences when implementing what they learned from this training. In *uncertainty*, the following were shared:

***Participant 5*** mentioned,

"With no doubts, we faced challenges, in the beginning, to decide where we could start, but after understanding some of the global problems and integrating them into the challenges, it makes more sense for us as teachers and more meaningful for students."

***Participant 6*** added,

"I learned to embrace the uncertainty of not having a concrete solution right away, which actually helped my students be more creative in their problem-solving."

For *empathy*, participants shared how collaboration with others helped them learn.

***Participant 3*** shared,

> "We realized the need for teachers to become facilitators to learners … collaborative work and highlighting the spirit of the challenge were one of the successful steps in our project."

***Participant 7*** shared,

> "I learned that truly understanding my students' perspectives allowed me to create lessons that were more engaging and relevant to their needs."

In *mindfulness*, teachers facilitated student learning by adapting discussion techniques to engage them better.

***Participant 1*** reflected,

> "I learned how to run a discussion in the classroom using open-ended questions and how to make a transition from lower-order to higher-order thinking using Bloom's."

***Participant 4*** added,

> "I learned to be more mindful of how I presented material, ensuring that I wasn't just delivering information but creating an engaging learning environment where students felt comfortable to explore."

In collaboration with others, one of the participants expressed the positive impact of collaboration.

***Participant 2*** mentioned,

> "We had excellent ideas generated at the end … I thank all my colleagues for sharing their insights and different perspectives in creating the STEM challenges … connecting ideas, respect others' opinions, expanding our thoughts to reach the best form of the challenge, and turning the ideas into a tangible reality were all positive outcomes we experienced and learned."

For orientation toward learning, teachers developed a strong orientation toward learning through collaboration and shared experiences.

***Participant 3*** mentioned,

> "We were learning from each other, not only from the instructor … we realized how to form an active learning environment …"

***Participant 5*** said,

> "This experience reminded me that learning is continuous, and I am always evolving in my approach to teaching, just as my students are evolving in their learning."

For creative confidence, explored new ideas through the DT process.

***Participant 4*** noted,

> "The diversity we had in design thinking and the development of the ideas gave us the sense that we think out of the box."

***Participant 1*** said,

> "I learned to trust my instincts when it came to generating new ideas, and I now feel more confident in taking risks with my lesson plans."

### *Q3. Now what challenges have you faced, and what changes will you apply in your practices?*

In *uncertainty*, teachers shared the challenge of navigating uncertainty in the design process.

***Participant 3*** mentioned,

> "The most challenging part I faced was the collection of ideas we had and deciding which concept would be more suitable, as well as the link between subjects. We had to change the concepts many times to ensure we focused on the problem and the question formulated in the beginning."

This reflects how uncertainty was a challenge, but one that led to a better outcome.

***Participant 6*** shared,

> "At first, I found it difficult to not have a clear direction, but I learned that by staying flexible and open, I was able to come up with more innovative solutions."

In *empathy*, teachers used it to connect their projects to real-world student concerns.

***Participant 2*** said,

> "Defining the challenge and formulating questions are very important steps as it introduces an interesting challenge for students, especially when it is aligned to a global problem; students feel they contribute significantly to their country."

***Participant 4*** added,

> "I learned that by listening to students' concerns and understanding their interests, I could design challenges that they felt passionate about."

Regarding *mindfulness*, teachers are required to keep track of student needs and continuously adapt the project.

***Participant 5*** mentioned the challenge of maintaining student engagement:

> "It was not easy, in the beginning, but students enjoyed it with proper planning."

***Participant 7*** shared,

> "I had to be mindful of the students' reactions throughout the project to ensure they were engaged and learning effectively, which required constant reflection on my teaching methods."

For *collaboration with others*, teachers noted the challenge of coordinating ideas across different subjects.

***Participant 2*** shared,

> "We sometimes had conflicts in how we taught the projects, but when collaborating in designing the challenge, we understood others' perspectives."

***Participant 3*** said,

> "Working with colleagues from different subjects was challenging at first, but ultimately, it enriched the project and provided a more holistic learning experience for the students."

In *orientation toward learning*, teachers reflected on how they plan to keep improving their teaching methods.

***Participant 1*** mentioned,

> "The main important step we need to start from is to organize the steps we follow by the same way we learned so we can list our priorities of the topics."

***Participant 7*** shared,

> "This training inspired me to seek out more learning opportunities, whether through additional courses or collaborating with other teachers, to keep growing as an educator."

For *creative confidence*, teachers gained confidence in experimenting with new teaching methods.

***Participant 5*** said,

> "What was challenging: how to highlight the projects and the ability to develop the students' creative skills and appropriately guide them."

***Participant 4*** said,

> "Initially, I didn't feel confident in leading creative projects, but as I saw the students' positive responses, I gained confidence in experimenting with new ideas in the classroom."

## DISCUSSION

This study aimed to enhance teachers' DT mindsets through reflective practice to cultivate innovation in an upskilling STEAM training program. The findings indicated an enhancement in the teachers' DT mindsets, with their scores surpassing the intermediate level outlined in the World Bank's (2021) report. Additionally, participants expressed a favorable encounter with the upskilling training initiative. This segment addresses two key dimensions: the evolution of teachers' DT mindsets and the practices they adopted along with their firsthand encounters.

### Teachers' Design Thinking Mindsets Development

This sub-section seeks to answer the first question of the study: How does incorporating reflective practice in an upskilling STEAM training program impact teachers' DT mindset? The results endorsed **H1.** The participants' mean score showed above average (intermediate level) after the training ($m > 4$). Reflective practice was pivotal in this improvement, allowing teachers to assess and refine their teaching methods in real-time constantly. Teachers reported how iterative reflection on their challenges and successes helped develop empathy for their students' learning processes and heightened their awareness of how DT could be applied to foster problem-solving and creativity. A study by ElSayary (2023) confirmed that reflective practice embedded in upskilling training programs positively influences teachers' skills and mindset development. Reflective practice is an essential component of effective teaching and learning. The participants' focus on empathy aligns with prior research by Razali et al. (2022), who highlighted the importance of empathy in the DT process. Teachers learned to place students at the center of their teaching design, making their learning more personalized and meaningful. Reflective practice involves a structured sequence of self-observation and self-evaluation, facilitating ongoing learning (ElSayary, 2021). This practice is central to fostering effective continuing professional development and enhancing educator proficiency (Razali et al., 2022). Encouraging the adoption of reflective practice within educational institutions yields advantages for individual teachers and the entire school community. Educators who engage in reflective practices are more inclined to cultivate students' reflective skills, as evidenced by insights from teacher focus group discussions. By incorporating reflective habits, teachers gain the ability to effectively guide students in reflecting on, analyzing, and evaluating their own learning experiences (Razali et al., 2022).

The consensus among teachers is that nurturing a culture of reflective practice contributes significantly to school enhancement by providing a solid groundwork for continuous improvements in teaching and learning.

Teachers attest to the affirmative influence of reflection and feedback through their collaborative endeavors, positively impacting their teaching. It is interesting to note that Cavalia et al. (2023) emphasized that DT and reflective practice allow for making education sustainable.

In addition to empathy, other DT mindset elements, such as uncertainty and creative confidence, show a positive impact. Teachers reported feeling more comfortable navigating uncertainty in their teaching approaches and began seeing it as an opportunity for exploration rather than a barrier. This is consistent with the findings of Ladachart et al. (2022), who emphasized that a DT mindset requires comfort with ambiguity. Teachers learned that embracing uncertainty, a core element of DT, allowed for the emergence of more innovative solutions during the ideation phase of their STEAM challenges. These reflections are consistent with the broader literature, which suggests that iterative learning, critical thinking, and flexibility are crucial in successfully integrating DT into education (Bassachs et al., 2020).

DT is a problem-solving approach that enhances students' learning by involving them in empathy, creativity, and collaboration (Razali et al., 2022). Teachers emphasized the importance of guiding their students to use the problem as an opportunity to learn, where the solution can result from unexpected directions. Razali et al. (2022) emphasized the students' roles in collaborating with their peers in order to solve complex problems, where the problem is seen as an opportunity for learning, and the solution can result from an unexpected direction, which leads to creativity. Teachers also emphasized that they often see the problem from the students' point of view when designing a STEM challenge, as they understand that promoting students' DT needs effort, proper planning, and time. Ladachart et al. (2022) also emphasized that cultivating students' design-thinking mindset takes time. They are also mindful of directing students to discover new things rather than worrying about failures by reflecting on their work. Thi-Huyen et al. (2021) showed that combining critical reflection and DT can develop integrative learners who do not worry about failure but focus on the solution. This promotes learners' problem-solving, deep conceptual understanding of a subject, communication, and collaboration skills (Novak & Mulvey, 2020).

### Teachers' Best Practices and Experiences

This section discusses the study's second question: What are the best practices and strategies for effectively integrating reflective practice and DT mindset development in an upskilling STEAM training program for teachers?

The results showed that teachers had positive experiences for effectively integrating reflective practice and DT mindset development in an upskilling STEAM training program. Kijima et al. (2021) explored the benefits of educational programs that utilize DT for a specific group of learners. Another study by ElSayary (2021) emphasized the importance of reflective practice in developing teachers professionally in STEAM education.

One key strategy identified by the participants was the importance of collaboration. Teachers reported that collaborative learning environments enabled them to generate and refine ideas effectively. This supports Avsec and Ferk Savec (2022) findings, who suggested that DT benefits from collaborative processes, as participants are encouraged to build on each other's insights. Teachers emphasized the need to work across different subject areas, finding that cross-disciplinary collaboration allowed for a more holistic approach to their STEAM challenges. One participant noted that understanding different perspectives was critical in overcoming initial conflicts and arriving at more comprehensive project designs. This aligns with research from Kijima et al. (2021), which highlighted that collaboration fosters a deeper understanding of complex problems, a core tenet of DT.

However, teachers faced challenges integrating these strategies, particularly in the beginning stages of their STEAM challenges. The complexity of developing real-world problems that students could connect with was a recurring theme in the focus group discussions. Several participants reported difficulties in selecting and narrowing down global issues, which made the early phases of the design process particularly overwhelming. This aligns with findings from Calavia et al. (2023), who reported similar challenges in fostering an entrepreneurial mindset among teachers due to the complex and sometimes daunting nature of DT tasks. While these challenges initially hindered progress, the iterative nature of reflective practice eventually led teachers to overcome these barriers and develop meaningful, engaging projects for their students.

Time constraints were another significant challenge noted by the teachers. Many felt that the time-intensive nature of DT made it difficult to incorporate it into their regular teaching schedules. This finding echoes earlier research by Naseem and Crichton (2022), who highlighted the resource-intensive nature of DT in educational settings. Teachers need to dedicate significant time not only to the design process but also to reflecting on their teaching strategies and making iterative adjustments. Despite these challenges, teachers agreed that the benefits of this approach far outweighed the costs, as the training allowed them to create more engaging and meaningful learning experiences for their students.

### Addressing the Challenges

One of the most critical aspects of this study is how the challenges faced by the teachers are framed not as insurmountable barriers but as opportunities for growth and development. For instance, the difficulty in formulating global challenges was ultimately seen as a learning opportunity that led teachers to rethink their approach to STEAM education. Thi-Huyen et al. (2021) noted that reflection is critical in navigating these difficulties, allowing teachers to adapt their strategies over time. Providing more professional development that focuses on time management, global challenge formulation, and collaborative support may further alleviate these challenges.

Moreover, the teachers' newfound confidence in creative risk-taking and their willingness to embrace uncertainty suggest that the reflective practice embedded in the upskilling training program was effective, as noted by ElSayary (2023). As teachers became more comfortable with the iterative nature of DT, they began to see obstacles not as failures but as integral parts of the learning process. This mirrors the findings of Novak and Mulvey (2020), who found that iterative, reflective learning leads to deeper conceptual understanding and more robust problem-solving abilities in both students and educators.

## CONCLUSION AND RECOMMENDATIONS

This study aimed to enhance teachers' DT mindsets through reflective practice in an upskilling STEAM training program. The findings indicate that the training program successfully developed teachers' DT mindsets, as evidenced by their positive attitudes towards using DT in creating STEAM projects. The results support the notion that incorporating reflective practice can cultivate innovation in teachers' practices and contribute to their ability to generate creative ideas. These practices are considered a transformation of education, the highest level of innovation (Androutsos & Brinia, 2019). Moreover, teachers demonstrated increased confidence in their capacity to address classroom challenges creatively and collaboratively, highlighting their improved ability to guide students through complex problem-solving processes. The study results revealed that teachers significantly impacted their DT mindsets using the reflective practice integrated with the DT process.

The study revealed that teachers experienced positive outcomes when integrating reflective practice and DT mindset development. In real classroom settings, teachers applied DT mindsets by encouraging students to engage in open-ended, student-centered problem-solving tasks, such as designing solutions for real-world problems like environmental sustainability or technological innovation. By allowing students to iterate their ideas and reflect on feedback, teachers facilitated deeper learning and encouraged students to embrace creativity and collaboration in their learning process. Collaboration emerged as a best practice, allowing teachers to generate excellent ideas, respect different perspectives, and transform ideas into tangible outcomes. Putting students at the center of the design process and embracing ambiguity was also highlighted as effective strategies. These findings align with previous research emphasizing the benefits of DT and reflective practice in professional development for educators (Avsec & Ferk Savec, 2022; Calavia et al., 2023; You, 2022). However, teachers initially faced challenges in deciding where to start and found the design of STEAM challenging and time-consuming. These challenges highlight the need for additional support and resources to facilitate the integration of reflective practice and DT in educational contexts.

Several suggestions were formulated considering the challenges and modifications reported by educators throughout the investigation. These included providing sustained professional development programs that integrate reflective practice and DT mindset development in upskilling STEAM training programs. These programs should emphasize collaboration, empathy, and open-ended questioning techniques. School leaders and administrators should create a supportive environment that encourages risk-taking, experimentation, and the implementation of innovative teaching practices. This can be achieved by providing continued access to resources, such as DT toolkits, digital collaboration platforms, and flexible scheduling for reflection sessions, alongside resources, time, and mentorship for teachers to engage in reflective practice and DT. In addition, it is crucial to facilitate cross-disciplinary collaboration and promote opportunities for cross-disciplinary collaboration and partnerships with external stakeholders to enhance the DT process. For example, partnering with local industries or environmental organizations could provide teachers and students with real-world challenges enriching STEAM projects. One of the most important things to ensure the sustainable development of teachers is to offer ongoing support after the upskilling STEAM training program, including access to mentorship, coaching, and follow-up workshops to refine teachers' skills further and provide regular opportunities for reflection and feedback.

While this study provides valuable insights into enhancing teachers' DT mindsets through reflective practice, several limitations exist. The findings of this study are based on a specific context, national charity schools in the UAE, and do not include any international or vocational institutes. This context, with its particular socio-economic and resource constraints, may limit the generalizability of the results to other settings, especially those with more resources or different educational infrastructures. Accordingly, the results cannot be

generalized to other educational settings. The study was conducted over a ten-week training period, which may limit the ability to capture long-term effects or changes in teachers' practices and mindsets beyond the training program. Future research could benefit from longitudinal studies that track teachers' DT and reflective practices over an extended period, ensuring the sustainability of the mindset shifts noted in this study. The study focused on K-12 teachers who specialized in science, technology, mathematics, and social studies from national charity schools in the UAE, and the findings may not apply to teachers from different backgrounds or levels of experience. Future studies could expand the scope to include teachers from other disciplines or regions to understand better how contextual factors influence the integration of DT in diverse educational settings.

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