# Teaching and Assessing Creativity in STEAM Education

**Areej ElSayary**
Zayed University
Abu Dhabi, United Arab Emirates

## ABSTRACT[1]

Science, Technology, Engineering, and Mathematics (STEM) has become an international focus of paramount significance. Through educational reform, the United Arab Emirates (UAE) government has stated national strategic measures in its Vision 2021 to raise students' attainment in TIMSS and PISA standardized assessments and to promote STEM education. Furthermore, developing STEM talents in Emirati students is one of the main purposes of the Science, Technology, and Innovation (STI) Policy. Adding art to STEM has a positive impact on students' attitudes, motivations, and interests, leading to development of their creativity skills. The purpose of this paper is to investigate the factors that affect teaching and assessing students' creativity. A mixed-method design was used to answer the research questions. The study was conducted in a private school in the UAE. The participants are science, technology, language art, and mathematics teachers (n=30). The results of the study emphasized that motivation, cognition, and metacognition set as factors affecting students' creativity in STEAM classes. A balance between formative and summative assessment should be considered, to shift the focus from raising students' attainment in standardized assessments to developing their creativity skills.

**Keywords**: STEAM Education, Cognition, Metacognition, Creativity, Convergent and Divergent Thinking.

## 1. INTRODUCTION

There is a distinct gap between the way students learn in class and how they are assessed. This is because most teachers do not use the depth of knowledge required to focus on students' cognitive levels. The standardized assessments of math and science (such as TIMSS and PISA) are designed according to the cognitive domains: knowledge, application, and reasoning. The questions included in the reasoning domain are to assess the students' skills in dealing with real-life applications and performance tasks where the students should reason, reflect, explain, and find solutions to the problems. However, the learning practices do not match the students' assessments, where teachers feel the tension between developing students' creativity and preparing them to perform well in the fact-based assessments [1]. Students experience the skills of each subject solely when learning separate subjects. In other words, students are not able to transfer what they have learned in different situations. However, in the STEAM class, the students experience the essence of the skills of all subjects that are intertwined together in order to produce new and unique ideas.

The STEAM program has been implemented in a private school in Dubai, United Arab Emirates, from grade 1–8, and this is used as a case study for this paper. The purpose of this study is to examine teachers' perceptions about the factors that affect teaching and assessing creativity and to recommend ways to fill the gap between students' learning and the way they are assessed. The factors that affect creativity are motivation, the cognitive process (convergent and divergent), and the metacognitive process [2, 3, 4]. These were used as a conceptual framework that guided this study using a mixed-method design with multiple tools. A questionnaire with open- and closed-ended items was used to measure teachers' perceptions about the factors that affect STEAM creativity. Observation was conducted for a duration of three weeks to explain and explore how STEAM education fosters students' creativity.

The following questions are used to fulfill the aim of the study:

In what ways are motivation, cognitive, and metacognitive processes set as factors that affect teaching and assessing creativity?

1. What are the teachers' perceptions about the factors that affect teaching and assessing creativity?
2. To what extent does STEAM education foster student creativity?

According to a previous study of Sternberg [5] concluding that motivation, cognitive and metacognitive process foster creativity, the hypothesis of teachers' perceptions is that they believe that motivation, cognitive, and metacognitive processes set as factors affecting creativity. However, they will differ in teaching creativity based on the subject taught. The hypothesis of the second question of the study is that the STEAM education is fostering students' creativity due to the use of the cognitive and metacognitive processes that increase their intrinsic motivation [6].

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Factors that affect developing creativity, such as motivation, cognition, and metacognition [7,8,9], are used as a conceptual framework to guide this study, as presented in figure 1.

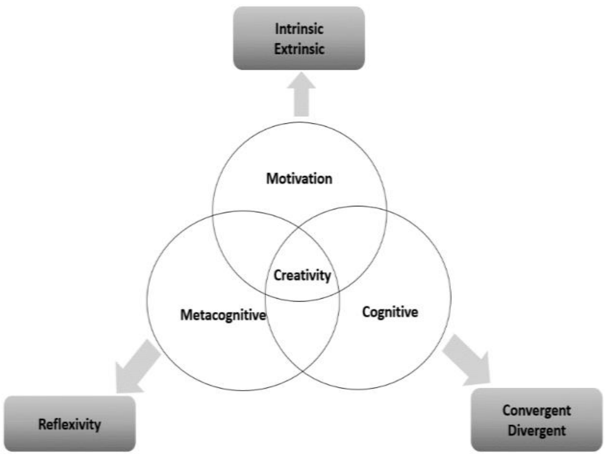


Figure 1. The conceptual framework used to guide this study (Runco, 1987; Sternberg, 1985; Tardif & Sternberg, 1988).

STEAM education is the fusion of the disciplines of science, technology, engineering, art, and mathematics, which is considered to be an essential paradigm for creative teaching and learning [6]. Students develop their cognitive and metacognitive thinking in STEAM classes and are intrinsically motivated to finish their tasks. Furthermore, adding "A" to STEM can enhance students' creativity and positively impact their attitudes and interests [10]. The UAE reinforces the importance of STEM education. The ADEC (Abu Dhabi Education Council) aims to develop 21st Century skills through enhancing creative thinking skills among students [11].

## 2. LITERATURE REVIEW

Creativity has been defined as the interaction between the field, domain, and individuals [12]. Guilford [13] stated that it is significantly important to teach students how to think, in order to produce innovative products. Kaufman and Beghetto [14] proposed a framework of the 4C model of creativity (Mini-c, Little-c, Pro-c, and Big-C) that enables people to understand the scale used to measure creativity.

As shown in figure 2, the Little-c creativity focuses on everyday activities such as creative actions in which non-experts may participate. People who scored high in the Torrance test are considered to be in the Little-c; even the students who learn new concepts or make a new metaphor are also seen as Little-c [14]. As a result of this, Kaufman and Beghetto [14] designed a new category inherent in the learning process called Mini-c. This focuses on the personal and developmental aspects of creativity, known as transformative learning [7, 15]. Mini-c highlights the importance of innovative interpretations of experiences and actions made by learners, where it is an essential indicator of how to assess, monitor, and develop creativity [16]. This model of creativity is in alignment with the Vygotskian conception of cognitive and creative development, as all learners use their working memory in organizing and transforming the input information by using the existing knowledge [14]. Pro-c creativity is known as professional expertise as it represents a developmental progression of the Little-c but has not yet reached the Big-C. The Pro-c level of creativity is implied in anyone who attains professional experience in any creative area. The Pro-c model is consistent with the acquisition approach of creativity [17,18].

Finally, the Big-C model is known for eminent accomplishments. People considered to be in the Big-C area of creativity are winners of prestigious awards or are included in an encyclopedia. Everyone starts with the Mini-c of creativity, and rare people jump to the Big-c.

The second step from the Mini-c is the Little-c, and from this level, there are two transitions. The first is informal preparation for the Pro-c level of creativity, and the second ends with reflection. On the Pro-c level, there are also two paths: the first is when people remain creative in their professional lives. The other path is the peak of creativity, where people develop and nurture their creativity to reach the Big-C level. Figure 2 shows the 4C model of creativity.

Mini-c creativity has been defined as the product and process of learning that shows a balance of novelty and assessment [19]. Creativity does not exist outside of a particular subject area, but it is shaped or defined partially by the subject area [20]. It has different forms from one subject to another based on the skills required to master the subject knowledge and innovate a unique idea. However, the integration between disciplines allows the student to easily connect the information to produce a meaningful product, especially by experiencing the flavor of the skills used to master the subjects. It is the shift from the Mini-c level to the Little-c level of creativity. A further shift to the Pro-c level can be reached when dealing with more specific areas of domains, projects, or problems.

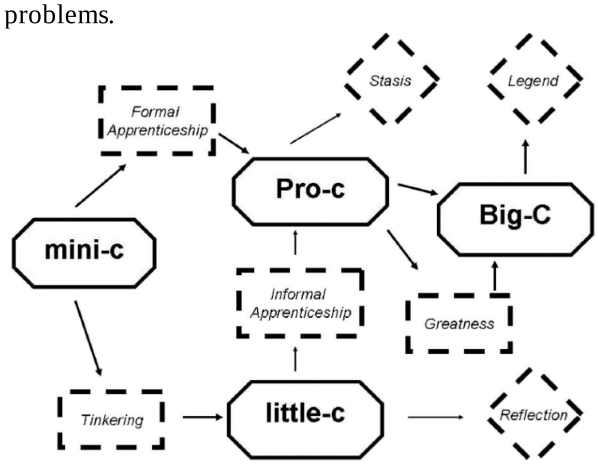


Figure 2. The 4C model of creativity [14].

**2.1 STEAM Education and Creativity:** STEM education aims to prepare an innovative and creative generation that focuses on technical skills. Adding "A" to STEM is sparking the interchange between convergent and divergent thinking [10]. According to Yakman [10], who has announced a framework for teaching integrated subjects, the art in STEAM is considered to be design art, language, sociology, philosophy, psychology, and history. However, the focus in this study is on language art. Corpley [6] mentioned three elements that enhance creativity. First, students should have the opportunity to be engaged in creativity through learning integrated courses, problems, or projects. Second, the importance of positive encouragement to students who are engaged in creative tasks. Finally, students should be rewarded for completing and producing innovative products. Furthermore, Sternberg [21] stated twelve strategies that are used to drive the habit of creativity. They are essential to developing students' creativity; however, many areas require the convergence approach. These strategies entail involving students in open-ended projects where they need to redefine problems and make good choices. Students should be encouraged to ask questions and analyze assumptions, and accept the problems given to them. Students need to be taught how to generate ideas and have a team spirit to persuade others about their ideas, and think about using the best idea and justifying it in their group activities. As a result, extrinsic and intrinsic motivation are important factors in students' learning. Students need to be users of information; for example, try to find a connection between a concept in biology and mechanical engineering when creating hinges on relating this to parts of the body. It is essential to challenge students when given a task to find obstacles and have the opportunity to fail and try again. They need to learn how to assess risk and judge whether this risk is acceptable or not—allowing students to deal with haziness and think independently by giving them ill-structured problems instead of well-structured steps of a project or problem. Build students' self-efficacy by requiring creativity as an assessable component of project work. Another strategy is by helping students to find what excites them through real-world projects, so they will be able to find their desired field. Pushing them to the extent of their ability within their comfort zone is allowing flexibility in assessments where each student will be assessed according to his or her limit. Finally, STEAM educators need to role model creativity.

**2.2 Factors that affect creativity:** Many psychologists and educators state that creative thinking improves students' motivation, metacognition, and interpersonal and intrapersonal skills, in addition to the ability to write creatively, solve problems, and interpret scientific processes [2, 4, 22, 23]. In recent years, policymakers and stakeholders have increasingly paid attention to the students' scores in the standardized assessments while being ignorant of teaching students creative thinking [3]. The main objective is to think constructively by teaching students how to think, as the success of this leads to the creative products of students' learning [24]. Torrance [23] indicated that creative thinking enhances personality development, information acquisition, and success in the future career. Vygotsky [15] described creative thinking as an exercise of imagination essential for students' futures. It is vital to note that the working memory has an essential role in the rehearsal and practice of cognitive and creative thinking in order to transfer information to the long-term memory; otherwise, it will stay in the short-term memory and result in a loss of information [25]. Ofsted [26] reported that creative approaches had improved students' motivation, progress, and attainment to learning by allowing students to question, explore, challenge ideas, reflect on and evaluate their learning.

Intrinsic and extrinsic motivation are two important types of motivation. Relying on one type may result in not completing the task. The intrinsic motivation is derived from the learning goal where the excitement and enjoyment of learning occur, especially in an unpleasant or difficult task [25]. The extrinsic motivation is derived from the performance goal, where the target here is to get a perfect product or reward from learning [27]. A result from dominant research indicated that intrinsically motivated learners are driven by curiosity, interest, and desire to learn [28]. A positive relationship between the intrinsic (learning-oriented) and extrinsic (performance driven) has been found [29, 30, 31]. Kaufman et al. [27] stated that extrinsic motivation might not reduce creativity as suspected; however, there is a relationship between extrinsic and intrinsic motivation.

Creativity is considered to be a cognitive ability that should be developed across one's lifespan. Learning through multidisciplinary classes encourages convergent thinking. Sternberg [21] stated that creativity requires the interconnection of knowledge, cognitive abilities, ways of thinking, personality, and motivation. It starts with the knowledge which is considered to be input information, where the working memory takes the role to influence the ability to think divergently (think about many solutions) and convergent (focus on one way) while solving problems [25]. According to Guilford [24], convergent thinking is to come up with a single answer to a well-structured problem. However, creativity fosters divergent thinking that focuses on innovative ways of thinking. Art inspires divergent thinking among different disciplines by shifting students' thinking from convergent thinking.

It is important to allow students to reflect on their learning process before interpreting their views [16]. One of the things that helped educators nurture students' creativity is listening to their points of view. Types of formative assessment are considered to foster students' metacognitive skills, where they are able to evaluate their work, reflect, write reports, maintain portfolios, and make presentations [2]. Infusing creative thinking into science, technology, engineering, art, and mathematics is enhancing students' creativity and academic achievements.

The advanced TIMSS assessments [32] provide specific information in preparing students to pursue careers in STEM fields and create a reference point to ensure the quality of students' learning. Earl [33] suggested a balance of three types of assessments: assessment of, for, and as learning, in a pyramid shape. The assessment *of* learning (summative and standardized assessments) is considered to be the least and at the top. The assessment *as* learning is at the bottom, and the assessment *for* learning is in the middle. In order to foster students' creativity, there should be a balance in assessing students' learning in terms of process and products, unexpected outcomes, subject knowledge, authentic tasks, and standard tests [34]. Assessment for learning (formative assessment) is essential to successful teaching, and learning creativity is where questioning, reflection, and evaluation occur. The Assessment Reform Group [35] proposed that assessment for learning is characterized by a cyclical process where teachers gather data about students' information and skills through observing, questioning, monitoring their work, and gathering feedback. This gives an indication to teachers about their teaching practices and for students to improve their work. Black and William [36] suggested that open questioning and dialogue, feedback, and peer and self-assessment form formative assessments that are inherent in the cognitive process. Furthermore, students need to know their goals and how to judge their quality for self-assessment to be successful [34], which is the metacognitive process.

## 3. RESEARCH METHOD

The study was implemented over three weeks in a private school in Dubai, UAE. The study highlights the gap between teaching strategies and assessments (exams). There are two paths used in this study. The first research question focuses on the teachers' perceptions, measured using the questionnaires to explain and explore their perceptions about teaching and assessing creativity. The second question focuses on fostering students' creativity, using observation tools with a rubric and field notes for science, technology, math, English language, and STEAM classes.

A mixed method is implemented to address the research questions of the study. The type of mixed method used is a concurrent transformative method with the features of the embedded design [37]. Both sets of data were collected concurrently; however, the main status is for the quantitative data where the qualitative data is nested and merged within it [37]. Morse [38] noted that the qualitative data is nested in the quantitative data in order to describe aspects of quantitative data that cannot be quantified. The results of both data are integrated.

The population is the large group to which the results are generalized [37]. The participants of the study are grade 1 – 8 teachers (N = 45). The characteristic of the population is that all the teachers are teaching science, technology, language art, or mathematics. However, the purposive sample is selected from the population because the main aim is to select the teachers of STEAM education, mixed projects, or have a cross-curricular link in their teaching strategies. As a result, the sample selected is n = 30.

Two instruments have been used: Teachers' questionnaire, and observation, to fulfill the study's research questions. The teachers' questionnaire is designed to address the first question of the study: What are the teachers' perceptions of the factors affecting teaching and assessing creativity? The questionnaire started with demographic information. It is categorized according to the factors that affect creativity: motivation, cognitive (convergent and divergent), and metacognitive. According to Johnson and Christensen [37], the questionnaire type is called an intra-method mixing questionnaire, where each category consists of a closed- and open-ended questionnaire. The responses of the closed-ended items are measured with a rating scale. The first category is the motivation, rated according to the Likert scale: strongly disagree, disagree, uncertain, agree, strongly agree. The cognitive and metacognitive categories are measured based on a 5-point rating scale: very often, often, sometimes, seldom, and never. The second part of each category is the open-ended questionnaire to clarify the teachers' perceptions.

The observation tool is conducted for confirmatory and exploratory purposes [37] to measure how STEAM education fosters students' creativity. It consists of a rubric based on the categories of the factors that affect creativity to collect data quantitatively, which is analyzed into frequencies and percentages. In addition, field notes are used to describe the results that cannot be quantified. The role of the observer in this study is a participant-as-observer. The participant-as-observer is one of the valuable styles of observation as the researcher is allowed to take a mix of insider and outsider roles [37].

The pragmatism philosophy reinforces the importance of combining and integrating qualitative and quantitative data [37]. The study duration was three weeks, and the teachers received the questionnaire at the beginning of the three weeks and these were collected after two weeks. Teachers' permissions were taken before the study for ethical consideration, and all data have been kept confidential. The observation was conducted over the three weeks of the study. The data collected quantitatively and qualitatively were merged in the light of the three factors that affect creativity: motivation, and cognitive and metacognitive dimensions.

## 4. DISCUSSION

This study explores and explains the factors that affect the teaching and assessing of creativity, teachers' perceptions, and how STEAM education fosters creativity, in a private school in Dubai. The factors that affect creativity (motivation, cognitive and metacognitive processes) are used as a conceptual framework to guide the study. The data collected from the teachers' questionnaire and the observation was merged and integrated in light of the conceptual framework.

The highest response of teachers' perceptions about motivation stated that students like to be praised for their efforts in any task, which implies extrinsic motivation. This is in addition to intrinsic motivation, which occurs when students enjoy doing experiments, activities, or projects. This is compatible with the results that mentioned a positive relationship between intrinsic and extrinsic motivation [29,30,31].

Regarding the observation, it has been mentioned that the highest percentage of students' motivation is in STEAM classes where students interact and collaborate effectively in a wide range of learning situations and communicate their learning to achieve goals. In addition, they showed a very positive and responsible attitude, demonstrated self-reliance, and flourished with critical feedback. Technology came in the second rank of students' motivation after STEAM classes. Surprising results have been shown in science and English classes where there was a flip between the observation results in science and English. In other words, students' interaction, collaboration, and communication were higher in science classes; however, their attitudes were higher in English classes than in science. On the contrary, students showed low motivation in math classes.

In this motivation category there are two dimensions: convergent and divergent thinking. Regarding convergent thinking, teachers responded that students ask their own questions and investigate them. They design their own activities, experiments, or projects. In addition, they make observations and write conclusions about what they have observed. Teachers stated that students show low performance in setting up data tables, which is compatible with the observation results that math classes have the lowest percentage in students' cognitive process. A study by Bolden et al. [39] mentioned that teachers have difficulty encouraging and assessing students' creativity in math. In divergent thinking, teachers noted that most students do tasks requiring generating ideas, doing concept maps, and mind maps. In addition, most of the students explain and provide further information to make connections with different areas. Teachers' low response is that students do not complete tasks that require designing activities, experiments, or projects, and became worried if these did not appear to work as predicted. However, this did not appear in the observation of all classes. The highest percentage was in the STEAM classes, where students used convergent and divergent thinking in the cognitive process as they ask questions, investigate them, design projects, define problems, generate ideas, and create models and prototypes. Sternberg [21] emphasizes that cognitive abilities and way of thinking are essential to foster creativity. The technology got the second rank in the cognitive process while in science and English there was again a flip in the results. In science classes, students showed a higher percentage than English in innovation, enterprise, inquiry, critical thinking, and technologies. However, in English classes, the percentage was higher in making connections to the real world and areas of learning. This proves what Evans [40] noted: language art sparks the interplay between convergent and divergent thinking.

The teachers mentioned that students are able to express their opinions, and think deeply in reflecting on and improving their work. Wang and Greenwood [41] emphasize the importance of students' reflection before forming their own opinions about their work. This has been shown clearly during the STEAM classes and some of the English classes. They were able to connect their ideas to real-life and to other disciplines. The observation showed that the highest percentage of metacognition was also in the STEAM classes. Surprising results were shown in technology and English classes where flipping between the metacognition items occurred. English classes were higher in students' interactions when involved in discussions and reflections, while technology classes were higher than English in students' self-evaluation and improvement. The science classes had a close percentage to English and technology while math classes had the lowest percentage.

## 5. CONCLUSIONS

Motivation, cognition, and metacognition are set as factors affecting creativity [3, 22]. Creativity is not receiving attention in teacher education programs [42]. Stakeholders, educators, and teachers need to understand creativity, its value, the factors that affect it, and the reason behind including it in the curriculum rather than giving great attention to students' scores in the standardized assessments. It is essential to increase teachers' awareness of identifying creative thinking, attitudes, and dispositions [43]. This will raise students' scores in the standardized assessments that focus on the use of cognitive and metacognitive skills. Earl [33] suggested a balance between the three types of assessments: assessment as, for, and of learning. The creative process focuses on the use of assessments for learning, to increase students' creativity through the use of cognitive and metacognitive processes driven by motivation. Tan et al. [2] emphasized the strong relationship between formative assessments in the learning process that enhances students' creativity. Motivation, cognitive, and metacognitive processes are considered the shift from the Mini-c to Little-c creativity that leads to Pro-c and prepares students for the Big-C [14]. STEAM education fosters students' creativity as they experience the flavor of skills acquired from all subjects to complete their projects. Surprising results were the flipping between science and Language art in motivation and cognition, while in metacognition, the flipping was between science and technology.

The math classes showed a low percentage in fostering students' creativity. This is compatible with the study of Bolden et al. [39], which indicated that teachers found difficulty in teaching and assessing creativity in math subjects. Furthermore, adding "A" to STEM encourages the cognitive process to flourish which increases students' creativity. Motivation, cognition, and metacognition are implied in the twelve strategies of Sternberg [44] used to drive the habit of creativity through STEAM classes. The benefit of STEAM education is that it deepens students' understanding by integrating content broadened by exposing them to STEAM contexts and increases their interest in STEAM fields [45]. Further research should focus on the nature of each subject of STEAM education, the relation between subjects, how using the skills of all subjects benefits students in STEAM classes, and explore the effectiveness of STEAM on students' scores in assessments.

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