A Designed Module for Support Problem-Solving Skills among Engineering Technology Education Students

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Abstract: ***The research study examined the effectiveness of the module designed intervention in supporting the problem-solving skills among students in Engineering Technology from Technical Vocational Education and Training Institution. A combination of Theory Inventive Problem Solving and Experiential Learning Theory were used in this module designed. The study had 68 students and formed two groups: control and experimental. Students from the experimental group were taught with a module designed during their final year project 1 course meanwhile control group learned the techniques in a natural way. The research instrument consists of a scheme of work, syllabus, lesson plan, student exercise sheet, module powerpoint, implementation checklist and also rubrics assessment. The questionnaires were used as a data collection for both pre-post-test and results were analyzed using the SPSS program package. Findings indicate significantly improved students' problem-solving skills as compared with the control group and highest score was for quadrant 4. The increase in the mean gain for quadrant 4 was the difference of 6.91-5.91=1.00 that showing positive changes in their problem-solving skills.***

Index Terms**: Keywords:** ***Engineering Technology, Experiential Learning Theory, Module Designed, Problem Solving.***

I. INTRODUCTION

The changes in engineering field more demand for the technical workers and engineers so that they become more efficient in problem solving thinking. Nowadays, industries emphasize on resolving the problems quickly and also to cope the information for under uncertainty things [14]. Malaysia industries need a highly skill workers to present supply gap specially to drive the economic transformation plan. As determined by government, Technical and Vocational Education and Training (TVET) are main programme to drive Malaysia become a high-income nation and at the same time providing highly-skilled human resources.

The 11th Malaysian Plan is more focuses in TVET development in producing of knowledge workers (k-workers) in order to pursuit and transformed Malaysia towards a high-income developed nation. Therefore, to achieve the required skill in k- workers, TVET needs to equip the trainees with important requisite skills. Challenges faced by the Malaysia Higher Education System clearly indicate that urgent measures need to be taken to overcome the barriers.

Furthermore, to move towards in TVET a teaching and learning need a paradigm shift by introducing outcome-based education (OBE). The OBE shift the education system towards competitive learners by emphasizes the students into focus of outcome of the learning rather than input or taught only. This reform the education toward students centered learning, by measuring of students' performance [15]. It views the attitudes and fostering skills for employability as well as productiveness. In addition, it offers the people opportunity by develop an employability skill and also actively participate in vocational mobility.

A report by the Department of Statistics Malaysia (2011) among a factor of the unemployment in institutions graduates is low problem-solving skills therefore numerous studies have emphasized the importance of problem-solving skills [2]. Problem solving skills is not just a knowledge that gained from experience, but it is an essential in daily routine. In addition, it is very important to emphasize and develop problem-solving skills among students to increase more quality graduates [3]. This supported by Yenice et al., that mentioned skills in problem solving a very important and crucial for people that almost faces it every day [4].

As a human capital for the future, graduates should prepare themselves with skills such as problem-solving skill and critical thinking because this is the element that employers focus in hiring new worker [5]. However, from the observation and investigation in some TVET institution students' are seen to have difficulties in problem-solving techniques which hinder their structured thinking and lead them not being able to solve problems due to a lack of systematic thinking in problem-solving skills.

II. LITERATURE REVIEW

Curriculum in Malaysia Technical Education is constantly changing from time to time based on industry and technology demands. The changes and development are essential in ensure that can meets the current market demand and needs. In line with technology and industry that are expanding rapidly, it indirectly affects the structure of education in general. Thus the government proposed the field of Technical Vocational Education and Training (TVET) a main platform to provide skilled human resources. The TVET sector is developed to assist students to become competitive workers so that they can fulfill the demands of the industry's workforce by providing the skills needed at the workplace [1]. A career in engineering has undergone significant changes in the efficiency of problem-solving and thinking skill.

They required engineers and technical workers to solve

open-ended problems faster, specific and also to overcome the problem of uncertainty and excessive information. Therefore effective strategies need to be considered to promote problem-solving skills in technical learning institutions.

A. Technical and Vocational Education and Training (TVET)

TVET has become crucial during these recent years for industries and the economy as a whole. The on-going changes at the workplace and the progressive development of technology enforce workforce to apply extra knowledge in workplace with a advance high skills and positive attitudes. Nowadays current industries need a worker with advance technical skills and also the ability to correlate it with others. Therefore to tackle a challenge in work surrounding graduates needs education and training to increase employability skills. Technical and Vocational Education and Training (TVET) is a main sector to produce graduates with reflexes they can interact with job duties in the organization of the workplace [21].In addition, TVET can give a positive impact on enhancing economic growth. It reflects the increase in society's welfare which effectively by doing industrialization.

A skilled worker need to able handle technology and also can keep up their needs in the industrial process. Hence to support economic growth, vocational education is important as it is focus at the needs of the demand market and therefore contributes for the more sustainable in economic growth of the country [22]. The changes of TVET are the re-engineering of the existing vocational education system in the development of a new vocational or technical education system that can contributes into a nation. TVET transforms also focuses on job components for graduates for their future. The success of this achievement transformation can be seen as it also contributes to the agenda of government in ensure Malaysia become a high-income nation.

Changes made through transformational programs in schools-and vocational, community colleges and polytechnics. The aspects covered include governance, process design, delivery system, quality assurance, curriculum development, quality resources, and efficient teacher training development, continuous innovation and recognition by the Malaysian Qualifications Agency (MQA). The government also strives to standardize the path from the TVET institute to the university by providing education and professional pathways. Even continuous learning is also taken into account as an additional element. Hence, many government agencies provide courses on skills and technology and Technical Vocational Education and Training (TVET) have been given greater emphasis to prepare Malaysians for the professional world. [23] Therefore, many training programs are offered by training institutions to achieve job efficiency.

Therefore to cope with the drastic changes of several TVET institutions, a new system of governance is required to stay relevant and responsive. Majlis Amanah Rakyat (MARA) in their Strategic Plan comes out with MARA Transformation Strategic Framework for 2011-2020. Firstly, to ensure the main objective is achieved by producing a human capital with global level and also in line with innovation and integrity. Next, the education has to transform to create professional entrepreneurs as well as excellent in academic. Third, is by strengthening the platform of education for undergraduate and postgraduate level program.

Moreover, in empowering TVET, the government also has created Malaysia Board of Technologies (MBOT) in recognizing world-class technologists and skilled workers. The recognition covers the undergraduates and post graduate in Technology area and it discover offered by other higher learning institutions. It also can provide a platform for technology and technical graduates to be recognized once they enter the workforce. The recognition is vital to ensure exceptional quality in services rendered and also indirectly can improve the public perception of TVET as a career of choice.

B. Students' Current Problem Solving Skills

Students can learn freely by their own way in problem-solving activities. These indirectly encouraged students to seek the root cause investigate and also explore the problem deeply. All the experiences and knowledge that gained via problem-solving process assist the students to become actively, creative as well as progressive. These elements are very important and necessary for student to overcome the challenges of towards being a developed country that exactly based on science and also technology. The general observations that not fulfill the needs of industries have been documented by various researchers. Some report from the Malaysian Employers Federation (2011) revealed most of the graduates do not meets the criteria to become excellent potential workers [24]. Thus, it is important in every industry, graduates should expert in every aspect of their daily routine to overcome some type of problem-solving.

The problem-solving skill can be considered as an individual thinking process because it can be applied to the many situation from the previously learned. As an initiative towards empowering TVET Malaysia, MARA has implemented industry training as a condition for graduation. Students will be evaluated from various aspects including soft skills where there are elements in problem-solving skills been assessed.

C. Review on Teaching and Learning to Enhance Problem-Solving Skills

The main mission of engineering education is to provide graduates to be more successful in their work environment [16]. Therefore, students should always be prepared with pure knowledge, skills, and attitudes [17]. One of the methods to develop and improve the students' knowledge, skills and attitudes is to intervene in the design module based on the desired learning outcomes. Problem solving is the most important cognitive activity in the daily context. However, learning to solve problems is somewhat in scientific contributions. This is because it requires an informal education setting and our level of understanding about the process is also quite eradicated. Similarly, research

and instructional design theory focuses too little on the study of problem solving. The point of education is to teach people to think, using their power to become a better problem solver.

To acquire individual problem solving skills should be trained and should be able to adopt a method to solve problems from one situation to another. At present, there are movements to divert the paradigm in line with the industry and domestic concerns .A student-centered approach where students play an active role in the classroom. In a student-centered approach, they are not entirely dependent on their lecturers all the time, waiting for instructions, approvals, advice, correction or praise. But they are stressed to actively engage with the activities they are doing. They are taught to communicate, appreciate the contributions of others, cooperate, learn and help each other. As well as referring to lecturers or specialists when they face difficulty after trying to solve this problem and students are exposed to various activities that help them develop certain skills.

In encouraging students to develop problem solving skills, students need to engage with real world design problems, case studies, internships, co-operative education and mentoring.Therefore, to address this issue; the emerging trend is the emphasis on student-centered learning had been introduced. Furthermore, it can be summarized researchers found that project can help a student in understanding the problem. Assignment project appears in the more traditional learning concept but the project or problem is centered around the notion of learning which gives the learner the opportunity to be involved in the learning process. In addition, the project also can simulate a real engineering work environment hence lots of the characteristics and benefits of project-based learning make it a relevant pedagogical strategy in engineering education where real problems can be solved.

Apart from it, Problem-based learning (PBL) also a major contributed to the student-centered pedagogy where students will learn about the subject through the experience of solving open problems found in the trigger material. This total understanding can at once improve the teaching and learning process as it focuses more on developing students as self-directed students than in traditional lectures that encourage students to be fed by lecturers.Therefore project, problem, and capstone are important learning based components that can increase the extent, complexity, and student autonomy in the future to be the best way to satisfy industry needs.

III. RESEARCH THEORY

Learning theory used to explain the ways students learn things. The different theory describes the different point of views on the acquisition of knowledge [12]. Learning exists when information is transferred from an educator to a learner and the information received is applied in appropriate activities [13]. Therefore the underpinning research theory used that based on these principles is Experiential Learning Theory and Theory of Inventive Problem Solving.

A. Experiential Learning Theory

The theory of experiential learning is a self-efficacy in individuals that tend to attempt what they believe which it can compete successfully and also tend to stay out undertakings whichever they believe surpass their capabilities. Moreover, self-efficacy also can be affect an individual's decision and the activities involved. Therefore the main factor that affecting is a personal experience which describes their educational process.

Sometimes, a person can acquire a boundless of information but less participates in the tasks, even though from that information it can persuade productively with less experience in doing so. Thus, experiential education is "education that occurs as a direct participation in the events or activity of routine life and it may comprise learning from reflection on everyday experiences or in other words is informal education.

Experience is a major component of the educational process. It must have interaction and continuity. The continuity refers to the "experience chain" where one experience leads to additional experience that encourages an individual to learn more. Whereby, interaction refers to the extent to which experiences relate to individual goals.Apart from that, the student's personal experience comes in the beginning. While educational achievement depends on the ability of the student, it also depends on their learning style consistent way which students respond or interact with stimuli in the context of learning. By considering the existing research, Kolb and Kolb [20] conclude that learning experience is an effective educational approach. Specifically, they found that learning experiences were effective in improving student meta-cognitive abilities, enhancing their ability to apply information to real situations and giving them the ability to become direct learners.

Frequently used in experiential learning theories is Kolb learning theories. Kolb's Experiential Learning Model defines learning as "the process whereby knowledge is created through the transformation of experiences" [19].

Various issues regarding the style to better understand the learning model and student learning priorities have been studied and investigated. Teachers and course designers should pay attention to the learning style of the students before the intervention of appropriate teaching and learning designs.

An educators' role, therefore changes from transmitter of information to the organizer and facilitator of meaningful experiences oriented around students' individual needs. The learning cycle theory uses as shown in Fig. 1. The Kolb Learning Cycle (ELC) also has a similarity with others active learning methods [6]. However, the important difference between ELC Kolb versus other active learning approaches is that this theory considers the experience as the basis of learning. With regard to different levels, Kolb explains that effective learning needs to undergo experience learning cycles. It starts with concrete experience, followed by reflective observation, then by the concept of abstract understanding, and goes on in active experiments to build effective student abilities. Experiential Learning Cycle and learning application are more prominent and it is best

suited for engineering education, especially in the science field of experience [7].

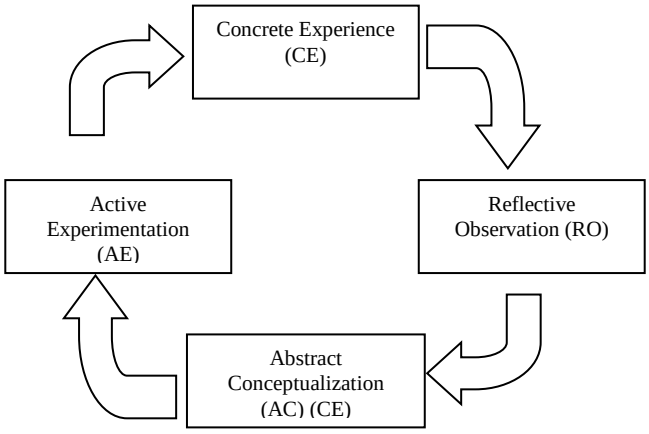

Fig. 1. Kolb Experiential Learning Cycle (ELC)

B. Theory of Inventive Problem Solving (TRIZ)

TRIZ was a Russian acronym for the theory. It is systematic approach to innovation and also a knowledge-based,. The theory was develop by Genrich S. Altshuller (1926-1998). Moreover the TRIZ method was derived from the most innovative inventions analysis in different industries, engineering fields and technologies. It began in 1946 when he found that the evolution of the technical system was not a random process, but it was governed by certain objective laws. He believe that these laws can be used to develop a systems in the technical evolution. TRIZ involves systematic analysis to improve and use a series of guidelines for problem definition.

This approach differs from traditional methods involving unconventional thinking methods specifically "trial and error" methods. It depends solely on the evolutionary law of uneven technical systems, therefore, allows the search to focus on possible solutions. The TRIZ principle used to solve problems is illustrated in Fig. 2. It is also supported by Darell Mann that explaining the combination of TRIZ's main tools, can achieve potential and excellence design in innovation [8]. A main step in the TRIZ approach was the Specific Problem. Here the exact problem needs to be specifically defined appropriately. Next is TRIZ Generic Problem where TRIZ had various tools to solve inventive problems by classifying the problem before choosing the appropriate tool. Next, use the TRIZ tool to generate solutions to the problem. Lastly, apply and consider the soundness of the solution for a specific solution.

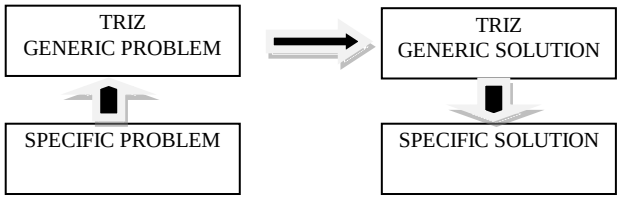

Fig. 2. General Principle of TRIZ

C. Research Framework

The framework used while designing the intervention module as shown in Fig. 3. The framework employs the intervention approach to education. The approach begin with current students problem solving as a input, then process of module development where the module has been intervene by considering the research theories used. Lastly the output was the measurement of the elements issues which discusses the performance and achievement after experience the module designed.

The framework is as a mechanism for aligning literature review, research design and methodology [18]. The output implies a description of the performance of students after being subjected to the educational process. In the beginning, the educator determines the learning outcomes of this course while considering the procedure in problem-solving steps during FYP, then integrate it with systematic problem-solving steps and Kolb experiential learning. Furthermore, appropriate teaching and learning strategies are selected to achieve the learning outcomes by developing the intervention module in determining to which extent the learning outcomes can be achieved. Finally, the issues elements of the learning experiences are then translate into students' performance in problem-solving skills.

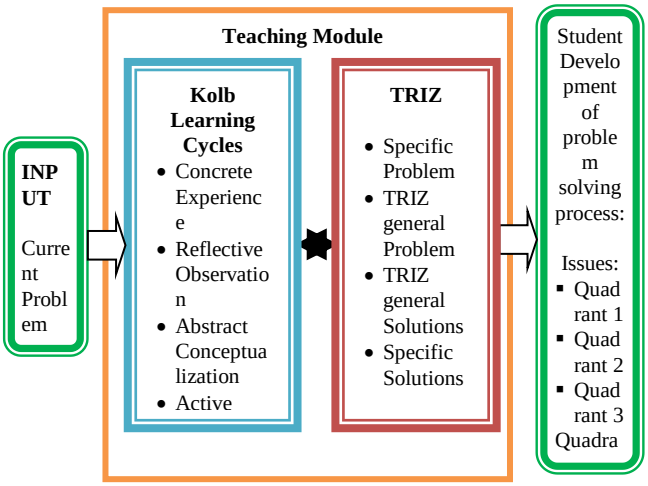

Fig. 3. Research Framework

IV. METHODOLOGY

A module designed that integrate with ELC and TRIZ been used as a module intervention class so that it can support students' problem-solving skill. Every cycle in the experiential theories was addressed in the TRIZ principle approach. Its purpose is to support students so that they become independent learners and thinkers and can attempt a new concept with efficiently. The TRIZ methodology approach and Kolb experiential step were integrated as shown in Fig. 4.

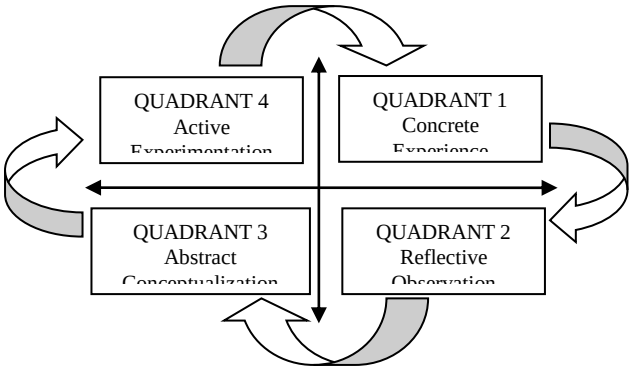

Fig. 4. TRIZ and ELC step

The cycle steps began with a concrete experience. This is fundamental for reflective observations. The learners begin by attempting the task that assigned in quadrant 1.Then followed the activity in quadrant 2. In this quadrant 2, the learners' roles were very important to generalize the problem. Next, from the second cycle, it leads to the abstract conceptualization.

In this step, learners actively engaged in quadrant 3 by generating the solution. Then the cycle towards active experimentation and lastly, in quadrant 4 learners apply the solution to solve the problem contradiction. Next, they need to practice what they have learned in quadrant 4 by creating and generate a new experience. A module designed had several case studies and students' have to attempt and explore it.

Exercise template was used for each case study. Then students were discussed among their group members and have to present the solution for every case study. Each question and each step in the exercise were covers the dimension quadrant as shown in Fig. 5. In addition, every cycle emphasized the learning process for each learning quadrant by using the TRIZ method.

QUESTION	DIMENSION
a)…. b)…. c)…. d)…. e)…. f)…. g)…. h)…. i)….	**Quadrant 1** For question a-c **Quadrant 2** For question d-e **Quadrant 3** For question f-g **Quadrant 4** For question h-i

Fig. 5. Exercise question mapped into a dimension

In this phase, each learning theories adapted in the design process and implemented in all students activity. The data gathered were from the mixed method and the samples taken were from students' second year in Engineering Technology. An investigation of the module effectiveness was from two groups which are control and experimental with pre and also post-test. Furthermore marks from both test then been analyzed. An instrument used for the assessment was adapted from the Innovation Situation Questionnaires [9]. Some modifications have been made to suit the research study. The content of the problem-solving test also has been validated by experts in the field. The problem solving questionnaires test is consists of 12 compulsory questions and it covers the entire dimension tested. In early of the semester, the pre-test was conducted and followed by intervention class in the middle of the semester.

Then students re-evaluated in posttest at the end of the semester and followed by an interview session. In addition, the purpose of the interview session was to gain a deep understanding of things that can't be observed [10]. The respondents' idea or thinking and their perspective also can be obtained via the interviews [11].

V. RESULTS AND FINDINGS

Based on the related research, there are four quadrants of the study to be analyzed. Each quadrant emphasized a different scope of problem-solving skills. In this study, the SPSS package program was used as the statistics software with paired sample t-test were employed to analyze the data for the experimental group. The marks for each quadrant were analyzed accordingly as shown in Table I to Table IV.

Findings from table I revealed that there is a significant difference between the means of quadrant 1 for both tests ($t= 2.240$, $p<0.05$). As result shown in Table I, the mean for post-test was higher compared to pre-test mean. In addition, the probability value of 0.032 indicates significant improvement from pre-test to post-test of quadrant 1 after exposure to the module intervention.

Table I: Quadrant 1 paired sample T test analysis results

Test	X	S	N	t	P
Post	6.23	0.973	35	2.24	0.032
Pre	6.06	0.968			

The achievement in quadrant 2 also a statistically significant difference for pre and post-test as illustrated in Table II. A mean shows an increment score from pre 5.54 to 6.40 for the post. Apart from that the probability value ($p<0.05$) also indicates significant improvement of quadrant 2 ($t= 6.0$, SD 0.919 and 0.847) accordingly. This indicates the module intervention positively support students skills in quadrant 2.

Table II: Quadrant 2 paired sample T test analysis results

Test	X	S	N	t	P
Post	6.40	0.847	35	6.00	0.00
Pre	5.54	0.919			

According to the result in Table III, there also statistically shown a significant difference in the pre and post-test scores which are favors in the post-test ($p<0.05$). From these results, the fact of a significant difference for the experimental group's pre-post test score means, it can be express that the module designed intervention class makes a positive and good effect on students' potential in quadrant 3.

Table III: Quadrant 3 paired sample T test analysis results

Test	X	S	N	t	P
Post	6.66	1.027	35	8.45	0.00
Pre	5.17	0.707			

Findings in Table IV also revealed that it was the statistically significant difference between both test scores in favors of the post-test ($t=4.45$, $p<0.05$). According to these findings, it revealed a significant difference between the experimental group's pre-test score mean and post-test score mean, it can highly indicate that after exposure to the intervention class students can enhance their abilities in quadrant 4.

Table IV: Quadrant 4 paired sample T test analysis results

Test	X	S	N	t	P
Post	6.91	1.483	35	4.45	0.00
Pre	5.91	1.245			

As summarize of the results findings, an improvement of the score for quadrant 1 indicates students can be encountered or decomposed the problem. They applied the existing experience to understand the problem effectively. Also, the improvement score can be seen in quadrant 2 where students can identify the design by comparing to other similar design by reflecting back their experience and observing for better understanding. Supported from the activity in quadrant 2 lead in increasing the number of students that can give a new idea or modification in determining the appropriate parameter and proposing the principles in TRIZ matrix that occur in quadrant 3. Finally, improvement in quadrant 4 shows students' can apply the model of the solution and identifies the specific solution to encounter the problem.

VI. CONCLUSION

As a conclusion, the module intervention was a focus on the dimension of TRIZ and experiential learning cycle. The module also was very important to be implemented in others TVET institutions because the dimension is significantly associated with the achievement of student problem-solving skills. Apart from that various aspect in problem-solving activity need to be considered so that it can enhance and give impact on the outcome of learning. In addition, students also can experience problem-solving skills in a systematic way.

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