Evaluating Learner Reasoning Skills through the Active Learning Flipped STEM Classroom Design

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***Abstract* — Developing learners to be the innovative thinkers through classroom activities is very challenging for educators. The active learning flipped classroom combined the STEM-learning activity design in this study then aims to investigate the learner reasoning skills. The results from the survey rated by samples of 396 learners studying at the undergraduate level at Prince of Songkla University, Thailand enrolled in the class of the Creative Problem Solving showed some significance in terms of the six domains of (1) Analysis reasoning, (2) Innovative thinking, (3) Decision making and judgment, (4) Mathematical reasoning, (5) Problem solving, and (6) Information researching. The reasoning skills of analysis and mathematics were related to the information researching. Interestingly, the improvement of decision-making and judgment skills were based on the learners' reasoning skills. In addition, the innovative idea of learners has been confirmed that was in accordant with not only the skills of decision making, but also the reasoning itself. Based on the experimental results, the designed approach in this study can also enhance learners to share their ideas with their classmates for giving comments and critiques on their assigned work in the classroom. Ultimately, the design thinking process can also encourage and stimulate learners to innovate new types of products or services through classroom activities more effectively.**

Keywords — Active Learning, Flipped Learning, Innovative Thinkers, Reasoning Skills, STEM Learning Design

I. INTRODUCTION

Transferring knowledge from the classroom activities is playing an important role in stimulating the thinking process and creative analysis of the learners. Organizing educational activities for learners in the 21st century is, therefore, important to not only uplift and improve the procedure in transferring knowledge creatively, but to enable supporting teaching and learning according to the students' aptitude and ability of integrating science with computer, communication and creative arts which can finally concur the needs of both national and international labor industries. This phenomenon reflects how the educational system need to be concerned not only providing education I general but the science, technology, engineering, and mathematics or STEM education is not excluded. Though STEM is generally known as a reference of some specific fields mentioned, science, technology, engineering, and mathematics or any domains related to science, it is debatable if the four mentioned fields deserve special attention as a sole collective methodology [1-4] . The research later has defined them as any shared importance promoting technological innovation, competitiveness, and long- term national prosperity and security education can be referred as a STEM [1-4].

Specifically considering to different teaching methodology applied in STEM education from time to time, lecture-based learning is one of traditional teaching methodologies found in the general classrooms which the teacher acts as a narrator or tells what he or she has learned to the students and perhaps they conform to the storytelling at the end [1-4]. However, this has been found that there are problems and limitations in this traditional teaching methodology. To illustrate, the unexpected learning outcomes caused from students' lack of experience concerning such knowledge or misunderstandings of the instructors' lectures causing the learners receive no apparent knowledge enough correctly [5,6]. To bring the learners to the top of the pyramid of learning concerning Bloom's Taxonomy [7,8], and achieve each of the learning domains, there is no better process nor method, unless the educators know how to understand and adapt the teaching process in a consistent and harmonious way to suit the nature and context of the individual learners. The teaching and learning in the 21st century is, therefore, based on the concept, "Teach Less, Learn More". This can be approached in a variety of ways, such as Flipped classroom, Project-based learning, Problem-based learning, or Real-life learning, etc. The emphasis should be on learners and approaches that consider the essential skills required for the 21st century such as self-learning, learning to build the knowledge, analytical thinking, problem solving, innovation development, teamwork, life, career, and technology, etc. The instructor must prepare all the above-mentioned tenets to motivate each learner to learn.

Therefore, applying the principle of the flipped classroom [9,10] in STEM approach is advised as a method presented in response to the different learning problems of learners mentioned earlier. By changing the teaching methods, listening to lectures solely in the classroom and returning to work after the class ends comes as a learner to do classroom activities but return to study contents from home instead [9,11,12]. Because each learner has different aptitudes and learning abilities, these methods are suggested in reducing the gap of learners'. To be more specific, this methodology applied in learning is to learn according to their aptitudes and flexibility in terms of time to search for any knowledge needed. This is an advised way to make the classroom more successfully. In addition, the approach of active learning and learning activities integrated with the STEM approach, which the learning management focuses on students' practice and applying knowledge themselves instead of listening to lectures solely together with the foundation of prioritizing on the learners' nature. This is how to enhance learners' competence in developing advanced thinking analysis, synthesis, and evaluation skills [13-20]. The expected

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successful skills mentioned could not occur without various teaching and learning activities in the classroom suggested such as activity-based learning [21,22], problem-based learning [23,24], and project-based learning [25].

Thus, the purpose of this study is focusing on how the students achieve the skills required as an innovative thinker through the designed evaluation model proposed applying the teaching and learning in an active learning flipped classroom align with the concept of the STEM design.

II. Meterials and Methods

This study was basically explored by evaluating the basic characteristics of the 21st century learners [26] in 3 important skills which are (1) Reasoning skill, (2) Innovative thinking and (3) Information researching skill. The samples were 396 undergraduate learners studying in Prince of Songkla University enrolled the class of the Creative Problem Solving which was normally conducted a period of 3 hour long a week totally 30 hours a semester. The research procedures can be shown in Figure 1 and explained as follows:

After the first meeting in the class, the learners have come to the class on the day after with high expectations to see what activities they would deal with in the classroom. Not only the lecturers need to prioritize the classroom activities, but also manage the classroom effectively. The class activities under the courses were covered by games, problem-based learning, and problem-solving coaching approach. These three approaches combined with the classroom questions are as an essential tool in this study.

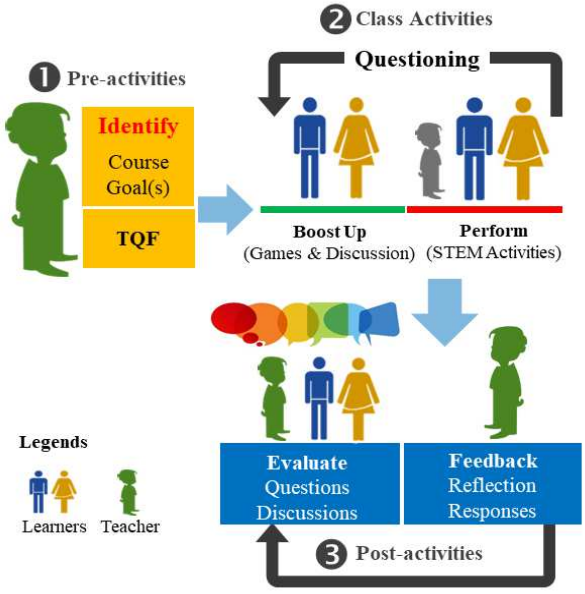

Fig. 1. Classroom activity and management.

The class, then, was started by changing the location of the classroom from the fixed tables, chairs, and areas to the outside classroom without tables and chairs. Setting up the entire environment like the play yard or some activities involved the use of outdoor space was considered. In each course module, case-studies and real-world issues were utilized as the scenarios and the key question of the classroom activities. Kahoot, Padlet, and Facebook are the primary tools to engage learners with the classroom activities. Facebook was another useful digital technology for the classroom which was applied to provide the class activities and photo albums that can remind learners about them later. Families to FB, Kahoot, and Padlet were the famous modern tools that were applied for class observation and questioning. At the end of every class, learners needed to give their reflection or summarize their knowledge via FB group. During the course, the Google Classroom was employed for the platform of the submission of assignment, homework, and examination.

The procedure can be summarized as follows:

A. *Preparation*

The researchers designed the units of contents according to the Thailand Qualifications Framework for Higher Education and Program Specification for constructing the course units and sub-units.

B. *Classroom activity and management*

The researchers have, then, organized the teaching style in accordance with the active learning approach combined with the 3 types of teaching methodology including the management of lecture-based learning, activity-based learning, and the STEM project (project-based learning) weighed the ration of 10 : 40 : 50, respectively. The course has been divided into 2 parts, (1) before the midterm examination — focusing on the lecture-based combined with active learning activities and (2) after the midterm examination — focusing on a STEM learning approach and its project (Fig. 1).

C. *Monitoring and evaluation*

The researchers prepared the form of assessment evaluating the basic characteristics desired by students in the 21st century. The follow-up procedure, then, was done. The evaluation of the classroom teaching and learning applying those 3 skills results have been evaluated by employing the five Likert scale survey which was 1 indicating the lowest level of achievement, 3 indicating a moderate level of achievement, and 5 indicating the highest level of achievement (Fig. 2).

The assessment results were done by the proposed designed 360-degree evaluation system which students have been evaluated by both their teacher and classmates. The results of the beginning as a pre-evaluation and ending semesters as a post-evaluation were, then, compared in order to explore if any development might show as the learners' achievement shown in Figure 2.

III. Results and Discusion

The pre and post evaluation results at the beginning and the end of the course concerning the basic characteristics of learners in the 21st century consist of 6 skills required as general characteristics needed as an innovative thinker: (C1) Analysis reasoning with the score, (C2) Innovative thinking, (C3) Decision making & judgment, (C4) Mathematical reasoning, (C5) Problem solving, and (C6) Information researching. The results show that all characters needed as an innovative thinker' scores in the post-test had higher than that of the pre-test done by the learners at the end of the semester. To illustrate, the researching information character was ranked the highest with the average score of 4.11 compared

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to other characters found in the post-test. The other four characters have been also found the higher scores in the post-test compared to the pre-tests themselves. To be more specific, learners' characters of analysis reasoning, innovative thinking, decision making and judgement, and problem solving were ranked the lower group scores compared to the highest one found in researching information characters, with the average scores of 3.99, 3.95, 3.92, and 3.85 respectively. Though the mathematical reasoning character was ranked the lowest in the post-test with the average score of 3.75 compared to other characters, it still shows the development of the learners as the post-test is higher than its pre-test, 3.35. Comparing the average scores of the learners' achievement in Table II and the characters' found in Table I, all characters' have been achieved by the students with the higher average scores of learners' achievement in Table II than that of the pre-test score in Table I. The highest average score of the learners' achievement is reasoning information (4.06) which correlates with its score (4.11) found in the post-test. The lower four achievement scores, analysis reasoning (3.88), innovative thinking (3.82), decision making and judgement (3.77), and problem solving (3.67), were ranked higher than that of their pre-tests scores.

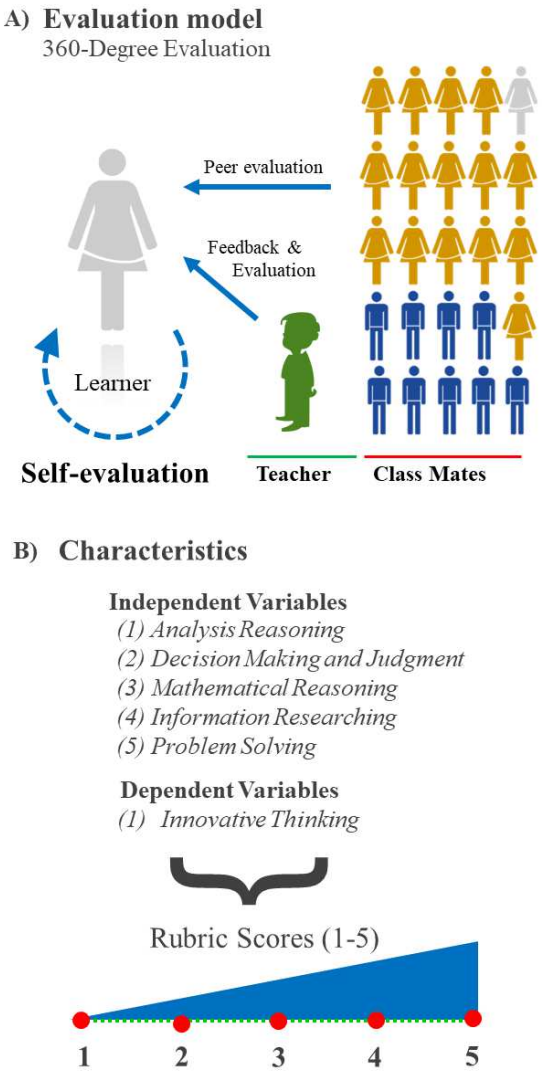

Fig. 2. Learners Monitoring and evaluation.

TABLE I. CHARACTERISTICS OF LEARNERS

Characteristics	Goal (Score)	Evaluation	
		Pre-	Post-
C1: Analysis reasoning *Examines data to grasp issues, draw conclusions, and solve problems*	5.00	3.77	3.99
C2 : Innovative thinking *Develops fresh ideas that provide solutions to all types of workplace challenges*	5.00	3.68	3.95
C3 : Decision making & Judgment *Makes timely, informed decisions that take into account the facts, goals, constraints, and risks*	5.00	3.61	3.92
C4 : Mathematical reasoning *Uses mathematical techniques to calculate data or solve practical problems*	5.00	3.35	3.75
C5 : Problem solving *(Resolves difficult or complicated challenges)*	5.00	3.49	3.85
C6 : Information researching *Identifies, collects, and organizes data for analysis and decision-making*	5.00	4.01	4.11

TABLE II. GOAL OF LEARNNER ACHIEVEMENT

Statistical (*N=396*)	Characteristics					
	C1	C2	C3	C4	C5	C6
Average	3.88	3.82	3.77	3.55	3.67	4.06
Maximum	4.83	4.75	4.58	4.58	4.58	4.83
Minimum	3.08	3.10	3.13	3.17	3.00	3.33
Number of learners[a]	222	190	206	190	206	174

[a.] Learner who had the average score the higher than the average of the samples

The classroom research results of both individual and group clearly confirmed that learning outcomes in terms of learners' six domain characters resulted from applying the flipped classroom in STEM approach are significantly better than that in the traditional lecture-based classroom. As the flipped-STEM classroom tasks are quite challenging for learners to develop their innovative thinking skills. The results also affirm that student perception and feedbacks also have shown positive achievement Applying this approach, it can effectively help stimulating students' attention as well as helping students to automatically remind the content without having to write down the lecture notes.

IV. CONCLUSION

In brief, the results of this study can encourage the educators support their learners by applying the learning activities stimulating the learners' curiosity and thinking skills through the flipped classroom along with the applied STEM approach as the supporting tools for specific learning objectives in the curriculum unit. Also, one of the most advantageous outcomes of the activities is that the learners are promoted and inspired to think, analyze, and design their own processes in acquiring relevant knowledge from outside resources by themselves. Furthermore, they can share their knowledge with their classmates in the classroom which is very important in acquiring higher level of learning. In terms of applying the STEM approach, not only the learners can

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integrate their knowledge, but also they can apply the information technologies as the tools properly to promote their learning compared with a traditional lecture approach which can result less positive outcomes. The study strongly suggests that motivating thinking skills is the successful key coaching learners to crystallize their implicit knowledge and increase the knowledge of exploring skills which are desirable skills for learners in the future. Ultimately, this suggested approach is also a shortcut key that can precipitate the skills of teaching and the processes of knowledge transfer for the teachers themselves to be a professional teacher.

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