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Beyond the Acronym: Entwining STEAM Education, Self-Regulation, and Mindfulness

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ABSTRACT

This study examines the philosophical constructs of Science, Technology, Engineering, Art, and Mathematics (STEAM) curricula entwined with self-regulation and mindfulness to afford students holistic learning. STEAM education is often presented as STEM, resulting in the loss of blended arts integration. The researchers present rationale for including the arts to provide students with interdisciplinary and transdisciplinary curricula that promotes increased creativity and emotive connections to learning. Blending of the arts in STEAM provides students with a greater depth and breadth of critical-thinking, creative-thinking, and social-emotional connections to content. The social capital and emotive connections students construct in STEAM learning present educators with opportunities to entwine mindfulness practices to empower students to develop confidence and competence in their STEAM abilities. Entwining STEAM, self-regulation, and mindfulness provides both a canvas and laboratory of aesthetic, holistic learning of the mind and spirit. The researchers provide instructional and clinical professional practices as well as recommendations for STEAM as a construct for not only providing opportunities for students to engage in cognitive progression, but also to assist learners in developing social, emotional, and behavioral skills for lifelong regulatory and mindfulness learning.

Keywords: STEAM, self-regulation, mindfulness, constructivism, executive functioning

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INTRODUCTION

The entwining of disciplines provides opportunities for teachers and students to engage in relational-rich education that affords multiple perspectives for learning. Entwined Science, Technology, Engineering, and Mathematics (STEM) and the inclusion of Art for STEAM are philosophical constructs that include entwining content to allow students to investigate phenomena and engage in constructivist, discovery-based learning. Both STEM and STEAM prioritize teaching and learning through the amalgamation of interdisciplinary and transdisciplinary teaching and learning to support the cognitive, social, emotional, and behavioral needs of all learners. While this paper emphasizes STEAM education, both STEM and STEAM are catalysts for entwining interdisciplinary and transdisciplinary learning within the acronym and beyond the acronym for holistic learning. Employing a STEAM philosophical approach to teaching and learning creates authentic learning opportunities that involve connecting prior knowledge with new experiences and skills in a natural environment, thus fostering meaningful learning (Jia et al., 2021). Entwining art within and beyond the acronym results in interdisciplinary and transdisciplinary real-world holistic learning that allows for creative expression, fosters critical thinking, and provides a means of communication and understanding across cultures (Henriksen, 2017). The inclusion of the arts creates multiple pathways for students to engage in collaborative learning through creativity and inquiry for academic development as well as mindful, emotive learning.

Philosophy of Mindfulness

The philosophy of mindfulness is rooted in various contemplative traditions, particularly within Buddhism, and has gained significant attention within the field of psychology. Mindfulness can be conceptualized as a state of open and non-judgmental attention to the present moment, characterized by an awareness of one's thoughts, emotions, and sensory experiences (Kabat-Zinn, 1990). The philosophy of mindfulness is based on the idea that individuals can gain deeper insight into their own minds and behavior through intentional and non-judgmental awareness. Mindfulness practice often involves cultivating attention and present-moment awareness through various techniques, such as meditation, breathing exercises, and body scanning (Bishop et al., 2004). Through sustained practice, individuals can develop a greater ability to observe their thoughts and regulate emotions.

Entwined Cognitive and Emotive Learning

Interdisciplinary, transdisciplinary STEAM learning fosters the development of a social environment that impacts student creativity and self-efficacy by promoting a prosocial atmosphere that supports students in experimenting and exploring capabilities (Conradty & Bogner, 2020). STEAM learning influences students' emotions due to the interdisciplinary, transdisciplinary, and solution-oriented characteristics of STEAM course content (Li et al., 2022). Entwining STEAM and mindfulness provides a canvas and laboratory of aesthetic, holistic learning of the mind and the spirit. STEAM is a construct that not only provides opportunities for cognitive progression, but also assists in the development of social-emotional skills for regulatory learning. Much like mindfulness, STEAM affords learners opportunities to

engage in the construction of knowledge as well as the development of social awareness, interpersonal interactions, and prosocial skills through collaboration and personalized learning. Constructivist-based STEAM education creates an environment for students to participate in real-life situations and cultivate empathy through practical experiential learning (Lam et al., 2019). Cognitive, social, emotional, behavioral, and mindful learning provides students in STEAM education settings with skills to achieve lifelong academic goals and collaborate with others.

STEAM Classroom Settings

Collaboration

Authenticity in STEAM is significant as it ensures students engage in real-world, relevant problems at the intersection of arts and STEM, fostering practical learning experiences (Dell'Erba, 2019). STEAM benefits the social skills development of children as early as primary school by enhancing self-image, self-esteem, self-efficacy, resilience, tolerance, empathy, teamwork skills, and assertive communication abilities (Voicu et al., 2022). When learners possess emotional awareness, they are better positioned to work with others and enabled to employ insight for problem-solving. Peer interactions impact bonding-cognitive/affective social capital by providing support, acceptance, and informational resources within STEM education (Saw, 2020). Engaging in collaborative team learning is essential for both STEM and STEAM, and when students are emotionally aware, they can engage in emotionally regulated inquiry, critical thinking, and problem-solving. STEAM fosters student autonomy, curiosity, and inquiry through project-based and student-centered learning and provides a foundation for prosocial collaboration, emotional regulation, and active engagement (Weyer & Dell'Erba, 2022).

Social Capital

STEAM cultivates confidence by allowing students to participate in cross-disciplinary, practical learning activities that enable students to utilize abilities across multiple disciplines, thereby nurturing a feeling of proficiency and self-assurance (Rikoon et al., 2018). STEAM affords new ways to engage emotions, impacting both cognitive and emotional aspects of teaching and learning. Emotional regulation is foundational for cognitive learning and influences how learners approach education. Emotions are vital in education, as they significantly influence the learning process by affecting memory, attention, and cognitive abilities (Steele & Ashworth, 2018). Emotions, motivation, and social recognition are important factors that influence students' STEAM academic achievement and social-emotional learning (Li et al., 2022). Emotional awareness is a precursor of emotional regulation, which influences social interactions for building capital. As a result of these entwined learning pathways, the construction of social capital enables students to access resources, supports, and networks through social connections, which is beneficial for academic achievement and possible career paths in STEM (Saw, 2020).

Personalized Learning

In a study conducted by Voicu et al. (2022), STEAM education during primary school provided children with vital skills and attributes that are essential for their personal growth, academic progress, and future achievements in diverse areas of life. As learners build capital, they are motivated to engage in further collaborative, interactive learning experiences with peers, thereby continuing the cycle of building capital and personalizing the learning. The personalization of learning facilitates improved academic outcomes as well as an increased ability to regulate emotions for meaningful sensory experiences. STEAM provides opportunities for collaborative and personalized learning and has a positive effect on students' social capital by nurturing creativity, recognizing diverse learning styles, increasing student engagement, and potentially enhancing STEM learning through shared skills in STEM, arts, and design (Allina, 2018).

Creativity of Expression

Transdisciplinary learning impacts students by enabling them to combine knowledge and skills from multiple disciplines, nurturing a comprehensive conceptualization of intricate real-world issues, and encouraging creativity, critical thinking, and innovation (Rikoon et al., 2018). Understanding and addressing emotions is crucial for successful teaching and learning, and the multidisciplinary and transdisciplinary nature of STEAM engages and capitalizes on student emotions (Steele & Ashworth, 2018). When students think critically and innovatively, they engage in discovery learning for creativity in problem-solving through experiential, sensory learning. Sensate experiences in a prosocial learning environment create an atmosphere for actuated learning. STEAM learning environments foster motivation by promoting students' autonomy and creativity on an ongoing basis (Conradty & Bogner, 2020).

Conceptualizing STEAM and Mindfulness

Gears, Degrees, and Ratios of Entwinement

In blended interdisciplinary and transdisciplinary STEAM learning environments, science, technology, engineering, art, and mathematics work in unison for entwined cognitive, social, emotional, and behavioral development. Transdisciplinary STEAM fosters creative and critical thinking as a result of blending the arts within STEM (Wilson et al., 2021). However, each discipline is not required and should not be expected to be equally emphasized within each lesson or unit of study. The researchers emphasize an analogy of this degree of synchronous relation to the gears of a mechanical device, moving in synchrony and transmitting torque from one gear to the next, but with different proportions. Much like the meshing of gears for synchrony, as educators, the researchers highlight that we must recognize that the intricate movements within the acronym of STEAM may differ in analogous gear size, degrees, and ratios. Through blended learning, there may be, on occasion, a greater emphasis on the gears of technology, engineering, and mathematics, resulting in greater "turns" and ratios than the other gears of science and art. Entwined learning allows for changes in breadth and depth from one

discipline to the next, yet unified for blended, interdisciplinary and transdisciplinary learning (Figure 1).

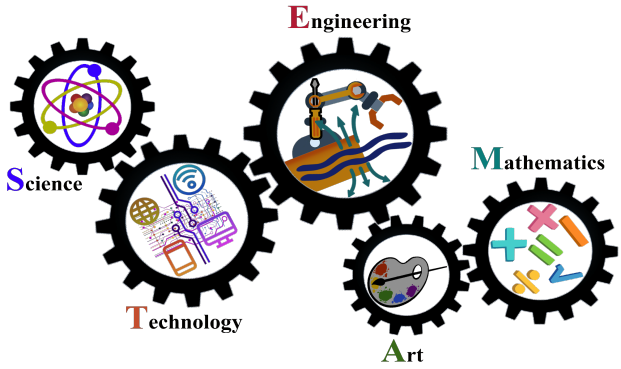

Figure 1. Gears of STEAM learning

The intricate movement of gears within a mindfulness construct are the meshing of gears for establishing open and non-judgmental emotive and cognitive awareness for empathy and social skills. In addition, each conceptual mindfulness turn also creates attention to the present moment and provides an equal awareness of sensate experiences for self-management, self-regulation, and self-actualization. The researchers' conceptualization of the degrees of mindfulness learning results in synchronous relational pathways for both social skills development and self-actualization. Mindfulness transmits torque for learners to observe and gain insight into their thoughts, which results in the development of empathy and social skills and the regulation of emotions for actualization (Bishop et al., 2004; Kabat-Zinn, 1990). Similar to how the synchronization and interlocking of gears ensure smooth and efficient mechanical operation, mindfulness techniques empower learners to cultivate an acute awareness of their thoughts. Student enhanced observations aid in regulating emotions, fostering empathetic social skills development, and balanced regulation for actualization (Figure 2).

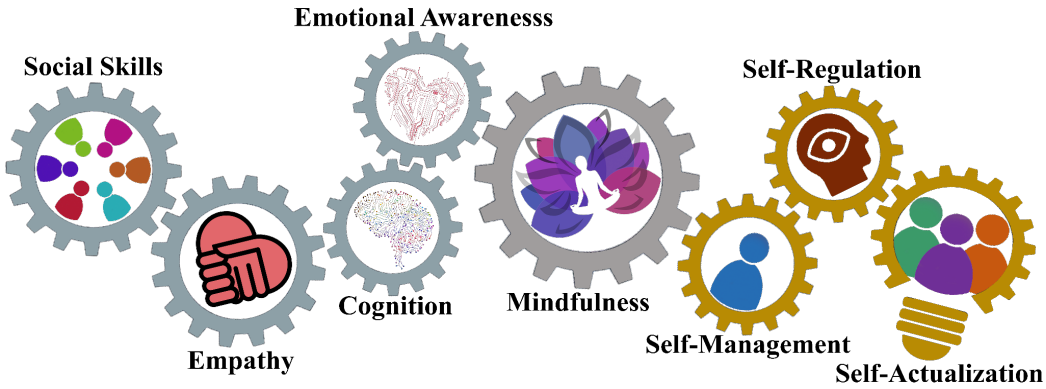

Figure 2. Gears of mindfulness learning

In addition, learning is complex. The STEAM and mindfulness gears of synchrony influence one another, with each movement causing countermovements from clockwise to counterclockwise. As such, STEAM and mindfulness learning environments are intricate and interactive because they are entwined spaces for independent, personalized learning as well as socialized learning, self-management, and self-regulation for self-actualization. STEAM education combined with critical thinking positively impacts students' social development by fostering empathy, reflective thinking, enhancing problem-solving abilities, and promoting collaborative efforts for social-emotional growth (Lam et al., 2019; Mariana & Kristanto, 2023). Philosophically, STEAM learning environments are places for degrees of movement, establishing the conditions for an atmosphere that facilitates self-regulation and mindfulness in learning. Integrating STEAM education with critical thinking enhances students' self-regulation by encouraging them to set goals that promote perseverance (Lam et al., 2019) (Figure 3).

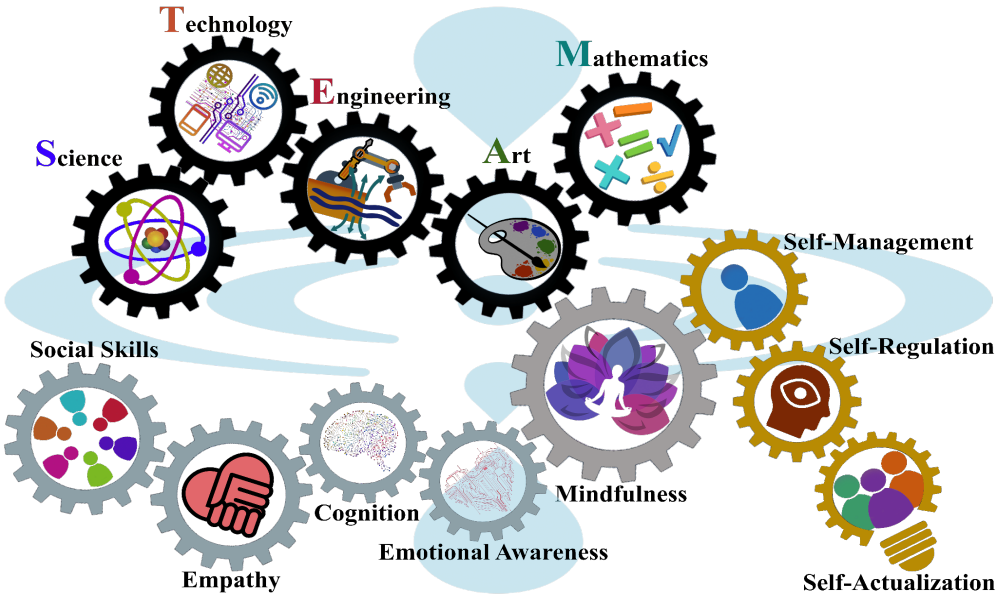

Figure 3. Gears of synchrony for STEAM, mindfulness, and self-regulation

Historical Context: STEAM Education

Interdisciplinary and Transdisciplinary Learning

Interdisciplinary approaches involve collaboration between different disciplines to address a specific issue, while transdisciplinary approaches entwine knowledge and methods from multiple disciplines in a way that transcends traditional academic boundaries, focusing on holistic problem-solving and the application of integrated knowledge to real-world challenges (Liao, 2016). Promoting the development of a holistic mindset in learners is vital for developing the whole child, which includes cognitive and social domains for mindset and emotive actualization. By breaking down traditional disciplinary boundaries, transdisciplinary education promotes a holistic understanding of issues and fosters innovative solutions with a meaningful impact on society and the environment (Clark & Button, 2011). Creating opportunities for students to utilize critical thinking skills within an emotionally supportive environment enables

learners to cognitively and emotionally explore solutions with an asset-mindset for creative problem-solving. Transdisciplinary STEAM learning facilitates students exploring and solving problems using multiple perspectives, leading to more innovative and effective solutions (Amalu et al., 2023).

From STEM to STEAM

Interdisciplinary and transdisciplinary teaching and learning are central tenets of STEM and STEAM education. However, STEM and STEAM are relatively new teaching and learning philosophical approaches for cognitive and emotive blended learning. In response to 21st-century challenges and in an effort to blend disparate content, the acronym SMET (Science, Mathematics, Engineering, and Technology) was conceived by the United States National Science Foundation (NSF) in the 1990s, which was later reframed as STEM by the NSF's Education and Human Resources Directorate (Breiner et al., 2012; Widya, et al., 2019). However, STEM philosophy did not simply begin with the NSF as a means to blend content. The initial concept of STEM education is primarily attributed to the launch of the Russian satellite Sputnik in 1957; this sparked a heightened emphasis on science and engineering education in the United States and marked the inception of STEM education (Granovskiy, 2018; Mohr-Schroeder et al., 2015). As STEM continued to be developed and refined, STEAM education was introduced in South Korea in 2011 as a strategy to reform STEM education by integrating "Art" into STEM (Widya, et al., 2019). Entwining art within the acronym STEM affords creativity throughout the interdisciplinary and transdisciplinary blended construct of STEAM. Intersections of cognitive and emotive learning occur throughout the acronym and influence learners' self-regulation for mindfulness. Integrating art into STEM education benefits students by enhancing convergent thinking, creativity, and character development and by providing a broader range of problem-solving approaches, ultimately preparing them for successful careers in growing fields such as sustainable energy technologies (Amalu et al., 2023).

Entwined Science of Learning

Incarnation of Constructivism

Constructivism is an essential theoretical methodology for facilitating STEAM education, as it empowers students to build knowledge through design processes and prepares students for the creative demands of 21st-century workplaces (Gross & Gross, 2016). STEAM teachers entwine constructivism within STEAM to design lessons and activities students engage in that provide opportunities to interact with peers, work independently, and employ discovery for creatively building knowledge. Constructivism supports students' cognitive, emotional, and social skills development through peer interactions and facilitates independent learning, inquiry, and connecting concepts in building knowledge (Zhu & Atompag, 2023). Inquiry allows students to examine phenomena and consider solutions for STEAM learning through hands-on experiential engagement. As a result, constructivism supports students' emotional regulation by prioritizing active participation in learning, enabling students to build their own comprehension, and offering hands-on experiences for autonomy, leading to emotional regulation (Videla et al.,

2021). STEAM academic achievement, emotional regulation, and social constructivism are entwined processes that empower holistic learning. In research conducted by Kussmaul & Pirmann (2021), social constructivism was identified as a significant form of STEAM academic and social-emotional learning due to its focus on collaborative learning and social interaction, contributing to improved critical thinking and deeper comprehension of concepts. The process of students building knowledge through social interactions and problem-solving was a significant, influencing factor in cognitive and social-emotional learning. Entwined social interactions through collaboration support students as they socially regulate their emotions for self-actualization and develop a growth mindset.

Manifestation of Collaborating

The shift from STEM to STEAM learning provides several cognitive, social, emotional, and behavioral regulatory advantages for students. Entwining the arts in education links STEAM and emotional intelligence, fostering creativity and emotional awareness among students for meaningful collaborative learning (de Vries, 2021). In addition, entwining the arts creates opportunities for collaborative student engagement that fosters creative and critical thinking among learners. In research on STEAM education, Li et al. (2022) linked interdisciplinary and transdisciplinary STEAM environments with cultivating self-awareness of thoughts and developing problem-solving skills in students, which are fundamental for self-regulated learning. STEAM education fosters a growth mindset and enhances character-building skills in students by affording opportunities to learn through resilience, inquisitiveness, creativity, and problem-solving (Bertrand & Namukasa, 2020). Collaborating while engaging in interdisciplinary and transdisciplinary learning provides multiple opportunities for students to form relationships with peers and develop emotional awareness. STEAM learning affords a learning environment that supports the development of relationships and shared norms, which are important for cooperation and teamwork (Li et al., 2022). Affording students an environment to engage in academic learning while also developing social skills through collaboration and teamwork provides opportunities for learners to develop emotional awareness, self-regulation, and mindset. In research conducted by Kim et al. (2019), the investigators found that student academic success and emotional regulation resulted from the entwined, collaborative nature of STEAM learning and prolonged artistic collaborations. STEAM education enhances students' capacity to engage in collaborative research and problem-solving, which are crucial competencies for self-regulated learning (Li et al., 2022).

Externalization of Communicating

Collaborative, prosocial learning environments create conditions for students to engage in both academic and emotive experiential learning for constructive, effectual communications. STEAM promotes positive relationships and the sharing of multiple ideas, and it encourages the use of socially appropriate interactions, which are essential for effective communications (Belbase et al., 2022). The collaborative sharing of ideas provides opportunities for students to not only communicate their thoughts, but also question the thoughts of others in a non-confrontational manner for constructing shared knowledge. Collaborating creates a communicative effect for stirring students' natural curiosities and contributing to students'

emotional development. Perales & Aróstegui (2021) emphasize the importance of the "emotional touch" in STEAM education due to its role in providing intrinsic motivation, enhancing communication skills, and contributing to the holistic development of individuals, aligning with the requirements of present and future society. STEAM education provides an environment for motivating learners and encouraging students to regulate emotions, which are key aspects of social-emotional learning for effective communications (Hsiao & Su, 2021). Student self-regulation contributes to a supportive, communicative environment for employing mindfulness and overcoming developmental obstacles. Mindfulness holds significance in STEAM learning environments as it shapes students' perspectives on challenges, their ability to persevere through obstacles, and their openness to embracing interdisciplinary methods through collaboration and communications (MacDonald et al., 2020).

Personification of Critical-Thinking

Constructivist learning environments empower students to take control of the learning by moving from a didactic lecture methodological approach for instructional delivery to a student-centered and student-led model for self-discovery and promotion of critical thinking. STEAM integrates creative and critical thinking by offering learning opportunities that capture students' interest, present challenges, and enable them to collaboratively design solutions (Henriksen, 2017; Mariana & Kristanto, 2023). STEAM learning environments that embrace self-regulated mindfulness allow students to engage in problem-solving through analyzing and evaluating data and information. In these types of learning environments, students are afforded a welcoming space to question and assess learning through critical thinking. In STEAM learning environments, critical thinking empowers students to analyze and generate solutions in tandem with creative thinking, which fosters the expression of original ideas (Mariana & Kristanto, 2023; Wilson et al., 2021). STEAM education and critical thinking positively influence students' social-emotional learning by nurturing empathy, problem-solving skills, and collaboration for social-emotional development, which fosters the utilization of goal setting for perseverance (Lam et al., 2019).

Actualization of Creative-Thinking

Entwining art throughout STEM education motivates student learning and affords opportunities for creative expression (Perignat & Katz-Buonincontro, 2019). A STEM to STEAM education provides a learning environment for students to engage in constructivist problem-solving and an atmosphere of collaboration, prosocial communications, critical thinking, and creative thinking. A learning environment that supports the cognitive needs of students in addition to the social, emotional, and behavioral needs for emotional awareness creates conditions for mindfulness. By entwining art throughout STEM, STEAM fosters a more comprehensive understanding of the subject matter, resulting in perspective-taking, emotional connections, and creativity (Leavy et al., 2023). In addition, STEAM learning provides a social environment that influences student creativity and self-efficacy (Conradty & Bogner, 2020). Utilizing creative forms of expression to showcase comprehension not only improves students' grasp and recall of the material but also fosters independence and self-assurance as students delve into and articulate their ideas. STEM educators can contribute to the development of mindfulness in

students by offering chances for students to creatively explore and articulate their ideas (Larkin 2015). Constructing knowledge includes collaborating and communicating to facilitate critical thinking and creative thinking. Dignam (2021) posits STEAM education consists of five cyclic processes; Constructivism, the interchangeability of Collaboration and Communication, and finally, the exchangeability of Critical-Thinking and Creative-Thinking (Figure 4).

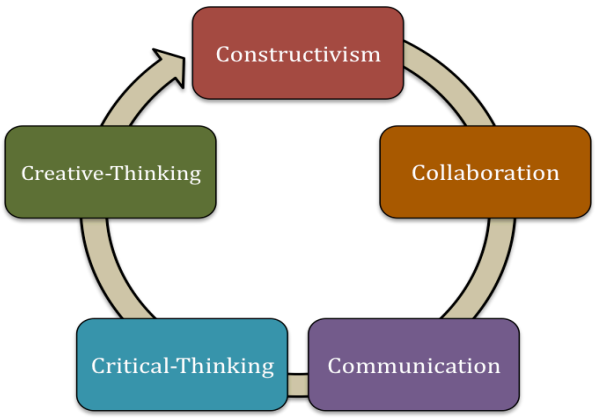

Figure 4. Dignam's 5 Cs of STEAM education

Historical Context: Mindfulness

A Universal Perspective

While originating from Eastern tradition, Western culture has witnessed a rise in the adoption of mindfulness techniques. Jon Kabat-Zinn, an American professor, is widely recognized in Western society for his contributions to the field of mindfulness. Specifically, he is known for his pioneering work in developing mindfulness-based stress reduction (MBSR) in the 1970s (Zenner et al., 2014). Kabat-Zinn defines mindfulness as the state of being aware and fully present in the current moment, achieved via the deliberate act of attentively observing one's experiences with an open and receptive mindset (Kabat-Zinn, 1990). Bishop et al. (2004) proposed a bipartite framework for delineating mindfulness. The initial component of self-regulation is the ability to concentrate on one's current experience, leading to heightened awareness of mental events occurring in the present moment (Bishop et al., 2004). The second phase involves cultivating a specific mindset towards one's current experiences, characterized by "curiosity, openness, and acceptance" (Bishop et al., 2004, p. 232). Mindfulness-based activities are now widely used in cognitive and behavioral mental health programs and school-based curricula.

A School-Based Perspective

The emergence of mindfulness interventions in schools can be attributed to Kabat-Zinn's mindfulness-based stress reduction (MBSR) program. Kabat-Zinn initially developed MBSR to assist adults in coping with persistent pain and stress (Zenner et al., 2014). However, in the

1990s, he modified the program to be applicable to children and teenagers, resulting in a specialized version called mindfulness-based stress reduction for teens (MBSR-T). This program marked the first instance of a mindfulness program specifically tailored for educational settings (Zenner et al., 2014). Following the creation of MBSR-T, several mindfulness programs have been designed to educate students on self-regulation within school environments (Zenner et al., 2014). The influence of mindfulness-based interventions in schools has been notably substantial. Furthermore, mindfulness-based interventions (MBIs) have demonstrated the ability to enhance a student's self-regulation, self-compassion, attention capacity, and temporal window size (Zenner et al., 2014).

Mindfulness programs utilize various meditation techniques and strategies in their teaching and training approaches (Bishop et al., 2004; Tang et al., 2020; Zenner et al., 2014). Mindfulness approaches facilitate the cultivation of psychological well-being and enable students to gain the psychological capacities required for self-awareness, self-control, social awareness, interpersonal interactions, and prosocial skills (Berti & Cigala, 2020). Entwined mindfulness and STEAM philosophy pave pathways for students to engage in cognitive and emotive experiential learning for attention, working memory, critical thinking, creative thinking, problem-solving, self-regulation, and building social capital.

According to the Collaborative for Academic, Social, and Emotional Learning (CASEL, 2023), students must possess a number of these fundamental skills in order to achieve goals, cultivate positive peer relationships, develop a positive sense of self, make ethical choices, and thrive in the learning environment. The ability of students to utilize a positive sense of self facilitates prosocial interactions among learners in cooperative learning settings for engaging in STEAM-centered critical thinking and problem-solving (de Vries, 2021; Mariana & Kristanto, 2023). These interactions are critical for students and influence the construction of social capital. Providing students with an entwined, interactive, and supportive STEAM learning environment that promotes both cognitive and emotional learning affords learners multiple perspectives and pathways for developing an awareness of emotions and an increased ability to regulate emotions.

A Neuro-STEAM Perspective

Students' teenage years are a crucial time for mental health, as most mental health conditions tend to emerge during this period (Tudor et al., 2022). Given the high prevalence and complexity of mental health issues among adolescents, it is crucial to gain a better understanding of learners' mental health and the neuroscience of regulation. Studies have shown that school-based mindfulness can be effective in enhancing the mental health and self-regulation skills of young learners (Tudor et al., 2022). Neuroscience research has shown a growing interest in mindfulness meditation over the past two decades, with studies providing compelling evidence of how such practices can lead to structural and functional changes in the brain (Fox et al., 2014; Tang et al., 2020; Tang et al., 2015; Taren et al., 2015). Behavioral studies have indicated that mindfulness meditation can potentially benefit various cognitive domains, including attention, memory, executive function, and cognitive flexibility. These effects have been observed in multiple brain regions, such as the cerebral cortex, subcortical gray and white matter, brainstem,

and cerebellum, which aligns with the diverse mental functions involved in mindfulness practices.

Mindfulness has the potential to promote positive social behaviors in learners by helping them become more attuned to their emotions, thereby improving their interactions with peers and bolstering their self-regulation (Berti & Cigala, 2020). It has been suggested that these changes occur by modifying brain connectivity patterns linked to general cognitive functions such as attention, self-reflection, rumination, and interoception. This shift may contribute to a restructuring of the self-schema, characterized by reduced inflexibility and a decrease in psychological symptoms (Crane et al., 2016). These neuroscientific insights into mindfulness pose significant implications for students dealing with emotional challenges. Mindfulness training, with its inherent emphasis on present-moment awareness, acceptance, and compassion, may offer these students a valuable tool for self-regulation and emotional management (Mitsea et al., 2023; Valero et al., 2022; Yuan, 2021).

STEAM nurtures active learning and social-emotional development (Weyer & Dell'Erba, 2022). Developing social-emotional skills through STEAM experiential learning provides students with abilities they can apply for self-regulating stress and focusing attention for executive functioning and attaining academic goals. STEAM increases self-assurance through hands-on, interdisciplinary learning experiences that enable students to apply their skills across various fields, fostering a sense of competence and confidence (Rikoon et al., 2018). In addition, STEAM promotes positive social interactions for modified neurological regulation and provides new ways to engage emotions by recognizing and dealing with the emotional side of learning (Steele & Ashworth, 2018). Just as mindfulness helps learners become more attuned to their emotions for prosocial behaviors, STEAM learning environments promote socialization for building social capital and enhancing self-regulation skills development. During the process of STEAM learning, positive emotions and active participation foster social connections and trust, which facilitates students working together on identifying solutions through interdisciplinary and transdisciplinary projects (Li et al., 2022).

Entwined Art of Learning

Realization of Self-Regulation

Self-regulation refers to an individual's ability to exercise control over their own responses and manage their attention, thoughts, emotions, and behaviors in the presence of distractions and impulses (Cary et al., 2023; Thomson & Jaque, 2017). Self-regulation involves finding strategies to deal with intense emotions, improving focus and attention, and effectively controlling behaviors to achieve goals and maintain positive social interactions (Montroy et al., 2016; Wang et al., 2022). Self-regulation can also be conceptualized as the capacity to adjust one's behavior in order to attain a goal despite potential distractions (Ezmeci & Akman, 2023; Izhar et al., 2022). This capacity is complex and combines higher-order and lower-level skills (Kopp, 1982; Williams et al., 2023). In an educational setting, the development of self-regulation is crucial. Without this skill, students may struggle to focus on tasks and engage meaningfully with others in the learning environment. STEAM education significantly

improves students' self-regulation and emotional awareness by fostering creative collaboration and promoting interdisciplinary learning experiences that motivate learners to engage and persist in their efforts (Kim et al., 2019). Students with strong self-regulatory skills demonstrate intrinsic motivation, independence, and initiative in pursuing their educational goals, actively guiding their own learning process (Oates, 2019). Acquiring self-regulation skills empowers learners to actively participate in the learning process, and the cultivation of self-regulation directly enhances their readiness for learning (Brenner, 2022; Gu & Zhu, 2023; Long et al., 2021; Louick & Muenks, 2022; Zeilhofer, 2023).

Incorporation of Executive Functioning

Self-regulation is just one aspect of a broader set of skills known as executive functioning. Executive functioning encompasses a range of cognitive processes and abilities, including working memory, cognitive flexibility, inhibitory control, decision-making, and problem-solving (Dong et al., 2023; Gu & Zhu, 2023). Entwined STEAM learning enables students to participate in activities that encourage empathy, teamwork, and self-regulation, which contributes to the actualization of student emotional intelligence (de Vries, 2021; Li et al., 2022). These skills collectively contribute to students' ability to organize thoughts, plan and prioritize tasks, solve problems, make sound decisions, and regulate their behavior. Executive functioning skills contribute to students' academic achievement, personal development, and overall well-being for lifelong learning. Executive functioning encompasses a range of cognitive processes that facilitate the execution of conscious, goal-directed behaviors (Sawyer et al., 2021). In contrast, self-regulation is a broad concept that encompasses a range of self-initiated behaviors aimed at regulating thoughts, emotions, and actions (Blair & Raver, 2014; McClelland & Cameron, 2011). While the terms executive functioning and self-regulation are sometimes used interchangeably and exhibit overlapping definitions, their usage can vary across different scientific domains. However, it is generally accepted that these terms refer to similar cognitive processes involved in regulating thoughts, emotions, and behaviors (Blair & Raver, 2014; Meuwissen & Carlson, 2015).

Reification of Entwinement

Self-regulation and executive functioning are entwined constructs, and their integration is crucial for promoting student success in various aspects of life, including academic achievement, social interactions, and overall well-being. Through self-regulated STEAM education, students gain the ability to manage their own learning, identify objectives, assess progress, and interact with one another (Li et al., 2022). Self-regulation involves the ability to direct and sustain attention on a specific task or goal, while executive functioning supports cognitive processes, such as working memory and inhibitory control, that are central to attentional control (Follmer & Sperling, 2016). Moreover, self-regulation and executive functioning play crucial roles in goal-directed behavior. Self-regulation enables students to establish goals, devise strategies, monitor progress, and make necessary adjustments to achieve desired outcomes. Executive functioning provides the cognitive flexibility and working memory capacity required to carry out these goal-directed behaviors (Follmer & Sperling, 2016).

Emotional regulation is another area where self-regulation and executive functioning entwine. Self-regulation involves recognizing and managing emotions, while executive functioning facilitates adaptive emotional responses through processes such as emotional working memory and cognitive reappraisal (Xiu et al., 2018). Entwined self-regulation and executive functioning are crucial for self-initiated, proactive learning behaviors. Students in STEAM education settings with strong self-regulation skills are more likely to exhibit intrinsic motivation, initiative, and goal-directed behavior, all of which are facilitated by executive functioning abilities such as cognitive flexibility, working memory, and inhibitory control (Dong et al., 2023; Gu & Zhu, 2023). By nurturing and developing self-regulation and executive functioning skills, educators can empower students to effectively manage their thoughts, emotions, and behaviors, leading to improved academic achievement and overall well-being (Figure 5).

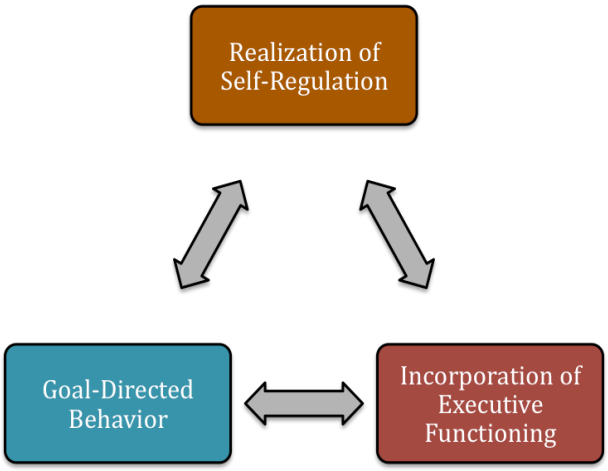

Figure 5. Entwined art of learning

Typification of Theory

According to Vygotsky's *Sociocultural Theory of Cognitive Developmen*t (1978), self-regulation involves both individual and social learning aspects. Social interactions serve as models that internalize the cognitive and metacognitive processes of self-regulation, fostering co-regulation in learners (McCaslin, 2009). When students are supported in reaching emotional goals they are empowered to attain their cognitive, emotional, and social objectives, while also facilitating independent learning, inquiry, and the construction of knowledge systems (Zhu & Atompag, 2023). Constructivism fosters active student engagement, hands-on experiences, and integrated teaching and learning in STEM and STEAM educational settings and enables students to construct their own understanding and participating in authentic, self-directed learning experiences (Videla et al., 2021).

The concept of socially shared regulation goes beyond co-regulation, indicating the regulation of shared learning goals within groups (Hadwin et al., 2017). Essential components of Self-Regulated Learning (SRL) include metacognition regarding experiences, knowledge, and control, as highlighted by Zimmerman (2008). SRL involves the interplay between metacognition and affect, with students' emotional experiences and motivation influencing their

metacognitive control decisions (Efklides & Metallidou, 2020). Casali et al. (2022) assert that the integrated Self-Regulated Learning (iSRL) model posits that academic learning encompasses cognitive, behavioral, and emotional outcomes. These outcomes comprise achievements in academics, adoption of effective study behaviors, and regulation of emotions. The iSRL model emphasizes the role of internal factors within individuals, such as self-regulated learning, motivation, personal skills, and genetics, in facilitating successful academic learning. These internal factors interact with external systems, including families and institutions, to shape the processes and strategies employed in academic learning.

Flexibility in utilizing these internal factors is posited by the iSRL model to be a critical factor in achieving positive outcomes in an academic journey. The ability to adapt and employ self-regulated learning strategies contributes to the development of a resilient and adaptable learner who can effectively navigate the complexities of the educational environment. STEAM education nurtures emotional intelligence, which is crucial for cultivating critical and creative thinking in students and for self-regulation. Entwined STEAM learning enables students to participate in activities that encourage empathy, teamwork, and self-regulation, which contributes to student actualization (de Vries, 2021). Supporting SRL is of significant importance as it aligns with contemporary educational initiatives and advancements, such as 21st-century learning, inquiry learning, inclusion, and assessment for learning (Perry et al., 2018). SRL promotes the cultivation of adaptive, lifelong learners who possess critical thinking and problem-solving skills. These learners are equipped with the capacity to learn and work both independently and collaboratively, enhancing their ability to thrive in diverse educational contexts.

Application of Theory

According to Self-Determination Theory (SDT), an individual's motives for their behavior are intricately linked to their level of engagement and overall well-being. Individuals who pursue their genuine interests and values tend to exhibit greater vitality and overall health (Ryan & Deci, 2000). However, for individuals to maintain this level of autonomy and self-determination, their environment must satisfy their basic needs for autonomy, competence, and relatedness. While promoting competence and relatedness can encourage the internalization of a behavior or value, they are insufficient in facilitating integration, a critical aspect of authentic self-regulation (Deci & Ryan, 1985; Grolnick & Ryan, 1989; Ryan & Deci, 2000). For integration to occur, individuals require the freedom to reflect on and endorse their motivations and regulations and align them with their self-identity, thereby fulfilling their need for autonomy. STEAM learning environments that enable students to control their learning create conditions such that they develop an interest in learning and thus actualizing SDT. Providing conditions for students to maintain autonomy presents learners with an environment conducive to integration and self-regulation. Relational-rich STEAM learning settings afford students constructivist, experiential learning for reflection and motivation for autonomy through socially and emotionally supportive environments.

Representation of Theory

A meaningful connection can be made between SRL theory and the practice of mindfulness. Mindfulness-based interventions have been shown to improve self-regulated learning skills (McKeering & Hwang, 2019). Mindfulness practice is strongly related to self-regulated learning, as it enhances students' ability to focus their attention on the task at hand, regulate emotions, and adapt strategies as needed. Self-regulated learning in STEAM learning environments fosters student resiliency and adaptability for self-efficacy. Applying mindfulness in an academic setting such as STEAM aligns with the philosophical principles of providing an experiential learning environment for students to actualize cognizance of thoughts and emotions for regulating learning and academic, social, emotional, and behavioral success (Figure 6).

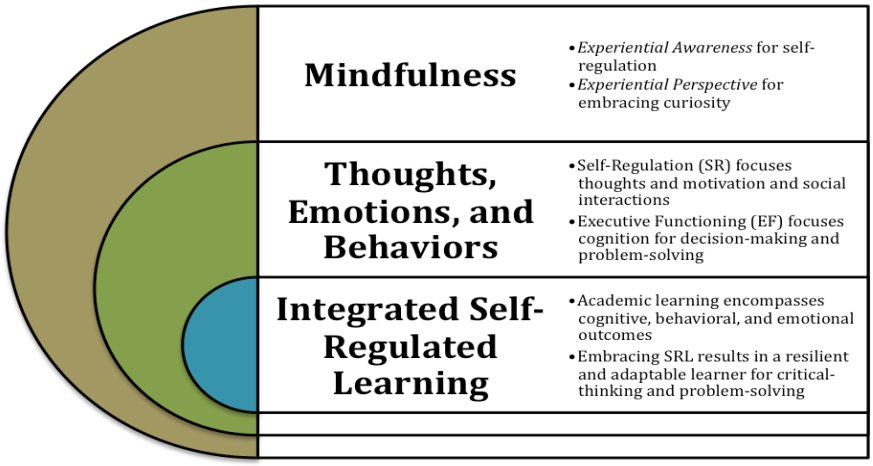

Figure 6. Mindfulness for connecting theory to application

Theoretical Framework

STEAM Learning Environment

Art encourages students to think creatively and imaginatively, which is essential for addressing complex, real-world problems in a transdisciplinary context (Clark & Button, 2011). STEAM fosters confidence in students by providing opportunities to engage in practical, multidisciplinary learning activities. These experiences empower students to apply their skills across diverse fields, fostering a sense of proficiency and self-assurance (Rikoon et al., 2018). STEAM learning environments that capitalize on student self-regulation and mindfulness create conditions for students to build social capital through constructivist, cooperative learning for actualizing resiliency and adaptability for inquisitiveness, creativity, and problem-solving. In STEAM, enhanced social capital contributes to improved STEAM learning, motivation, and participation among students. This is achieved by providing emotional resources within students' social networks (Saw, 2020). Prosocial communications, self-management, and actualization motivate learners and provide opportunities for engaging in both critical thinking

and creative thinking. Emotional awareness, motivation, and social recognition play crucial roles in shaping students' academic success in STEAM and their social and emotional learning (Li et al., 2022). Cognitive and emotive experiential learning entwine in STEAM for self-regulation and self-regulation for mindfulness (Figure 7).

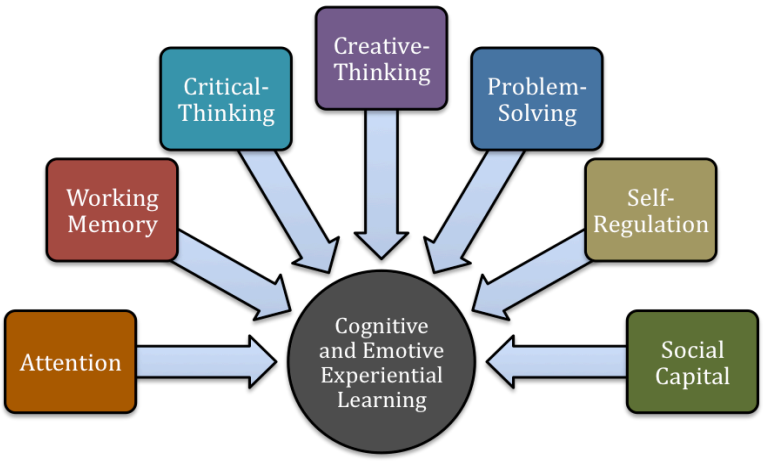

Figure 7. Entwined STEAM and mindfulness

Mindfulness for Academic Achievement

Executive functioning is a critical cognitive foundation that plays a crucial role in student success. Executive functioning consists of essential cognitive skills, such as working memory, cognitive flexibility, inhibitory control, planning, and self-monitoring, which provide students with the tools needed to regulate their thoughts, actions, and emotions, ultimately facilitating task completion (Lam & Seiden, 2020; Qi, 2023). Possessing strong executive function skills can lead to academic and social success for students (Andreu et al., 2023; Senter et al., 2023; Valero et al., 2022). Research has shown that executive function skills are significantly related to children's learning abilities, with implications for subjects such as literacy and mathematics (Chan et al., 2022; Delisio et al., 2023; Yousefi et al., 2023). An effective strategy for promoting academic success is mindfulness, which can enhance self-regulation skills. By improving self-regulation skills, students can better focus their attention on academic tasks, resist distractions, and manage time efficiently, which are all key components of executive functioning. Mindfulness not only fosters cognitive skills such as attention, working memory, and self-regulation, but also reinforces social-emotional competencies, allowing students to better manage emotions, build constructive relationships, and make responsible decisions (Ahmed Aboalola, 2023; Day et al., 2022; Qi, 2023).

Mindfulness for Social and Behavioral Success

Mindfulness-based interventions are commonly implemented in educational settings to target social-emotional development and promote emotional and behavioral regulation (Phan et al., 2022). Neurological and psychological research supports the integration of mindfulness-based strategies in STEAM, highlighting the potential benefits of such interventions. Zenner et al.

(2014) conducted a comprehensive analysis of mindfulness interventions in educational settings and found that these initiatives yielded significant improvements in cognitive functioning and resilience to stress. Furthermore, they observed a notable reduction in symptoms of depression, anxiety, and stress. Providing executive function training to children is considered a preventive measure for mental disorders, with approaches encompassing behavioral, movement-based, and mindfulness methodologies (Goldberg et al., 2022; Gupta & Lee, 2020; MacDonald & Neville, 2022). Behavioral training has also demonstrated effectiveness in addressing attention deficits among children (Lee et al., 2022). Mindfulness training, with its emphasis on non-judgmental experiences of thoughts, feelings, and actions in the present moment, has been shown to reduce stress and anxiety while enhancing cognitive control (Duarte et al., 2022; Felver et al., 2017; Sousa et al., 2021).

CONCLUSION

STEAM is a philosophical catalyst for entwining interdisciplinary and transdisciplinary learning, both within and beyond its acronym, promoting comprehensive, holistic learning. By incorporating the arts, STEAM offers diverse paths for students to participate in collaborative learning, fostering creativity and inquiry for academic growth and mindful, emotional learning. The philosophy of mindfulness centers around the belief that individuals can achieve a deeper understanding of their minds and behavior through intentional and non-judgmental awareness. Both mindfulness and STEAM create supportive social environments for students to cultivate awareness of their thoughts, emotions, and sensory experiences.

STEAM learning influences students' emotions and fosters an environment that cultivates emotional awareness. Entwined cognitive, social, emotional, behavioral, and mindful learning in STEAM education equips students with essential skills to pursue lifelong academic success and mindfulness for collaborating with others. Emotional awareness empowers learners to build cognitive and affective social capital, facilitating teamwork and effective problem-solving. STEAM not only nurtures emotional awareness but it also encourages its application in regulated inquiry, critical thinking, and problem-solving, enhancing students' overall academic and mindfulness abilities.

STEAM ignites student curiosity and inquiry, promoting collaborative learning, emotional regulation, and active engagement. By entwining the arts, STEAM offers unique ways to engage emotions, influencing both cognitive and emotional aspects of education. Personalized learning enhances academic outcomes and helps regulate emotions, creating meaningful sensory experiences. The arts in STEAM contribute to a sensory-rich, collaborative learning environment, fostering critical thinking, creativity, and active learning. The entwined philosophies of mindfulness and STEAM guide experiential learning in cognitive domains for problem-solving, as well as the mindfulness domains of experiential awareness for self-regulation and experiential perspective for embracing curiosity. Entwined mindfulness and STEAM philosophy pave pathways for students to engage in cognitive and emotive experiential learning for attention, working memory, critical thinking, creative thinking, problem-solving, self-regulation, and building social capital.

Cultivating social and emotional skills through STEAM experiential learning, coupled with experiential awareness and experiential perspective for mindfulness, equips students with tools for self-regulating and focusing attention for executive functioning and attaining goals. Collectively, these skills empower students to organize thoughts, plan tasks, prioritize, solve problems, make sound decisions, and regulate behavior. Executive functioning skills significantly contribute to academic success, personal growth, and overall well-being, which lead to goal-directed lifelong learning. STEAM builds student confidence by providing hands-on, interdisciplinary, and transdisciplinary learning opportunities. Blending cognitive and emotional experiential learning intertwines STEAM with self-regulation and mindfulness. Entwining mindfulness-based strategies in STEAM creates conditions and an atmosphere for students to engage in meaningful academic, social, emotional, and behavioral lifelong learning.

Recommendations

The researchers provided rationale for entwining self-regulation and mindfulness strategies alongside STEAM curricular delivery to provide holistic learning for students. A STEAM construct naturally creates opportunities for students to engage in social capital-building due to the collaborative nature of STEAM learning. In addition, STEAM learning environments naturally create an atmosphere for students to engage in emotive learning, thereby providing students with opportunities to capitalize on emotional awareness for self-regulation and mindfulness. The researchers recommend incorporating mindfulness exercises, such as diaphragmatic breathing to create emotional and physical awareness (body scans). These activities aid in increasing the student's self-awareness and focus on the present moment, thus mentally preparing them to participate in STEAM activities.

Furthermore, the researchers recommend that teachers capitalize on the social, emotional, and behavioral learning that takes place, in addition to academic learning, through STEAM education. The social, emotional, and behavioral benefits of STEAM include opportunities to better promote the self-efficacy beliefs of learners. By integrating mindfulness activities in the context of STEAM education, educators can empower students to develop greater self-efficacy and increased confidence and competence in their own STEAM abilities. Supporting the self-efficacy beliefs of learners can be accomplished by affording opportunities for students to reflect on their progress, set goals, and celebrate their success, thus increasing their confidence in their ability to excel in STEAM. Emotionally connecting students to academic content facilitates ownership of the learning and motivates students to succeed. A natural relationship exists between STEAM learning and mindfulness that most STEAM educators traditionally overlook. While student academics are essential, the potential for entwining student self-actualization and self-regulation exists because of the inquisitive, creative, and emotive qualities of STEAM education. Capitalizing on this entwined relationship does not modify curricular content, but it does modify the ways learners think in order to improve student self-efficacy, which promotes holistic learning.

Teachers also require opportunities to grow professionally and advance skills to support students better. STEAM teachers are also highly skilled in delivering interdisciplinary and transdisciplinary instructional delivery for cognition, but providing professional insight

regarding the social, emotional, and behavioral benefits of STEAM learning, alongside self-regulation and mindfulness, provides STEAM teachers with transferable skills to aid all students. Rather than simply engaging in episodic professional development or periodic professional learning, the researchers recommend employing professional erudition, which is an amalgamation of targeted professional learning and development for site-based professional growth. Professional erudition is a form of STEAM-based professional growth that affords educators a continuous and evolving process for supporting students' academic and self-regulatory needs. In a study conducted by Dignam (2023), employing professional erudition in STEAM resulted in students developing both improved STEAM-related academic achievement as well as improved social-emotional growth, actualization, and efficacy. The researchers recommend providing teachers with professional growth opportunities through a professional erudite lens, as professional erudition is a strategy that employs multiple professional growth pathways. Entwined site-based professional development, targeted professional development, and professional learning via professional erudition create meaningful, targeted professional growth to support STEAM education and mindfulness.

Lastly, the researchers recommend that educators capitalize on the experiential learning relationships that exist between and within STEAM education and mindfulness. The discernment of social and emotional skills development as a result of STEAM experiential learning, alongside the experiential awareness and experiential perspective of mindfulness, provides students with skills for self-regulating, focusing attention, employing executive functioning, and attaining goals. A primary objective and intention of education is to equip students with skills and tools they can employ throughout a lifetime of learning. Entwined cognition and emotional, experiential learning, awareness, and perspective create holistic learning for a lifetime of application. Entwining STEAM education, self-regulation, and mindfulness affords students adaptable skills for lifelong learning.

DECLARATIONS

Ethical Considerations: This study did not require ethics committee approval or informed consent because it did not involve human participants. All research methods were conducted in accordance with institutional guidelines and applicable laws.

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Conflicts of interest and competing interests: There is no conflict of interest or competing interests.

Data Availability Statement: The data utilized in this study are publicly available and were used by the authors for constructing original STEAM and mindfulness theory and practices for use by educators and clinicians. Specific sources of the data are included as in-text citations and can be accessed through the links and DOIs within the References section.

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