Teaching and Assessing Creativity in STEAM Education

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ABSTRACT

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 the Vision 2021 to raise students' attainment in TIMSS & PISA standardized assessments as well as promotes STEM education. Furthermore, developing STEM talents within 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 that leads to developing creativity skills. The purpose of this chapter is investigating the factors that affect teaching and assessing students' creativity. A mixed method design is 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 assessment 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 the classrooms and the way 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. In addition, the questions included in the reasoning domain is to assess the students' skills in dealing with the real-life applications and performance tasks where the students should, reason, reflect, explain, and find the solutions of the problems. However, the learning practices don't match the students' assessments where teachers feel the tension between developing students' creativity and between 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 which is used as a case study for this chapter. 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: motivation, cognitive process (convergent and divergent) and metacognitive process [2, 3,4] will be used as a conceptual framework that guided this study using a mixed method design with multiple tools. A questionnaire with open- and close-ended items is used to measure teachers' perceptions about the factors that affect STEAM creativity. An observation is conducted in 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 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 fosters student creativity?

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

The STEAM program has been implemented in a private school in Dubai, United Arab Emirates from grade 1 – 8 which is used as a case study for this research. 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: motivation, cognitive process (convergent and divergent) and metacognitive process [2, 3,4] will be 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 is used to measure teachers' perceptions about the factors that affect students' creativity. An observation is conducted in a duration of three weeks to explain and explore how the STEAM education fosters students' creativity.

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.

The STEAM education is the fusion of the disciplines; science, technology, engineering, art and mathematics which is considered to be an essential paradigm for creative teaching and learning [6]. In STEAM classes students develop their cognitive and metacognitive thinking and are intrinsically motivated to finish their tasks. Furthermore, adding "A" to STEM can enhance students' creativity and has a positive impact on students' attitudes and interests [10]. The United Arab Emirates reinforce 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]. Guliford [13] stated that it is significantly important to teach students how to think in order to produce creative products. Kaufman and Beghetto [14] proposed a framework of the 4C model (Mini-c, Little-c, Pro-c, and Big-C) of creativity that enable people to understand the scale used to measure creativity. As shown in figure 2, the Little-c creativity is focusing on everyday activities such as the creative actions where the non-experts may participate in. People who scored high in the Torrance test considered to be in the Little-c even the students who learn new concepts or make a new metaphor also seen as Little-c [14]. As a result, Kaufman and Beghetto [14] designed a new category to inherit in the learning process called Mini-c. It focuses on the personal and developmental aspects of creativity and known as transformative learning [7,15]. The Mini-C highlights the importance of innovative interpretations of experiences and actions made by learners where it is important indicators on 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 development progression in the little-c but not reached yet the Big-C. The Pro-c level of creativity is implied in anyone who attained a 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 as eminent accomplishments. People who are considered to be in the Big-C creativity are winners of prestigious awards or being included in encyclopedia. Everyone starts by the mini-c of creativity and rare people jump to the pro-c. The second step of the mini-c is the little-c and from this level there are two transitions. The first is informal preparation to the pro-c level of creativity and the second end by the reflection. In the pro-c level there are also two paths, the first one when the people remain creative in their professional lives. The other path is the peak of creativity where people develop and fertile their creativity to reach to the Big-C level. The following chart shows the 4C model of creativity.

Mini-c creativity has been defined as 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 the other based on the skills required to master the subject knowledge and innovate a unique idea. However, the integration between disciplines allows to easily connect 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. Further shift to the pro-c level can be reached when dealing with more specific areas of domains, projects or problems.

2.1 STEAM Education and Creativity

The aim of STEM education is to prepare an innovative and creative generation that focuses on the 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 used for teaching integrated subjects, stated that the art in STEAM is considered to be design art, language, sociology, philosophy, psychology, and history. However, the focus in this study is on the 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 the positive encouragement to students who were engaged in creative tasks. Finally, students should be rewarded for completing and producing creative products. Furthermore, Sternberg [21] stated twelve strategies that used to drive the habit of creativity. They are essential to develop students' creativity however, there are still many areas required the convergence approach. These strategies imply in 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 not only to accept problems given to them. Students need to be taught how to generate ideas and to have a team-spirit for persuading others about their ideas and think how to use the best idea and justify 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 connection between a concept in biology and mechanical engineering when creating hinges and relating this to parts of the body. Challenging students in a task given 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 no. Allowing students to deal with haziness and think independently by giving them ill-structured problems instead of well-structured steps of 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 a real- world projects so they will be able to find their desired field. The importance of pushing students to the extent of their ability within their comfort zone 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 stated that the creative thinking improves students' motivation, metacognition, and interpersonal and intrapersonal skills in addition to the ability to write creatively, solve problems, and interpret scientific process [2,4,22,23]. Recently, policymakers and stakeholders are increasingly paying attention to the students' scores in the standardized assessments with ignorance on 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 future career. Vygotsky [15] described creative thinking as exercise of imagination which is essential for students' future. It is interestingly important to note that the working memory has an essential role for the rehearsal and practice of the cognitive and creative thinking in order to transfer information to the long-term memory otherwise it will stay in short-term memory and causes loss of information [25]. Ofsted [26] reported that students' motivation, progress and attainment have been improved by creative approaches to learning through allowing students to question, explore, challenge ideas, reflect and evaluate their learning.

The intrinsic and extrinsic motivation are two important types of motivation. Relying on one type of them may result of not

completing the task. The intrinsic motivation is derived by the learning goal where the excitement and enjoyment of learning occur especially in the unpleasant or difficult task [25]. The extrinsic motivation is derived by the performance goal where the target here is to get a perfect product or reward from learning [27]. A result from a dominant research indicated that the intrinsically motivated learners are driven by the curiosity, interest and desire to learn [28]. A positive relationship between the intrinsic (learning oriented) and extrinsic (performance prove) has been found [29,30,31]. Kaufman et al. [27] stated that the extrinsic motivation may not reduce the 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 the lifespan. The learning through multidisciplinary encourage the convergent thinking. Sternberg [21] stated that creativity requires the interconnection of knowledge, cognitive abilities, ways of thinking, personality and motivation. It starts by the knowledge that 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 Guliford [24], convergent thinking is to come up with a single answer of well-structured problem. However, creativity foster the divergent thinking that focus on innovative ways of thinking. Art inspires divergent thinking among different disciplines by shifting students' thinking from convergent thinking.

It is significantly important to provide students the opportunity to reflect their learning process before interpreting their own views [16]. One of the things that helped educators to nurture students' creativity is through listening to their point of views. Types of formative assessment is 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 not only enhancing students' creativity but also their academic achievements.

The advanced TIMSS assessments [32] provides specific information in preparing students to pursue careers of STEM fields as well as creating 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 the most and at the bottom where 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, standard tests [34]. Assessment for learning (formative assessment) is essential to successful of teaching and learning creativity where questioning, reflection and evaluation take place. The Assessment Reform Group [35] proposed that assessment for learning is characterized by cyclical process where teachers gather data about students' information and skills through observing, questioning, monitoring their work, and gathering feedback. This gives 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 are forms of formative assessments which inherit 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 implemented over a period of three weeks in a private school in United Arab Emirates, Dubai. The study highlights the gap between teaching strategies and assessments. There are two paths used in this study. First research question focuses on the teachers' perceptions which is measured using the questionnaires in order to explain and explore their perceptions about teaching and assessing creativity. Second question focuses on fostering students' creativity using observation tool with a rubric and field notes that are conducted for the science, technology, math, English language, and STEAM classes.

A mixed method is implemented to address the research question of the study. The type of mixed method used is concurrent transformative method with the features of the embedded design [37]. Both data were collected concurrently however the big 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 who taught STEAM education, projects or 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 fulfil the research questions of the study. The teachers' questionnaire is designed to address the first question of the study: What are the teachers' perceptions about the factors that affect teaching and assessing creativity? The questionnaire started by 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 intra-method mixing questionnaire where each category consists of closed- and open-ended questionnaire. the responses of the closed-ended items with rating scale. The first category is the motivation rated according to Likert-scale: strongly disagree, disagree, uncertain, agree, strongly agree. The cognitive and metacognitive categories are measured based on 5-point rating scale: very often, often, sometimes, seldom, and never. The second part of each category is the open-ended questionnaire to allow further clarification of the teachers' perceptions.

The observation tool is conducted for confirmatory and exploratory purposes [37] to measure how STEAM education foster students' creativity. It consists of 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 observer in this study is a participant-as-observer. The participant-as-observer is one of the useful styles of observation as the researcher is allowed to take a mix of insider and outsider roles [37]. The observation is conducted in a duration of three weeks.

The pragmatism philosophy is reinforcing the importance of combining and integrating between qualitative and quantitative data [37]. The duration of the study is three weeks where the teachers received the questionnaire at the beginning of the three weeks and collected after two weeks of the study. Teachers'

permissions were taken prior the study for ethical consideration and all data have been kept confidentially. The observation is conducted during 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, cognitive, and metacognitive dimensions.

4. FIGURES AND TABLES

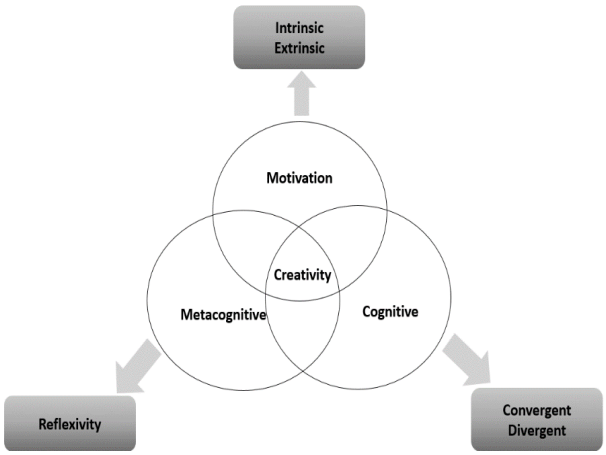

Figure 1. the conceptual framework used to guide this study (Runco, 1987; Sternberg, 1985; Tardif & Sternberg, 1988).

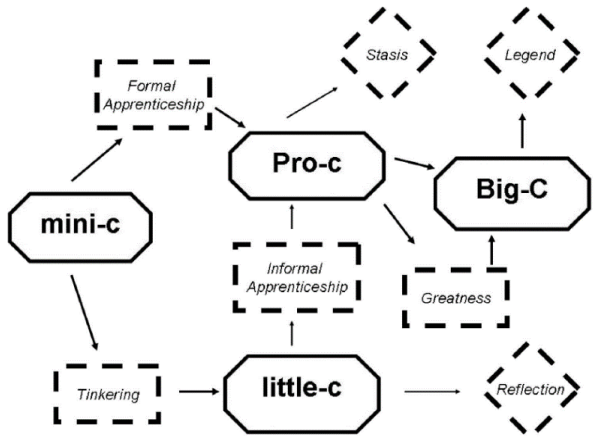

Figure 2. the 4C model of creativity [14].

5. DISCUSSION

This study set out with the aim of exploring and explaining the factors that affect teaching and assessing creativity, teachers' perceptions, and how STEAM education foster creativity in a private school in Dubai. The factors that affect creativity (motivation, cognitive, and metacognitive process) are used as a conceptual framework to guide the study. The data collected from the teachers' questionnaire and the observation is merged and integrated in the light of the conceptual framework.

The highest response of teachers' perceptions about motivation stated that students like praising their efforts in any task which implies in the role of extrinsic motivation. In addition to intrinsic motivation about how students enjoy doing experiments, activities or projects. This is compatible with the results that mentioned 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 very positive and responsible attitude, demonstrated self-reliance, and flourish in 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 is flip between the observation results in science and English. In other words, students' interaction, collaboration, and communication was higher in science classes however their attitudes were higher in English classes than science. On contrary, students' show low motivation in math classes.

In this category there is two dimensions; convergent and divergent thinking. Regarding the 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 by the observation results that math classes have the lowest percentage in students' cognitive process. A study of Bolden et al. [39] mentioned that teachers' have difficulty in encouraging and assessing students' creativity in math. In divergent thinking, teachers noted that most students do tasks that require generating ideas, do concept maps and mind maps. In addition, most of students explain, and provide further information where they can make connections with different areas. The low responses of teachers' perceptions that students do not complete tasks that require designing activities, experiments, or projects and they get worried if it did not appear to work as predicted. However, this doesn't 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, try to investigate them, design projects, define problems, generate ideas, and create models and prototypes. Sternberg [21] emphasizes that the 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 is again flip in the results. In science classes students show higher percentage than English in innovation, enterprise, enquiry, critical thinking, and use of 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 that language art sparks the interplay between the convergent and divergent thinking.

The teachers' mentioned that students are able to express their opinions, think deeply in reflecting and improving their work. Wang and Greenwood [41] emphasizes the importance of the reflection of students before putting their own opinions about their work. This has been shown clearly during the STEAM classes and some of the English classes. They are able to connect their ideas to the real-life and to other disciplines. The observation showed that the highest percentage of the metacognition is also in the STEAM classes. Surprising results were shown in technology and English classes where flipping between the results of 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 got a close percentage to the English and technology while math classes got the lowest percentage.

6. CONCLUSIONS

Motivation, cognition, and metacognition 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 of the standardized assessments. It is essential to increase teachers' awareness of identifying creative thinking, attitudes and dispositions [43]. This will lead to raising of 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 in increasing students' creativity through the use of cognitive and metacognitive process that are driven by motivation. Tan et al. [2] emphasized the strong relation between the use of formative assessments in learning process that enhance students' creativity. Motivation, cognitive, and metacognitive process considered to be the shift from mini-c to little-c of creativity that lead to pro-c and in term prepare students for the Big-C [14]. STEAM education is considered to foster students' creativity as students experience the flavor of skills acquired from all subjects to complete their projects. Surprising results were the flipping between science and English art in the motivation and cognition while in metacognition the flipping was between science and technology. The math classes showed 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 subject. Furthermore, adding "A" to STEM flourish the cognitive process that increase students' creativity. Motivation, cognition, and metacognition implies in the twelve strategies of Sternberg [44] that are used to drive the habit of creativity through STEAM classes. The benefit of STEAM education that it deepens students' understanding by integrating contents, broaden it by exposing them to STEAM contexts, and increase their interests toward STEAM fields [45]. Further research should focus on the nature of each subject of STEAM education, the relation between subjects and how using the skills of all subjects benefit students in STEAM classes. In addition to exploring the effectiveness of STEAM on students' scores in assessments.

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