

Integrating STEM (Science Technology Engineering and Mathematics) Education on Advancing Vocational Student's Creative Thinking Skills

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Abstract— STEM is integrating four specific disciplines area (science, technology, engineering and mathematics) into interconnected learning process based on practical applications. This study aims to gain several ways of advancing students' creative thinking skills through STEM education based on the learning process. This study uses a literature review method with big data from several online database resources. There are several necessary skills needed for employees to face the tighten workforce competition. Creative thinking skills are very crucial for the worker to increase their productivity in the revolution industry 4.0 era. The lecturer needs to design a curriculum with the newest techniques that are ensuring all components of STEM are met with student's creative thinking skills development. Finally, some suggestions were proposed for future research on reforming and delivering the STEM content to enhance vocational students' creative thinking skills.

Keywords—STEM, creative thinking, vocational education

I. INTRODUCTION

An employee should have good soft skills for get successfully on their career, for example: leadership, team work, creative and critical thinking, and the employee should also be good at solving problems skills [1]. There are several significant skills important for facing competition in the workplace, including communication, interpersonal, analytical and problem solving, organizational, fast learning, teamwork, innovation, creativity, and the ability to adapt to environment changes [2]. According to Selamat, Ismail, Ahmad, Hussin, & Seliman [3], there are numerous soft skills that should be included in the education curriculum, including communication, critical thinking and problem-solving, team-working, lifelong learning and information management, entrepreneurial, moral and professional ethics, and leadership. Soft skills are vital elements in the work force for advancing businesses. Hence, it is important to prepare students with great soft skills, such as creative thinking, imagination, and self-efficacy in the earlier of their education. Various soft skills are significant not only for academic achievement, but also for develop their competencies, as well as charging a personal value to future career success.

Creative thinking is an essential soft skill for assuring the outcome of daily work. It involves generating original ideas and forming them into reality in order to perform done better in the future. According to Tanner [4], many industries outperforming their competitors in the workplace depend on their own creativity and conception. In addition, creative achievements are fundamental to progress in the multiplication of high-caliber, original, and elegant solutions to complex or novel problems [5]. Creativity also plays a significant key role in invention, innovation, problem solving, and improving the value of people to an organization [6]. Creative employees contribute in more advantageous ways in their workplace. Universities, as the higher education level, face the challenge of delivering students who are more creative in solving problems through school assignments so that they can exercise and improve their soft skills, especially creative thinking.

Teaching and learning activities are still teacher-centered and have not yet been integrated into the upgrading of 4Cs. Learning paradigm in the 21st century that we need to know is that learning is directed to encourage students to find out by utilizing the available information from various sources, not through being told, the learning is directed to be able to formulate the problem (ask), not just solve the problem (answer). Learning is directed to train analytical thinking (decision-making) instead of mechanistic thinking (routine), and learning emphasizes the importance of cooperation and collaboration in solving problems [7].

STEM-based learning (Science, Technology, Engineering, and Mathematics) is one of the most appropriate models to be applied in teaching and learning activities as an effort to cultivate 4Cs skills in learners. In the face of increasingly complex global challenges, some countries have tried to integrate STEM in learning and have achieved great results in improving the skills of 4Cs [8]. They added that, STEM learning is also able to cultivate the latest science and technology invention with problem base learning process. In addition, STEM bridges someone in preparing for a career because with STEM-based learning can improve a variety of literacy skills.

II. LITERATURE REVIEW

A. STEM Education

STEM stands for science, technology, engineering, and mathematics. The word STEM was introduced by the National Science Foundation (NSF) in 1990 as the theme of the educational reform movement in all four disciplines to foster the labor force of the STEM fields, as well as enhance global competitiveness in science and technology innovation [9]. Furthermore, [9] stated that the STEM education reform movement is driven by a study report that indicates a shortage of candidates to fill the field of transversal/ transferable skills or better known as life skills/ soft skills. According to [10], STEM education has been defined as "a standards-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one lively, fluid study."

B. STEM Education Approach

Three methods of teaching approach in STEM education at this time are often done. The difference between each method lies in the applicable level of STEM content. The three most frequently used methods of STEM education approach are (1) separate method, (2) embedded, and (3) integrated approach [11].

A separate approach known refers to isolated instruction, where each subject of STEM is taught separately or individually. Emphasis is placed on the acquisition of "knowledge" as opposed to technical / engineering abilities. Each individual concentrated study enables students to gain a deeper understanding of the content of each subject. Focused instruction on one subject can awaken the appreciation of the beauty of the content itself. The silo approach emphasizes how science, technology and engineering, and mathematical education have been approached in curriculum design and teaching [11]. [11] added an embedded STEM may be widely challenged as an approach to education in which knowledge domains can be gained through an emphasis on real-world situations and problem-solving techniques in a social, cultural, and functional context. In practice, teaching with an embedded approach, instruction becomes effective as it seeks to strengthen and complement student learning materials as in other classes. A technology and engineering education teacher using an embedded approach aims to reinforce a lesson that is beneficial to students through understanding and application.

Multidisciplinary integration requires students to connect content from different subjects taught in different classes at different times. Furthermore, [11] explains interdisciplinary integration can begin with real-world problems. Combine cross-curricular content with critical thinking, problem-solving skills, and knowledge to reach conclusions. Multidisciplinary integration asks students to link content from a particular lesson, but interdisciplinary integration focuses students' attention on the problem and combines content and skills from various fields.

C. Creative Thinking Skills

Soft skills characterize certain career attributes that individuals may possess, such as team skills, communication

skills, leadership skills, customer service skills, and problem solving skills [12]. Lavy and Yadin [2] surveyed 250 job descriptions for software developers and concluded there were nine soft skills that were required: 1) communication; 2) interpersonal relations; 3) analytical and problem solving; 4) organizational; 5) fast learning; 6) team playing; 7) ability to function independently; 8) innovative and creative; and 9) open and adaptive to changes.

In the context of college teaching and learning, creative thinking deliberately and actively engages students in bringing together existing ideas into new configurations, developing new properties or possibilities for something that already exists, and discovering or imagining something entirely new. Lau [13] added to the definition of creativity as a matter of coming up with new ideas that are also useful in generating alternative possibilities to solve the countless problems that we encounter in our workplace/daily life.

Torrance [14] defined creativity as, "A process of becoming sensitive to a problem, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypothesis about these deficiencies; testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results" (p. 6). The creative thinking attributes are fluency, flexibility, originality, elaboration, abstraction of the title, resistance to closure, emotional expressiveness, articulation, movement or action, expressiveness, synthesis or combination, unusual visualization, internal visualization, extending or breaking the boundaries, humor, richness of imagery, colorful imagery, and fantasy [15]. Csikszentmihalyi [16] argued that the intellectual standards for judging creative thinking are: (a) Originality: constructive imagination and independent thought; (b) Adaptability and flexibility: the ability to adjust thinking under new or unstable conditions and to move between various vehicles of thought (numerical, linguistic, visual) depending on the situation or context; (c) Appropriateness: goodness of fit between the constraints of the problem and the properties of the solution; and (d) Contribution to the domain: the accepted worth of new ideas within the discipline

III. METHOD

This study uses large literature on STEM education and creative thinking skills from several online database resources, including ProQuest, Web of Science and EBSCOhost. There are several techniques that a lecturer can use to deliver STEM in a good direction. More than 47,000 articles are discussing STEM education and self-efficacy. The search was conducted in October 2018. The purposes of this review was to identify peer-reviewed research that discusses STEM education and student's creative thinking skills.

Brown [17] noted that for literature study there were several inclusion criteria used to determine the relevance publication: (1) The study focused on instructional decision-making or practice intended for undergraduate students in a residential/on-campus course or academic program, (2). The article was written in English. (3). The article was published as part of a peer-reviewed academic journal or peer-reviewed conference proceedings. (4). The article provides a full accounting of the research process, as well as information

about the reliability and validity of the data presented. No summary research reports or research in brief articles were included.

IV. FINDING AND DISCUSSION

Integrated STEM education programs apply equal attention to the objectives of the STEM fields. Previous studies showed that the integrated STEM learning has the potential to prepare competitive future workforce with the 21st-century skills and positive impacts towards students' interest and achievement [18]. However, STEM faced huge challenges to strengthen the effectiveness of its implementation in education. They added that STEM educations develop problem-solving skills, promote student-centered learning, and cultivate higher order thinking skills. Integrated STEM education can be complimented by prevailing teaching and learning approaches such as project-based, problem-based, inquiry-based and theme-based learning.

There are some barriers of the implementation of STEM education according [19]: (1) Poor preparation and shortage in supply of qualified STEM teachers; (2) Lack of investment in teachers' professional development; (3) Poor preparation and inspiration of students; (4) Lack of connection with individual learners in a wide variety of ways; (5) Lack of support from the school system; (6) Lack of research collaboration across STEM fields; (7) Poor Content preparation; (8) Poor Content delivery and method of assessment; (9) Poor Condition of laboratory facilities and instructional media; and (10) Lack of hands-on training for students.

Given that academic success and extracurricular involvement may represent a start along one of many paths to positive growth, it is important to realize the components that lead adolescents to achieve good degrees and participate in extracurricular activities [20]. Experts believed that critical and creative thinking skills grow over time. They advised universities to begin with first-year general education classes and extend instruction developmentally upward into the majors, alongside a culture of critical and creative thinking which should define students' curricular and co-curricular experiences at university [21].

Sdouh [22] concurred with former studies, remarking that the advantage of creative thinking helps students to gain an in-depth knowledge of the topic they are learning, and it also helps apprentices to create dialogue, to persuade, to respect and accept the beliefs of others, and to unite intellectual variables with each other. He added that creative thinking also encourages learners to operate within groups which can grow the feeling of cooperation among students. Nickerson [23] summarized the various creativity techniques developed by both academia and industry, including: (1) Establishing purpose and intention; (2) Building basic skills; (3) Encouraging acquisitions of domain-specific knowledge; (4) Stimulating and rewarding curiosity and exploration; (5) Building motivation, especially internal motivation; (6) Encouraging confidence and a willingness to take risks; (7) Focusing on mastery and self-competition; (8) Promoting supportable beliefs about creativity; (9) Providing opportunities for choice and discovery; (10) Developing self-management (metacognitive skills); (11) Teaching techniques

and strategies for facilitating creative performance; (12) Providing balance.

V. CONCLUSIONS AND RECOMMENDATIONS

The conclusion from previous research findings, as mentioned above, is that youths who participate in extracurricular activities can get benefit from a means to enrich their social skills and heighten their sense of self, ultimately increasing soft skills [24]. A creative person has several behaviors which they apply to solving tasks in their daily life, as follows: (a) Examining and assessing the data/contexts in order to cast the problem's scope. This includes being involved in many events that arouse curiosity and that arise from the necessities associated with a specific problem or challenge. They are making preparations in terms of framing and articulating the problem's scope and collecting and analyzing data. (b) Synthesizing information and generating multiple solutions to the problem. This occurs over a period of time in which ideas spread relevant (and sometimes irrelevant) associations according to rules established by the thinker's knowledge within the field. Idea generation requires the synthesis of concepts and information, often in original configurations; (c) Exercising insight about alternatives and selecting a solution. This is when one of these associations fits the problem so easily (i.e., is appropriate) that it springs into consciousness. The thinker monitors developing work, pays attention to goals and feelings, compares ideas to domain knowledge and methods, and interacts with others involved in dealing with similar problems; (d) Evaluating the worth and consequences of an implemented solution. This is a critical judgment that results in modifications to the original idea; and (e) Elaborating. This occurs when the thinker develops convincing modes of presentation that communicate ideas to others [21].

VI. REFERENCES

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