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RESEARCH REPORT

'Ah!-HaHa!-Aha!': A Tool of Creativity Development in STEM Education

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Abstract

Creativity is a complex phenomenon. This paper highlights emotion mediates creativity development in various situations that happen in our everyday life. Particularly, three important emotional expressions of 'Ah!'(wonder/curiosity), 'HaHa!'(laughter/fun), and 'Aha!'(discovery/inspiration) are focused on in the theoretical discussion that helps to explore links between emotion, creativity, teaching, and learning in STEM education. The interplay between experiences of 'Ah!', 'HaHa!' and 'Aha!' forms a new tool of 'Ah!-HaHa!-Aha!' that can be used to foster a creative climate. Furthermore, a pedagogical model is proposed for developing creativity in STEM education. The model integrates with 'Ah!-HaHa!-Aha!', Inquiry and Problem-Based Learning, Playful Learning, and Teaching for Deeper Learning in one framework. It regards everyday life as the learning context and underpins a systematic perspective to facilitate creativity in STEM education. This also provides STEM teachers with various methods and strategies to develop students' creativity in their daily pedagogical practice.

Keywords: *Creativity, Emotion, Pedagogy Design, STEM Education*

Introduction

Creativity is one of key skills in the 21st century; it has been addressed as a necessary and fundamental to personal achievement and organization innovation. The importance of creativity has been recognized in STEM education. Scientific creativity can be defined as any thought or behavior in science that is both novel and useful (De Vires, 2021); it is an ability of exploring new discoveries, conducting science experiments, solving science problems, and carrying out science activities (Raj, 2016; Zhou, 2019).

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Scientific creativity also involves 'everyday creativity' that regards everyday life as a learning context, concerns everyone's learning experience and occurs in many ordinary situations (Craft, 2005; Zhou, 2020). This also means creativity is a phenomenon in which a scientist, a technician, an engineer, or a mathematician habitually responds to daily tasks in a novel and meaningful way (Conner & Silvia, 2015; Villanova & Cunha, 2020). Social-cultural theories have emphasized creativity as a contextual activity (Amabile, 1996; De Vires, 2021; Sternberg, 1999;). As Zhou (2019) addressed, creativity can be explained partly by personality characteristics but also by situational variables related to changing or enhancing affective states, which leads to options that creativity happens in the interaction between individuals and their situations. Like Amabile (1983, 1996), Mihaly Csikszentmihalyi (1988, 1996, 1999) developed the systems model of creativity, addressing how creativity is influenced by three components: the person, the domain, and the field. This model suggests that creativity is not only a property of individuals but also a property of societies, cultures, and historical periods. Meanwhile, growing from diverse perspectives (i.e., cognition, personality, creativity techniques, etc.), four interesting areas of focus have emerged: a) the Person, who is the creator; b) the creative Process, how creativity occurs; c) the Place or Press, which emphasizes environmental influencing factors; and d) the Product, what the creative outcomes look like (Zhou, 2018, 2019, 2020).

In this sense, 'climate' has been argued as one of key concepts in creativity research. As Ismail (2015) suggested, the climate evolves in the confrontation between the learners and their situational realities, and the situational factors are its determinants, for example, task challenge, freedom, time, playfulness, humor, and idea support, and openness, etc. As well as the physical places in which digital technologies have also been used to support the creative climate and creative learning environment by imaginative play, speculation, and brainstorming, etc (Zhou, 2017; 2018). In learning situations, creativity is also embedded in the process of problem-solving that shapes as many opportunities of gaining new knowledge and experience (Craft, 2005; Zhou, 2014). Both creativity and learning are emotion-related concepts (Zhou, 2017). According to Illeris (2007), 'incentive' is one of dimensions of learning covering motivation, emotion, and volition. This might be uncertainty, curiosity or unfulfilled needs that cause us to seek new knowledge and develop our sensitivity in relation to ourselves and our environment. As Zhou (2019) suggested, having fun provides potential conditions for students to be creative in certain learning processes and learning environments. In comparison with negative emotions, positive emotions play more crucial roles in developing creative thoughts, fostering creative climate, and achieving learning objectives.

The above lines drive this paper to consider emotion as one of important aspects in fostering creative climate in STEM education, discuss three emotional expressions of 'Ah!'(wonder/curiosity), 'HaHa!'(laughter/fun), and 'Aha!'(discovery/inspiration), and explore their relations with creativity. 'Ah!-HaHa!-Aha!' is addressed as a tool that teachers can use to cooperate with diverse creative pedagogies to facilitate students' creativity and foster creative

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climate in STEM education. This paper has its important significance of rethinking STEM education innovation across various levels from primary to higher education.

Linking Creativity with Emotion and Learning

STEM as Creative Work

Creativity has been defined as the generation of novel, appropriate ideas in any realm of human activity in science, arts, education, business, even in everyday life (Amabile, 1996). In general, creativity can be divided into three types: creating something new, combining things together, and improving or changing things (Al-Ababneh, 2020; Mikdashi,1999). Creativity includes two characteristics: one is the notion of novelty which means a phenomenon in everyday life and therefore anyone can be creative as an essential aspect in tackling any challenges and solving any problems (Zhou, 2016); and one is the notion of usefulness which refer to material, product, or practical methods of assessing the usefulness of novel ideas (Zhou, 2019; Shalley, Zhou & Oldham, 2004).

STEM involves creative field of work that interplays disciplinary and interdisciplinary learning. For example, scientists develop their creative ideas to find and solve scientific problems (Draper et al., 2021). As Zhou and Larsen (2025) suggested, in mathematics education, problem solving is a crucial part in teaching and learning activities; it is a means to sharpen reasoning that is careful, logical, critical, analytical, and creative. To solve a mathematical problem requires creativity; problems are sources as well as goals for developing creativity. Previous studies have discussed the concept of scientific creativity (Daud et al., 2011; De Vires, 2021; Simonton, 2008). These studies have been compatible with the general notion of creativity, the nature of science and engineering, the complexity in STEM professional practice, and the realistic issues in contexts of STEM education (Draper et al., 2021).

According to the previous studies (Zhou, 2019; 2020), creativity in STEM contexts can be identified either with 'historical creativity' (i.e., when something, like a new idea, a new theory, a new discovery, is historically new) and/or with 'personal creativity' (when something is new in a personal sense regardless of whether that something is not new to others) (Zhou et al., 2017). This involves both extraordinary 'big creativity' in 'revolutionary science' (Kuhn, 1970) and everyday 'little creativity' in 'normal science' (Craft, 2005; Simonton, 2004).

The recent efforts have paid much attention to 'everyday creativity' or 'little creativity' (Zhou, 2020). As Hadzigeorgiou and his colleagues (2012) suggested, it is true that everyday scientific work like problem finding and solving, hypothesis formation, and modelling, requires creative, imaginative, and logical thinking; in other words, everyday scientific work is the context of creativity development. As Richards (2010) mentioned, the construct of everyday creativity is defined in terms of human originality at work and leisure across the diverse activities of everyday life. Zhou and Frisdahl (2024) describe that everyday creativity drives us to explore our individual identity, foster competence, and enhance ingenuity. This contributes to positive development, as we are motivated by possibility thinking. We become accustomed to asking 'what if?' to explore diverse solutions. This mindset further promotes the generation of new knowledge and self-insight, enabling us to solve daily problems, chart our future course, achieve more, shift paradigms, and adapt flexibly to ever-changing environments. Moreover, creativity is the result of a complex interplay between the person and his/her context (Amabile, 1996). This complexity coupled with the way and the context under which scientific ideas burst forth (Gardner, 1997), sometimes makes scientific creativity an emergent ability or unpredictable event (Sawyer, 2012). As Zhou (2019) addressed, creativity happens in between routine and non-routine problem-solving contexts. It is influenced by different factors including intellectual abilities, prior knowledge, domain-specific knowledge, personality trait, motivation, emotion, environment, and culture.

Creative Climate and Learning

Creative climate has been discussed much as a means to evaluate and promote scientific creativity (Peter-Szarka, 2012; Daud et al., 2012). 'Climate' has been used to describe the recurring patterns of behavior, attitudes, and feelings that characterize life in certain learning or working environments (Al-Beraldi & Rickards, 2003). Climate may arise from interactions between two approaches: one is the cognitive schema approach that highlights individuals' constructive representations or through attempts to uncover individuals' sense making of their proximal work environment (Anderson & West, 1998); and one is the shared perceptions approach that highlights in learning situations, the individuals' shared perception on their joint experiences or the manner of working together with others (Mathisen et al., 2004; Zhou, 2017). So, creative climate influences and is influenced by the interaction between the person and the situation in which creativity takes place; it provides conditions of creative learning. As Zhou (2017) argued, creativity cannot be taught, only the conditions created to encourage it. Similarly, Kaufman (2014) addressed when it comes to nurturing creativity in the classroom, classroom context matters. The learning environment is one of the most important factors - determining, in large part, whether creative potential will be supported (or suppressed).

Creative climate reflects subjective experience of learning. This highlights that creative learning is a process of involving emotions, the development of the self, identity, and humanist social relations (Jeffrey & Craft, 2006; Conner & Silvia, 2015). This also views individuals as agencies for making decisions (sometimes only implicitly if not unconsciously) that are guided by and have consequences for emotions. Rationality and emotions are thus so intricately connected at all levels of the biological, the cognitive, and the behavioral (Cornett, 1986; Averill, 2005; Zhou, 2020). As Jeffrey and Craft (2004) suggested, creative learning involves the experience of dynamic atmosphere, climates of anticipation and expectation, the generation of emotional expression, and development of understandings, skills, processes, appreciation and thinking. For

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STEM teachers, it is important to remember that all students have creative potential, understand how students experience the learning environment, and recognize how students express their creativity in different ways. As Kaufman (2014) suggested, the key question is not so much about whether creativity has a place in the classroom, but rather when and how creativity can be best supported and encouraged.

Emotion-Mediated Creativity

Emotion is one of the elements in fostering creative climate. It is well known that emotion plays crucial roles in mediating our social life (Zhou, 2017). Most emotions are organized by a combination of biological and social factors. As Newton (2013) suggested, emotions are mental states arising from personal evaluations of the world with prompt a readiness to act in support of well-being. Emotional expressions provide information to observers, which may influence their behaviors (Van Kleef et al., 2010). Emotions such as anger, happiness, and love are sharable and public, which are sued for interpersonal communication such as expressing how one feels about an object, person, or event (Lubart & Getz, 1997). Emotions sometimes confer flexibility in action by enabling people to reorder priorities as situations change and to set long-term goals especially when choices involve incomplete data or incommensurate alternatives (Zhou, 2017).

Emotions influence creativity in general (Averill, 2005). Previous studies on mood and creativity show that emotional states such as feeling happy, enthusiastic, and elated, are likely to foster creative ideas (Conner & Silvia, 2015). These states are positive and activated that help to foster approach toward a desired goal rather than avoidance of an undesired goal. As Turner and Stets (2005) emphasized, emotions influence decisions, both consciously and unconsciously. Emotions are the gyroscope of human behavior, keeping it on track in diverse situations so that individuals can experience positive and avoid negative experiences. However, some negative emotions can have both positive and negative effects on creative performance (Van et al., 2010). Particularly, sadness and anxiety have been studied more often than others; the effects of anger have received scant empirical attention. Shortly, findings pertaining to negative emotions have been less conclusive than positive emotions (Zhou, 2017). Accordingly, research on emotion and creativity has much focused on intra-personal effects in examining how individuals' emotional states influence creative climate and innovation process (Zhou, 2019). As Lubart and Getz (1997) suggested, emotion can serve as a motivating force. For example, in a collaborative performance context, individuals may infer from another's expressions of anger that performance is unsatisfactory, which may increase motivation and effort (Huy, 2005; Zhou, 2018; 2019).

'Ah!', 'HaHa!', 'Aha!' and 'Ah!-HaHa!-Aha!'

'Ah!', 'HaHa!' and 'Aha!'

'Ah!' arises from curiosity and wonder. It usually accompanies deliberate musings about something, a puzzling over or pondering sparked with extraordinary curiosity (Parse, 2002). According to L'Ecuyer (2014), wonder drives learning motivation, as it is an inner desire to learn that awaits reality in order to be awakened. Curiosity is also an intrinsically motivated exploration with an information-seeking goal (Bzahydai & Westermann, 2020). As Glăveanu (2019) suggested, the experience of wondering defines a particular kind of relation between person and world, this opens the space of the possible in thought and action. The experience of wondering includes three interconnected, cyclical processes: a) awareness (of the possible), b) excitement (about the possible), and c) exploration (of the possible). These processes can be described in terms of what 'triggers' wonder, of the 'hunches' specific for wondering, and the 'search' for new ideas and perspectives. Accordingly, an expansive state of wonder (the kind most similar to awe) affects creative thinking through modification of pre-existing mental frames and openness to alternative perspectives (Chirico et al., 2018).

'HaHa!' expresses our laughter. When fun is found, 'HaHa!' happens simultaneously that usually fosters a kind of positive mood. 'HaHa!' indicates the context of glimpsing an unexpected moment with exhilaration (Zhou, 2017). There is buoyancy that accompanies with the surprise in 'HaHa!' that bubbles forth in the joyful and pleasant experiences (Parse, 2002). According to Zhou (2017), individuals in an 'up' mood tend to be more creative problem-solvers. As Cornett (1986) addressed, laughter helps students to relax and release themselves from stressful situations such as test taking. Laughter opens our energy channel and places us directly in the present moment, where memories of the past no longer burden us, and speculations about the future seem irrelevant (Steven, 2004). When 'HaHa!' happens, it usually releases oneself and informs other people that all is going well and the environment is unproblematic; thereby it prompts looser, less systematic, and less effortful information processing; it fosters an attitude or outlook that encourages divergent thinking for new possibilities (George & Zhou, 2007).

'Aha!' indicates a discovery or an inspiration. The 'Aha!' experience in history is well-known as Archimedes' 'Eureka!'. According to Topolinski and Reber (2010), we should consider four attributes: a) 'Aha!' occurs suddenly, without any conscious awareness, b) the solution to the problem can be processed quickly and fluently once it has been found, c) 'Aha!' yields positive affect before the assessment of the solution, and d) the problem solver experiencing the 'Aha!' moment is convinced that the solution is true. These four attributes are not separate but can be combined. 'Aha!' indicates the discovery is a sudden insight and shows the unpredictability of creativity. It is a hint of an emergent process transforming implicit ideas to an explicit discovery (Zhou, 2017). As Shen and his colleagues (2016) addressed, 'Aha!' springs forth in the wake of calm-turbulent drifting with an availability to see the new possibilities. Additionally, happiness is the most typical psychological feature in the feeling of ease that is the closest cognitive characteristic of 'Aha!' experience (Zhou, 2017).

Addressing 'Ah!-HaHa!-Aha!' as a Tool

Following the above, 'Ah!', 'HaHa!', and 'Aha!' are all emotional expressions leading to 'coming to know' that indicate the situations where are friendly with creativity development. In STEM education, when teachers learn these expressions from students, they may adjust their ongoing teaching strategies that help students to gain creative learning experience. Previous studies also addressed the experiences 'Aha!', 'HaHa!' and 'Aha!' may interplay with each other that grows potential of creativity. 'Aha!' brings curiosity-driven knowledge acquisition, information seeking, question asking, and active exploration (Bazhydai & Wstermann, 2020). This fosters possibilities of 'Aha!', which further underpins the feeling of fun that brings moments of 'HaHa!'; while 'HaHa!' expresses positive mood that may bring possibilities of 'Ah!' or 'Aha!' (Zhou, 2017). These interplays facilitate students to engage their learning process backwards and forwards in the process of seeking answers to questions, which also gives birth to creative ideas (Zhou, 2019). As Thagard and Stewart (2010) addressed, creative thought combines different emotional components; creative mind can employ a full range of sensory modalities derived from sight, hearing, touch, smell, taste, and motor control.

In this sense, 'Ah!-HaHa!-Aha!', as a new compound indicating interplays between emotional expressions of 'Ah!', 'HaHa!' and 'Aha!', and between emotional components of wonder/curiosity, laughter/fun, and discovery/inspiration, is addressed as a tool to facilitate creativity in STEM education. As a tool, 'Ah!-HaHa!-Aha!' highlights the mediating roles of emotion in creativity development and fostering creative learning environments. As Beghetto (2013) addressed, science teachers should be able to 'read the environment', know when (and when not) to be creative, and timely take corresponding measures. Creative climate requires, supports, and interacts with an atmosphere where there is full of mutual respect between teachers and students, and where incorporates open dialog and collaborative activities. As Sawyer (2003) addressed, creativity is a kind of 'collaborative emergence', which means novelty is a collective process involving the dialogues between individuals in a way of constructing the unexpected meaning. 'Ah!', 'HaHa!', and 'Aha!' are vital parts of language in daily dialogues; they help to shape the turning points in exploring trajectory of creativity both individually and collectively; they show the creators are enjoyable in the process of sparking new ideas and working with others together (Zhou, 2017).

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Creative Pedagogies by, for and through 'Ah!-HaHa!-Aha!'

Triggering 'Ah!', 'HaHa!' and 'Aha!'

Regarding pedagogy design, a holistic approach becomes a necessity to foster creative climate. 'Ah!-HaHa!-Aha!' requires to be cooperative with appropriate designs of pedagogies that may provide conditions to trigger the interplays between experiences of wonder/curiosity, laughter/fun, and discovery/inspiration. This means the selected pedagogies should construct an open environment where encourages students' active learning and social-emotional learning experience. Based on these ideas, a new pedagogy model of 'Ah!-HaHa!-Aha!' is proposed (Figure 1).

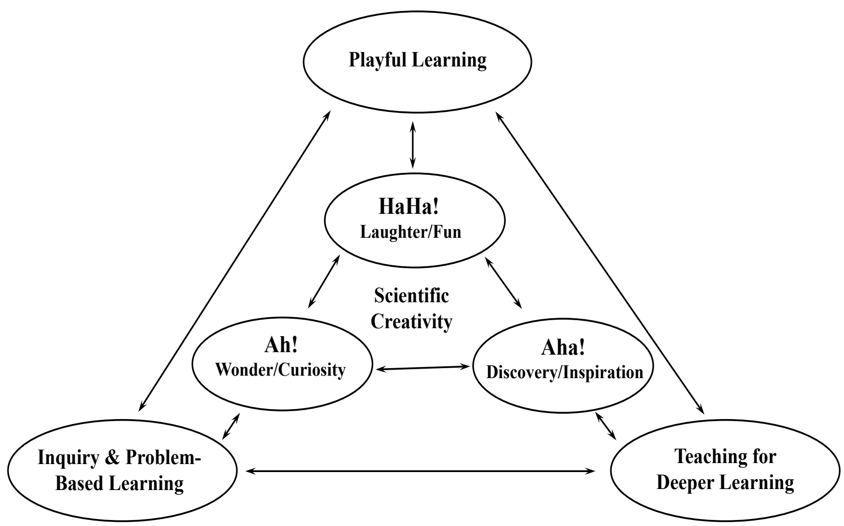

Figure 1. A Pedagogy Model of 'Ah!-HaHa!-Aha!' for Creativity

In the model, it shows the interplays between 'Ah!' (wonder/curiosity), 'HaHa!' (laughter/fun), and 'Aha!' (discovery/inspiration) grow potential of developing creativity in learning situations. Pedagogy methods of 'Inquiry and Problem-Based Learning', 'Playful Learning', and 'Teaching for Deeper Learning' are integrated into one framework with roles of fostering creative climate. In comparison with any other two pedagogy methods, Inquiry and Problem-Based Learning provides students more opportunities of 'Ah!' (wonder/curiosity); Playful Learning engages students with more experience of 'HaHa!' (laughter/fun); and Teaching for Deeper Learning motivates students more to learn through 'Aha!'(discovery/inspiration).

The formulation of 'Ah!-HaHa!-Aha!' extends the author's previous studies in STEM education. In Zhou (2017), a theoretical discussion examines how 'HaHa!' interacts with 'Aha!' and how the 'HaHa!-Aha!' interplay supports a playful approach to fostering a creative learning environment. Playfulness is highlighted as a key facilitator of creative learning and explores various pedagogical strategies to encourage the 'HaHa!-Aha!' interplay, such as incorporating

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games, pretend play, digital tools, and collaborative interactions (Zhou, 2017). In a subsequent study (Zhou, 2019), the roles of 'HaHa!-Aha!' in cultivating creative group learning environments are further investigated. This research focuses on using Problem-Based Learning to support the creative learning processes of technology design students and examines how the integration of humor into group learning environments can influence creativity. Building on these studies and linking 'HaHa!-Aha!' to the concept of 'Ah!' (wonder/curiosity), the 'Ah!-HaHa!-Aha!' tool is formulated in this article. This framework enriches the findings of previous research (Zhou, 2017; 2019) while emphasizing an active and reflective learning cycle that integrates curiosity, fun, and discovery into pedagogies in STEM education.

The proposed pedagogy model regards everyday life as the learning context in STEM education. This means we try to consider how to bridge informal and formal learning environment, how to extend STEM learning to outside the classrooms, and how to mobilize the full resources - e.g. the new discovery of knowledge in daily life, literacy practices, experiential learning- of STEM students within specific situations (Edwards, 2009). STEM teachers should consider how to best involve students' entire sensorial body in the process of learning and how to best use both individual and social factors that play supportive roles in development and expression of creativity (Zhou, 2020).

Inquiry and Problem-Based Learning

Inquiry-Based Learning (IBL) and Problem-Based Learning (PBL) engage us to start new learning experience from wonder or curiosity, moments of 'Ah!'. Even though there are differences between them (Ayse& Sertac, 2011), both pedagogies hold on principle of 'student-centered learning' and encourage students to learn knowledge through triggering and engaging student curiosity (Purichia, 2015). IBL and PBL help students to develop their 'hard knowledge' and 'soft skills' and facilitate them to understand how scientists study the natural world (Anderson, 2002; Zhou, 2020). As Coombs and Elden (2008) suggested, these pedagogies overcome the gap between theory and practice and between general knowledge and skills and abilities to apply it appropriately to unscripted but authentic problematic situations typical of work in the professions. Thus, we can call them social inquiry pedagogy. 'Social' means that learning is an interpersonal, constructivist process. 'Inquiry' connotes active, student-driven learning. In this sense, we combine IBL and PBL as Inquiry and Problem-Based Learning.

STEM teachers should design students' learning activities through open problems or inquires in which 'Ah!', wonder or curiosity arise. For example, in primary mathematics education, teachers may use open-ended math questions. Since open-ended questions have more than one correct answer or solution, they are typically presented as problems in real-world situations. For example, a question like, 'How many different shapes can you use to draw a ship? As Zhou and Larsen (2025) suggested, focusing on 'everyday creativity' in mathematics or STEM education means that every student can respond creatively to daily learning tasks in a novel and

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meaningful way. According to Zhou (2016), problems usually indicate a wondering which takes the concrete form of a question. A problem triggers the context for inquiry, engagement, curiosity, and a quest to address a real-word concern. These psychological events, in turn, set in motion certain mental processes and behavioral changes such as the development of creative ideas. Abd-El-Khalick et al. (2004) distinguish between inquiry as: means-inquiry in science, a way of teaching to help students understand science content, inquiry as ends, or inquiry about science involving students learning about epistemic aspects of science practice and development of knowledge, as well as inquiry skills such as generating research questions. As Zhou (2020) emphasized, when the inquiry process skills (i.e., observing, classifying, measuring, communicating, predicting, inferring, and experimenting) relate to the science content, the students gain opportunities to discover meaningful concepts and understandings.

In practice, Inquiry and Problem-Based Learning advocates experience-based education. Diverse models of PBL have been developed, range from limited implementations that present a question or case, to broad implementations where students define and research their own problems in collaboration with a teacher or practicing professional (Simons & Ertmer, 2005; Zhou, 2020). In general, there are at least five dimensions to be considered to design PBL: a) engaging students in an ill-structured problem, b) introducing students to the problem before they have acquired content-relevant knowledge, c) allowing students to work collaboratively, d) supporting students throughout the problem- solving process, and e) promoting student reflection following the presentation of their solutions to the problem. These dimensions can serve as effective ways to bridge formal and informal learning environments. For example, in teaching the Pythagorean Theorem, a project titled 'Pythagorean Theorem in Daily Life' can be assigned to students. Under this theme, students might begin by observing various phenomena in daily life, such as road transportation, mechanics, aviation, and electronics. Based on their observations, they can formulate group research questions and collaborate on a detailed project exploring how the Pythagorean Theorem is applied in practical contexts.

Moreover, Socio-Scientific Inquiry-Based Learning (SSIBL) has been paid much attention to bring together three supporting and mutually interactive pillars (Amos et al., 2020): a) Learning through Socio-Scientific Issues that addresses climate change, pandemics, digitalization, and sustainable development, etc. to engage students in educational activities, resulting in an environment which is characteristically more enjoyable and accessible to students; b) Citizenship Education shapes a form of science that relates in reflexive ways to concerns, interests and activities of citizens as they go about their everyday business, which broadens students' world views, promotes their critical thinking, and contributes to their capacity to navigate an increasingly culturally diverse world; and c) Inquiry-Based Science Education reflects a focus on the creativity and possibilities of learning through inquiry in science education.

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Playful Learning

Playful learning usually gives birth to experience of 'HaHa!'. Playful learning supports learning through play. As Singer (2013) suggested, play has the following characteristics: a) play has value in itself and play gives pleasure; b) play binds through rhythms, rules and structure; c) play gives freedom to change experience; d) play is bounded by fluid boundaries, through rules in time and space; and e) play is one of the wellsprings of culture. Shortly, play involves players' engagement in a voluntary leisure activity and/or choosing non-serious behaviors just for fun, enjoyment, satisfaction, involvement, and pleasure (Chang et al., 2013). Thus, play encourages learners' cognitive, affective, motivational and skill dimensions of creative processes; it fosters a psychological and social-relational climate that is conductive to creativity (Zhou, 2017).

A playful learning environment is characterized by playfulness. As Change (2013) described, playfulness can be interpreted in terms of abilities such as emotional expression and the use of intrinsic motivation as well as in terms of characteristics and behaviors such as naturalness, a sense of freedom, happiness, being childlike, playing or being funny. It allows safe experimentation and, like jokes, institutionalizes disorder with order, expression of taboo issues within a legitimate form, and surfacing of the repressed without extreme discomfort (Huy, 1999). This increases learners' willingness to develop interpersonal relationships through synergistic endeavors. So, playful learning is well suited to scientific investigation, Inquiry and Problem-Based Learning in classrooms, because it allows students to develop self-awareness as well as control over environmental objects, their movements, and their bodies (Zhou, 2017). Additionally, playfulness also drives students to attain traits such as flexible thinking, persistence, commitment, and a love of and fascination with learning (Boyer, 1997).

In practice, it is coherent with Inquiry and Problem-Based Learning, student-centered learning is the core principle to construct a playful learning environment. Diverse strategies are full of potential to bring as many opportunities as 'HaHa!'. As Zhou (2017) suggested, these strategies include game-based learning and gamification (Ejsing-Duuun & Karoff, 2015), pretend play (Russ, 2003), use of digital technologies (Loveless, 2002), and appropriate use of humor (Garner, 2006), etc. All the strategies allow 'openness', 'freedom' and 'enjoyment' to design learning activities. For example, when students learn the Pythagorean Theorem, teachers may design various games. They can encourage students to become 'Pythagorean Explorers' by engaging in hands-on learning activities. Teachers might also present real-world scenarios that require calculating distances, combining spatial reasoning with geometry skills. Students could play a game where they calculate the distance between two points on a coordinate grid. Through playful learning, this leverages elements such as challenge, competition, exploration, and achievement, which are naturally stimulating for students. As Furman (1998) suggested, when students are in a free and carefree environment, they can be urged to attend activities to explore questions by their intrinsic motivation. Cognitive studies also show that students will be more creative when internally motivated, when they feel some ownership of or control over the learning process, and when they look beyond one correct answer (Zhou, 2016).

Teaching for Deeper Learning

Deeper learning goes along with 'Aha!', inspiration and discovery. According to Pellegrino and Hilton (2012), deeper learning can be understood as learning for transfer, which means a process through which science students become capable of taking what they learn in one situation and applying it to new situations. Through deeper learning, STEM students recognize when a new problem or situation is related to what they have previously learned, and they can apply their knowledge and skills to solve them. This also is associated with students' intrinsic motivation and their interests in the content of the tasks, a focus on understanding the meaning of the learning material, an attempt to relate parts to each other, new ideas to previous knowledge, and concepts to everyday experiences (Chin & Brown, 2000).

STEM teachers should be able to capture students' 'Aha!' experience that can be used in evidence-based facilitation and summative assessment of learning tasks (Harris et al., 2019). When students engage in meaningful learning, they are purposeful and constantly monitor and reflect on the process of learning to evaluate the results of their own learning efforts (Chin & Brown, 2000). Teaching for deeper learning requires improved assessments with new types of tasks and situations that call upon students to demonstrate well-integrated learning (Harris et al., 2019). 'Aha!' shows evidence that students engage in learning towards correct directions. Teachers may use appropriate strategies to encourage higher level of constructive activity and foster deeper learning among students (Zhou, 2020). For example, 'dialogic teaching' or 'question-based instruction' can be applied when 'Aha!' is noticed (Oyama & Yagihashi, 2020; Philipson & Wegerif, 2020), like asking students to 'explain' or 'share ideas' in classrooms (Zhou, 2017). Students should be encouraged to answer questions such as 'what', 'how', and 'why', and to reflect on their learning experiences through practice. For example, when students engage in the game of 'Pythagorean Explorers', teachers should provide opportunities for immediate feedback and rewards, promoting a sense of accomplishment and reinforcing perseverance in tackling complex problems. As Wittrock (1994) suggested, understanding in science can be facilitated by learners generating analogies, metaphors, problems, models, and related devices that build meaningful relations between new information and previous experience; self-explanations of the new understanding (i.e., those spontaneously generated) are associated with greater problem-solving success and gains in deeper understanding. Students should also be told about what counts as an explanation and the attributes of a good explanation, which helps move to a deeper level of explanation (Chin & Brown, 2000).

Teaching for Deeper Learning can be cooperative with Inquiry and Problem-Based Learning and Playful Learning in one framework. As Rath and Brown (1996) addressed, science inquiry orients students to engage in deeper learning in different ways emotionally, conceptually,

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and socially; those modes of engagement are embodied by different actions such as exploration, pet care, performance, and fantasy (Chin & Brown, 2000). According to Roo (2020), beyond motivating students' engagement, playful learning pedagogies such as humor and joy can encourage critical thinking and communicative competence, which further support deeper learning. Additionally, different technologies can also be used in service of deeper learning and provide various tools of supporting learners as makers and creators, online and hybrid education environments, immersive media, games, and simulations (Dede, 2014).

Conclusions

Creativity often emerges when learning is relevant to students, granting them significant ownership and control over the materials, techniques, and processes involved in engaging with knowledge or skill-based activities. Creativity can be expressed through scientific knowledge in various forms. Emotional expressions like 'Ah!' (wonder/curiosity), 'HaHa!' (laughter/fun), and 'Aha!' (discovery/inspiration) stem from the creative problem-solving process. These expressions are typically unconscious, surprising, and unexpected, requiring science teachers to apply appropriate pedagogies to nurture a creative climate. The 'Ah!-HaHa!-Aha!' tool is closely intertwined with pedagogies such as Problem- and Inquiry-Based Learning, Playful Learning, and Teaching for Deeper Learning. These approaches foster creativity by encouraging divergent thinking, allowing freedom to explore new methods, and providing ample resources and space rather than imposing rigid controls or limitations. In this context, this paper makes significant contributions to the development of a theoretical framework which also reveals its limitations of lacking empirical cases. This also reflects the need for intentional and positive support for diversity in pedagogical design, as well as the importance of encouraging various approaches to open-ended exploration. Such practices can make STEM teaching and learning more engaging and enjoyable, ultimately promoting creativity in pedagogical practice.

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