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เย เนา

อธิปัตย์ คลี่สุนทร

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Remote Labs for Automation Engineering and Technical and Vocational Education: Proposing a New Training Model

เย เนา[1*] และ อธิปัตย์ คลี่สุนทร[2]
Ye Naung[1*] and Athipat Cleesuntorn[2]

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนารูปแบบการฝึกอบรมออนไลน์ สำหรับนักศึกษาวิศวกรรมศาสตร์อัตโนมัติที่ทำงานสาขาที่ศึกษาในโรงงานอุตสาหกรรมของประเทศสิงคโปร์ ให้สามารถได้รับพัฒนาสมรรถนะวิชาชีพระหว่างการทำงานได้ การวิจัยใช้ระเบียบวิธีวิจัยกึ่งทดลอง แบ่งนักศึกษาที่ทำงานในสาขาวิศวกรรมอัตโนมัติ โดยวิธีสุ่มเลือกเป็นสองกลุ่ม คือ กลุ่มควบคุมและกลุ่มทดลอง กลุ่มละ 20 คน โดยมีการทดสอบก่อนและหลังของช่วงเวลาการทดลอง รูปแบบการฝึกอบรมออนไลน์ คือ “Empower Training Model” โดยกลุ่มควบคุมจะได้รับการฝึกอบรมแบบการอบรมปกติ ส่วนกลุ่มทดลองใช้ระบบอบรมออนไลน์ ETM เกณฑ์การวัดประเมินทักษะและกระบวนการ ใช้แบบสอบถามของ American Association of Colleges and Universities สาระ ประกอบด้วย การแก้ปัญหา การคิดวิเคราะห์ ความคิดริเริ่มสร้างสรรค์ การตั้งคำถาม และการวิเคราะห์ผล สถิติที่ใช้ในการวิจัย คือ ค่าเฉลี่ย ส่วนเบี่ยงเบนมาตรฐาน และ *t*-test รวมทั้ง การใช้โปรแกรมคอมพิวเตอร์วิเคราะห์ค่าทางสถิติ ผลการศึกษา พบว่า รูปแบบฝึกอบรมออนไลน์ ETM ช่วยทำให้ผลการเรียนรู้ของนักศึกษาพัฒนาอย่างมีประสิทธิภาพมากขึ้น

คำสำคัญ *:* อัตโนมัติ, รูปแบบการฝึกอบรมแบบเพิ่มพลัง, เกณฑ์การประเมิน

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[1] Graduate Student, Graduate School of Business and Advances Technology Management, Assumption University
Email: yenaung5002@gmail.com

[2] Lecturer of Graduate School of Business and Advances Technology Management, Assumption University Email: athipatcls@au.edu

* Corresponding Author

Abstract

This research intended to explore the existing skill of automation, develop and implement a new online training model for automation engineering students who are working in the industrial automation-engineering field to improve their professional skills, and lastly to evaluate the learning outcomes. This was quasi-experimental research. Two groups were performed with the use of a pre-test and post-test to compare the results of skill evaluation tests of two groups of students. Twenty working persons who have been working in the industrial automation-engineering field in Singapore were selected as samples and were grouped into two groups: the control group and the experimental group. The new training model, "Empowered Training Model", was used as a treatment for the experimental group, and the control group received a conventional training model. Rubrics from the American Association of Colleges and Universities were used in the skill evaluation process. The research data was analyzed with SPSS statistic software. The student's professional skills of problem-solving, critical thinking, creative thinking, inquiry and analysis, and lifelong learning skills were observed and evaluated. Also, the research hypotheses were tested with an independent sample *t*-test and paired sample *t*-test. The results showed that the new TVET training model effectively improves students' learning outcomes.

Keywords: automation, empowered training model, rubrics

Introduction

Due to the rapid transformation of industry 4.0 technology and its advancement, a shortage of skilled automation engineers has become challenging for nations. Tan and Tang (2016) stated that a shortage of industry-ready skilled workers presents one of the biggest challenges for the five core member countries of the Association of Southeast Asian Nations, ASEAN-5, including Indonesia, Malaysia, Philippines, Singapore, and Thailand. The Malaysian education minister Maszlee Malik said that changing people's attitudes towards technical and vocational training and education (TVET) and convincing more industry players to cooperate with the government remains one of the main challenges that the field faces (Choong, 2019).

United Nations Educational, Scientific and Cultural Organization [UNESCO] (2016) informed that a rising youth unemployment rate is one of the most significant problems facing economies and societies in the world today, for developed and developing countries alike. The global trend of engineering training also leads to online and off-campus teaching and learning with the help of simulation software and prototype experimental kits. The effectiveness of virtual and simulated labs is still in question and the usage of remote labs as a technology assisted tool in the educational service is gaining popularity. Scanlon et al. (2004) highlighted that a remote lab system enables students to conduct real world experiments from a distance. A new research study on the skill improvements of training students was made with the use of a new training model applying remote labs for students who are studying automation engineering.

Statement of the Problem

The upskilling and reskilling of workforces to meet current demands is critically needed to face technology advancement. In the meantime, those workers who are at risk of automation because of this transformation shall swiftly seek available career opportunities to work as automation technicians, if possible. On the other hand, in many countries, unemployment is a critical problem as socioeconomic concerns are hindering progress. The lack of technical skills possessed by fresh engineering graduates and the skills required by employers are major concerns that affect unemployment. The skills of the workforce are totally related to the schools and institutes in which engineering students are trained. These issues have really pushed the author to get involved in this investigation. This research focusses on automation engineers who have been working in an industrial environment.

Automation engineering training really needs hands-on and practical work and most of the training centers provide only simulation as a practice, which cannot lead to sufficient understanding and constructive knowledge for learners. This is the main problem in that automation engineers and fresh graduates are not able to catch the rapid advancement of new technologies and lastly, they are not able to secure a career. Researchers notice that today's industries are being innovated along with the fourth industrial revolution, but the needs and the shortages of skillful and talented engineers to facilitate their automated industries have become a serious issue that is still yet to be resolved. Furthermore, the current TVET training courses are being transformed to online and distance learning approaches with the help of emerging technologies. Yet, the nature of automation engineering training means there is a need for practical experience of learners on their studies but most of the current training courses provide virtual and simulated testing experience.

Literature Review

Accreditation Board for Engineering and Technology [ABET] (2018) suggested that a student learning environment should be provided with the necessary classroom facilities like laboratories and its associated equipment, and from there, it should support the appropriate student's learning outcomes. Bal (2014) made his study on the effectiveness of the developed remote robotic workstation used for distance learning under Miami University Ohio. He studied both local and distance students' learning outcomes and motivation through that remote laboratory. The assessment suggested that the remote laboratory systems are highly effective in distance education as distance-learning students gain a similar experience to local students.

The expression "backward design" was utilized by Wiggins and McTighe, who proposed the curriculum design in 1998 (Understanding by Design). In the backward design model, the starting point is to define the intended learning outcomes that focus on how the learners transfer the knowledge and skills at the end of learning process. Only after the intended learning outcomes are set, then, the method of teaching, assessment and feedback methods shall be designed. Many, if not most, teachers still construct subjects by starting with preferred topics, texts or teaching methods without explicit reference to the intended outcomes or standards (Wiggins & McTighe, 1998).

The Criterion Referenced Instruction, or CRI, was developed by Robert Mager and is a method of design and delivery of training programs which focuses on the self-directed learning experience. This method is significantly effective in the eLearning environment. Educational institutes place emphasis on these growing demands, and they have begun their innovation to improve engineering education in developing modules and programs (Crawley, 2014; Kolmos, 1996; Mills & Treagust, 2003). It is observed that one of the newly developed approaches is the task-centric holistic agile teaching approach T-CHAT (Mäkiö et al., 2016). T-CHAT emphasizes on the improvement of disciplinary knowledge, social and personal skills, and competencies. The best-known definition of self-directed learning (SDL) is that of Knowles (1975): "a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes." In order to get effective learning, Kolb (1984) stated that the learner should have four different abilities such as concrete experience, reflective experience, abstract conceptualization, and active experimentation. So, the learners participate themselves in the learning experience and they utilize respective abilities to increase and develop their new knowledge and skills. Bal (2014) expressed his findings in an assessment in a remote lab with a robot that remote laboratory systems are highly effective in distance education as distance-learning students gain a similar experience to local students. In this research, it added the teaching and learning model integrated with the remote lab facilities and it found significant improvements in learning outcomes of student's professional skills. Billett (2009) realized that the effective integration of practicing and work experience in the educational programs were of worth in practice-based experiences within the totality of higher education curriculum.

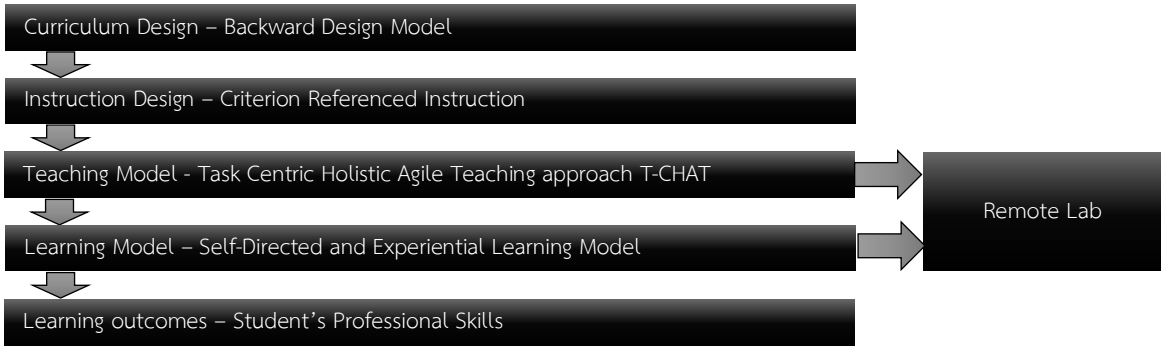
Tyson (2016) demonstrated in his research with the enriching knowledge of vocational tasks, conceptual knowledge development and critical thinking reflection, the advancement of practice, development of 'practice fields' in educational settings. Mäkiö et al. (2016) stated in their research on the T-CHAT approach that the results were very promising and encouraging to hold similar courses in the future. In this research, the researcher made further studies on the T-CHAT teaching approach with the combination of two learning models, namely the self-directed learning model and the experiential learning model. Barrows and Tamblyn (1980) informed that problem-based learning stimulates student's prior knowledge by presenting a problem to students and encouraging new knowledge constructively. Healey (2005) presented that the research-based learning method develops critical thinking skills of learners and supports problem solving, active participation, inquiry, and analytical skills. In this research, the researcher asked students to do a research project in which a new and better design creation was questioned to students. Considerations of critical thinking, problem solving and student's motivation with active participation were observed in the research-based lesson assignment class. Knowles (1975) demonstrated self-directed learning and Kolb (1984) presented experiential learning. With the help of self-directed and experiential learning models, this research brought forward that utilizing the Empowered TVET Training Model helps students to get more efficient learning as well as more effective delivery for the training instructors.

Designing New Training Model

The backward design model was utilized and the desired outcome as a professional skill improvement was set. To identify the acceptance, a criterion-referenced assessment was involved to measure student performance against goals and objectives. Criterion Referenced Instructional Design was adapted as an instructional design to emphasize the student's professional skills improvement. In developing the learning module, the specific objectives of skills improvement were tied together in the lesson plans. The teaching model was adapted with the T-CHAT approach, and the learning models as the Self-Directed Learning Model and Experiential Learning Model. The researcher designed the new training model as below.

Figure 1

Empowered training model by the researcher



The remote lab facility was introduced in this training model and students could get real industrial engineering experience with this technology assisted remote lab. The remote lab was equipped with actual industrial control devices to form an actual control system. The student's visualization could be accessed through remote cameras installed inside the remote lab, with a full control of pan, tilt and zoom positioning. The individual student was assigned to work with the remote lab facility to do a functional test, an improvement study, and problem-solving activities. The mode of training was through the internet with the help of online meeting applications such as Microsoft Team, Microsoft WebEx, and ZOOM. Students were given the access to the researcher's own VPN server, remote desktop connection, and remote lab PLC control system facility. The theoretical lecture was conducted in synchronous mode and students were allowed to make queries and discuss. The reflection paper, project assignment work, problem solving assignment work, and system improvement and research assignment work were involved, and students are asked to submit a report and practical test results.

Methodology

This was quasi-experimental research. The sample group consisted of 20 working graduates and all participants were working employees or self-employed engineers who are working in automation engineering field, in Singapore. The control group and experimental group were assigned with 10 each.

All samples in groups were tested examine their learning outcomes after having attended the training classes. The empowered TVET training model was used as treatment to the experimental group and the control group was received the conventional TVET training model.

The classic experimental research method will be used to study the effectiveness of the new TVET training model named as “ETM”, the Empowered Training Model. The main purpose of this research is to answer the research questions, measure the variables, and prove or disprove the research hypotheses. To achieve the research objective, the Pre-Test Post-Test Control Group Design is to be used to collect and analyse data in a quantitative research method. The pre-test and post-test scores of students’ outcomes on the industrial control training lesson utilizing the new TVET training model shall be compared to find out whether the new training model is effective on the students’ learning outcomes.

The data collections were made after completion of each lesson modules, as students are required to submit four assignment reports, namely a reflection paper, project assignment report, problem solving assignment report, and research assignment report, upon completion of individual lessons in module. Also, the student’s self-assessment report is produced. Before the pre-test, the researcher will deliver the module PRx. The first module of PRx, named “Air Compressor Pressure Control” was delivered. In this module, students learn how to control and stabilize the pressure of an air compressor with its control system. Both the control group and the experimental group were delivered the first module “PRx” with the conventional training model using a pre-recorded video lecture, pdf notes, and simulation software for the practical and testing. Before the post-test, the module “POx” was delivered. In the second module of “POx”, students learn about how an air compressor’s stabilized pressure is utilized to charge a car tire. In the post-test, the control group was delivered the second module with the conventional training model, but the experimental group was delivered with the newly designed training model, “Empowered Training Model” as a treatment.

Researcher utilised the LEAP VALUE Rubrics to assess the student’s learning outcomes and the rubrics are (1) Critical Thinking Skill Rubric, (2) Inquiry and Analysis Skill Rubric, (3) Problem Solving Skill Rubric, (4) Creative Thinking Skill Rubric, and (5) Foundation and Skill for Lifelong Learning Rubric. Rhodes and Finley (2013) acknowledged the first validity found at the national level on which college and university campuses which have been accessed by more than seventeen thousand people from more than four thousand institutions and organizations, internationally and domestically since June 2010. Secondly, more staffs and experts are recruited as development experts involved to provide the rubrics with additional content validity.

Data Analysis

The learning outcomes are to be used to analyses with the following procedure.

1. The statistics such as mean, percentage, standard deviation, and variance are to be used to calculate the score of individual skills.

2. The statistics for hypothesis testing accessing new TVET training model and learning outcomes by using sample t-test.

The test results were collected from the Pre-Test and Post-Test of both Control Group and Experimental Group. The scores were presented with five skill areas such as Critical Thinking Skill, Inquiry and Analysis Skill, Problem Solving Skill, Creative Thinking Skill, and Foundation and Skill for Lifelong Learning.

Finding

The test results came from the researcher's Pre-Test and Post-Test to both the Control Group and the Experimental Group. The scores are presented with five skill areas such as Critical Thinking Skill, Inquiry and Analysis Skill, Problem Solving Skill, Creative Thinking Skill, and Foundation and Skill of Lifelong Learning. The post-test score of both groups showed an improvement and the mean improvement between the two groups is different than the individual skills. In comparing the pre-test and the post-test of the Experimental Group, the score improvement can be observed in each and every dependent variable.

Table 1

Mean and standard deviation of test scores for five skill areas for both groups

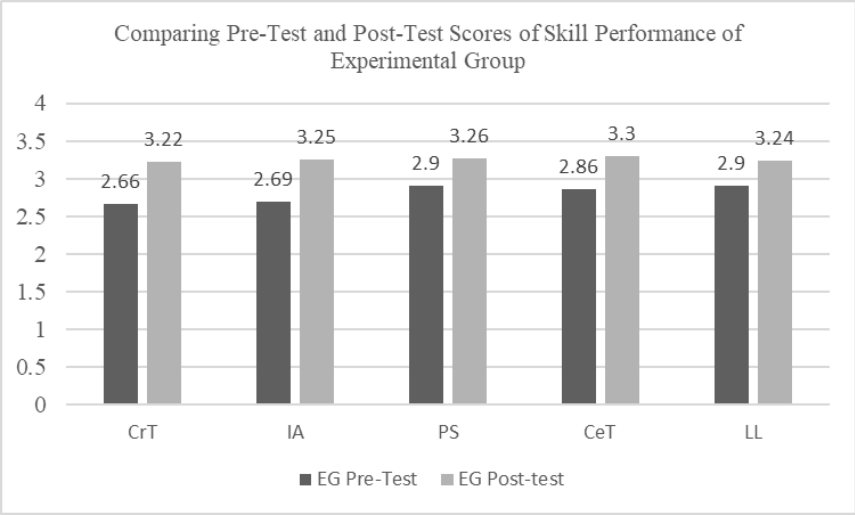
Group	Assessment	Pre-Test		Post-Test	
		Mean	*SD*	Mean	*SD*
Experiment Group (N=10)	Critical Thinking	2.66	0.32	3.22	0.30
	Inquiry and Analysis	2.69	0.30	3.25	0.21
	Problem Solving	2.90	0.28	3.26	0.25
	Creative Thinking	2.86	0.17	3.30	0.21
	Lifelong Learning	2.90	0.39	3.24	0.20
Control Group (N=10)	Critical Thinking	2.70	0.25	2.78	0.22
	Inquiry and Analysis	2.73	0.28	2.8	0.33
	Problem Solving	2.85	0.38	2.94	0.23
	Creative Thinking	2.88	0.32	3.05	0.17
	Lifelong Learning	2.82	0.31	2.96	0.27

Looking at the variances, almost equal variances are observed in the scores of Critical Thinking Skill and Problem-Solving Skill of the Experimental Group. However, a difference in variances of other scores is obviously seen. After the experiment, the data was analyzed using an independent sample t-test and a paired sample *t*-test. The pre-test and post-test of the control group were studied, and an overall accountable improvement was observed. The experimental group treated with an empowered training model showed some improvement on the overall skills in learning automation engineering with the help of remote lab access. The five professional skills of participants of the control group found noticeable improvements in general but those participants did not show an improvement compared between

the pre-test and post-test scores of them individually. The experimental group using an empowered training model showed a statistically significant improvement on overall skills. At the stage of the pre-test, the CTM was applied to test the participants and the scores of the skills were recorded. The post-test was performed with the ETM to the experimental group. For the Critical Thinking Skill, the results showed that the experimental group had a mean score of 2.66 before the experiment, and 3.22 after the experiment. The results of the Inquiry and Analysis Skill showed that the experimental group had a mean score of 2.69 before the experiment and 3.25 after the experiment. In the Problem-Solving Skill's comparison, an improvement is observed with the score improving from 2.90 with the CTM test to 3.26 with the ETM test. Similarly, for the Creative Thinking Skill, and the Foundation and Skill for Lifelong Learning certain improvements were observed. The control group was tested with the conventional training model (CTM) in both stages of the pre-test and post-test. Observing the score results, it was found that there is not much difference between the pre-test and the post-test.

Figure 2

Comparing the pre-test and post-test score of the experimental group.

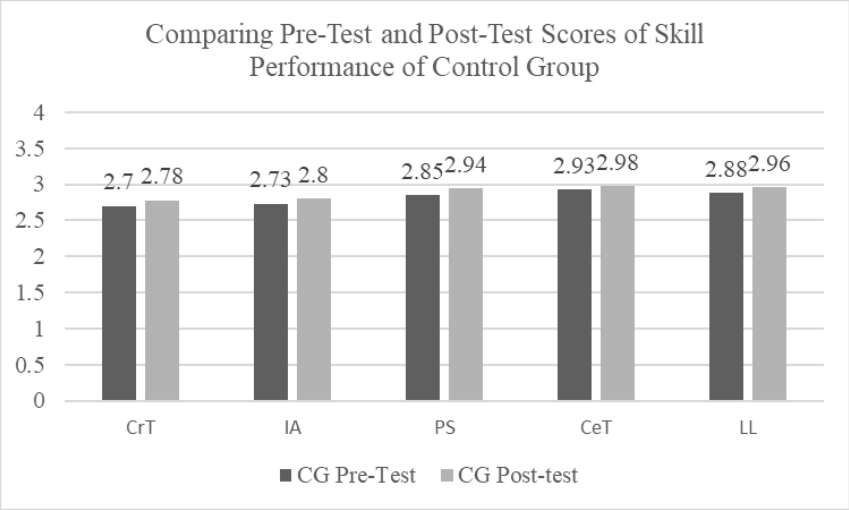


By looking at the critical thinking skill scores, the control group showed a slight improvement in the mean value of 2.7 in the Pre-Test and 2.78 in the post-test. Also, comparing the scores of the Inquiry and the Analysis skill, the control group had a slight improvement from a mean value of 2.73 in the pre-test, to a mean value of 2.80 in the post-test. In the Problem-Solving Skill's comparison, it was observed that the score improved from 2.85 with the CTM test to 2.94 with the CTM test. Similarly, for the Creative Thinking Skill and the Foundation and Skill of Lifelong Learning, slight improvements were found. Even though the control group delivered the training course with a traditional and conventional training method, it was observed that students had made undeniable improvements, but they were little in scale. The experimental group using the empowered training model had a higher improvement than the control

group by using the conventional training model. This research outcomes deliver that the ETM model for online TVET training makes a significant improvement in automation engineering student's learning skills.

Figure 3

Comparing the pre-test and the post-test scores of the control group.



In looking at individual skill improvement, it is also found that there is no skill improvement in the control group's participants between the pre-test and the post-test. In particular, no improvement in the problem-solving skill of the five participants is observed.

Table 2

The control group's participants who had no improvement in skills.

Control group participants	Number of participants with no skill improvement
Critical Thinking Skill	4
Inquiry and Analysis Skill	4
Problem Solving Skill	5
Creative Thinking Skill	2
Foundation and Skill for Lifelong Learning	2

Again, looking at the experimental group, there are three participants who did not show skill improvements. Two participants who have no skill improvement in "Foundation and Skill for Lifelong Learning" are observed. The other participant is under the Problem Solving Skill.

Table 3

The experimental group's participants who have no improvement in skills.

Experimental group participants	Number of participants with no skill improvement
Critical Thinking Skill	0
Inquiry and Analysis Skill	0
Problem Solving Skill	1
Creative Thinking Skill	0
Foundation and Skill for Lifelong Learning	2

As per the research objectives, the research questions were answered as per the outcomes of the score evaluation. For the first question, which asked about the current and existing possession of the skills of automation engineers, it was found that both the control group and the experimental groups demonstrated the skill performance criteria within the upper range of the milestone region. This informed that the current and existing possession of the skills of automation engineers is yet to reach the capstone region and it can be determined that the possession is slightly above the average compared to the full scale score value of 4.

The second research question asked the effectiveness of new TVET training model and the answer is determined by comparing the skill improvement of the control group and the experimental group were made. As per quasi experiment, the independent sample t-test was conducted to compare the levels of improvement of five professional skills, between post-test scores of control group utilized with conventional training and post-test scores of experimental group treated with Empowered training model. The *t*-test was significant, and the result showed that all *p*-values < 0.05. It found significant proof that the new TVET training model improves the student's learning process by measuring with the five skill rubrics.

Table 4

Independent sample t-test comparing post-test mean scores of control group and experimental group.

Pair	Assessment	p-values	Mean Difference
Pair 1	Critical Thinking Skill	0.002	0.430
Pair 2	Inquiry and Analysis Skill	0.002	0.449
Pair 3	Problem Solving Skill	0.009	0.318
Pair 4	Creative Thinking Skill	0.012	0.250
Pair 5	Foundation and Skill for Lifelong Learning	0.021	0.021

In answering the third research question, the paired sample *t*-test was conducted to compare the levels of improvement of five professional skills, between pre-test scores of experimental group utilized with conventional training and post-test scores of experimental group treated with Empowered training model. The *t*-test was significant, and the result showed that all p-values < 0.05. Also, it is obvious that all

five skill scores in post-test were comparatively higher than that of pre-test scores. it found significant proof that the new TVET training model improves the student's outcomes reaching to capstone region.

Table 5

Paired sample t-test comparing pre-test and post-test mean scores of experimental group.

Pair	Assessment	*p*-values	Mean Difference
Pair 1	Critical Thinking Skill	0.002	0.430
Pair 2	Inquiry and Analysis Skill	0.001	0.551
Pair 3	Problem Solving Skill	0.002	0.366
Pair 4	Creative Thinking Skill	0.001	0.433
Pair 5	Foundation and Skill for Lifelong Learning	0.012	0.340

The last research question, which asked about student's perception on the new TVET training model, was answered and the skill evaluation of students was conducted and the results of inquiry and analysis skill, problem solving skill, and creative thinking skill were collected and refer below table of score results. By comparing the pre-test and post-test score results of the above three skills, significant improvements were observed and it was determined that the students' perception is accountable and acceptable.

Table 6

Mean and standard deviation of test scores for three skill areas for experimental group.

Group	Assessment	pre-test		post-test	
		Mean	*SD*	Mean	*SD*
Experiment Group (N=10)	Inquiry and Analysis	2.69	0.3	3.25	0.21
	Problem Solving	2.9	0.28	3.26	0.25
	Creative Thinking	2.86	0.17	3.3	0.21

Conclusion and Discussion

With the help of emerging technologies, the informal education training models are being submerged under distance and online deliveries as the world dramatically changed towards a remote and online oriented nature. Those training in subjects such as IT, arts, science, and literature are not really impacted with respect to the online training method. However, for the TVET training, which really needs practical training demonstration as well as student's hands-on activities, it has a significant effect in that there may be a potential loss of training ground in that not all TVET students may be able to upskill and reskill as they need to do timely throughout their careers. The researcher is motivated to develop a new

TVET training model with technology assisted remote lab facilities, which should be relevant to the current global and technological trends.

In learning engineering, especially in the subject of automation engineering, the conceptual knowledge transfer is the first and foremost activity to be achieved and consecutively, the procedural knowledge transfer is followed. Hiebert (1986) claimed that conceptual knowledge is the foundation of procedural knowledge. In order to achieve more understanding on concepts and theories, student needs to have practical experimentation in which procedural knowledge can be transferred. The conceptual knowledge, which attained from theoretical lectures, supports effective knowledge transferring in acquiring the procedural knowledge while students perform practical experiments. Students should recycle conceptual knowledge and procedural knowledge in learning loop. The results of the data analysis of the experimental and the control group were compared, and the results showed that the experimental group utilizing the empowered TVET training model has a higher score improvement in five professional skill areas compared to the control group utilizing the conventional TVET training model.

This is summarized that the student's learning outcomes in the experimental group were significantly improved with the treatment factors which contributed were (1) teacher's involvement in delivering theories with perceptual teaching, (2) the student's utilization of remote lab which had a significant influence not only on students' performance but also on their perception of learning and satisfaction with remote lab access, (3) teaching with criterion reference through self-paced instruction, (4) the motives of students' self -directed learning plus experiential learning, and (5) ultimately the implementation T-CHAT teaching model with the project based as well as problem based assignments. Lastly, the individual student's cognitive process of capturing and constructing knowledge is fundamental and a biological matter as it is a real and essential process of transferring while triggering such kind of external influences, with predetermined performance criteria based new training model together with well-designed performance criterion-based rubrics, to students by means of effective educational technology.

Recommendations

It is suggested that the following additional research works could be further explored and developed. These are (1) Future research could explore in the other disciplines such as electrical and mechanical engineering and applying the same research methodology to analyze the professional skill improvements. (2) Future research could utilize a sample of senior students from technological colleges and institutes and applying the same research methodology to analyze the improvement of professional skills. And, (3) Future research could utilize with other available tools such as LabVIEW and MATLAB remote lab facilities and applying the same research methodology to analyze the improvement of professional skills.

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