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THE DEVELOPMENT OF INTERACTIVE CASE-BASED SMART THINKING AND INDUSTRIAL PROBLEM-SOLVING STIMULATOR TO ENHANCE TVET STUDENTS' THINKING SKILLS

NURULWAHIDA AZID[1,*], RAFIZAH RAWIAN[1],
SARIMAH SHAIK-ABDULLAH[1], TEE TZE KIONG[2]

[1]School of Education and Modern Languages, University Utara Malaysia,
06010 Sintok, Kedah, Malaysia
[2]Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia,
86400 Parit Raja, Batu Pahat, Johor, Malaysia
*Corresponding Author: nurulwahida@uum.edu.my

Abstract

Thinking skills have a pivotal role in the new global economy and should be a part of the Technical Vocational Education Training (TVET) curriculum. The current curriculum has excelled in preparing students with the technical skills required to participate in heavy and medium industries. Nevertheless, the current economic climate has positioned thinking skills as one of the central issues for prospective employees. Apart from having the technical capacity of manufacturing industry, it is crucial for TVET students to be able to solve problems and make decisions at the workplace. Therefore, this study investigated the development of Smart Thinking and Industrial Problem Solving Stimulator (STIPPS) that was created as a platform for supporting interactive use of industrial cases to enhance TVET students' thinking skills. The stimulator's construction is based on a 4-D model (Define, Design, Develop, and Disseminate) and is using an Android system. Ten experts were appointed to evaluate 18 cases in STIPSS. Mixed method was used to obtain quantitative and qualitative data. There was a high degree of reliability between them. The findings showed that the average measure for Intra-class Correlation Coefficient was .915 with a 95% confidence interval from .812 to .194 (F (9, 153) = 11.71, p < .000). In short, there was a near-perfect agreement among the panel of experts on the 18 industrial cases simulations. The qualitative data, on the other hand, showed that a panel of experts agreed that STIPSS is a good pedagogical tool to stimulate analytical, practical and creative thinking skills among TVET students.

Keywords: Case-based simulation, Curriculum, Industrial problem solving, Thinking skills, TVET.

1. Introduction

Technical and vocational education (TVET) focuses on developing graduate marketability in the working industry [1]. This is in tandem with the 2011-2020 strategic plan outlined by UNESCO-UNEVOC [2], which aims to hone TVET students' skills to be competitive. For instance, Uganda citizens are required to have technical and vocational skills, including primary and secondary school students. This is due to TVET being a field that can provide manpower opportunities for manufacturing industry [2]. Even developing countries, like the Caribbean, have adopted this approach [3].

In today's economic status, students should possess 21st-century skills, which include soft skills, in addition to their own skills and knowledge of the position of employment to increase their employability and value. Therefore, teaching staffs of TVET should equip the students with these skills [4]. The World Health Organization (WHO) listed thinking skills as one of the living skills; this is to ensure individuals' capability to address everyday life challenges [5]. Thinking skills encompass personal management and social skills such as learning how to do, learning to do, learning to be and learning to live [6]. In addition, problem-solving skills should also be implemented in the TVET program as it is often referred to as one of the "best practices" by most employees [7, 8]. Therefore, the development of Smart Thinking and Industrial Problem Solving Stimulator (STIPSS) curriculum aims to enhance analytical, practical and creative thinking. The industrial cases that were included in STIPPS were served to stimulate TVET students' thinking skills to solve problems. Alagaraa and Arthur-Mensah [9] survey report had documented lack of research related to the construction of interactive applications based on multimedia learning for TVET students. In addition, Ismail et al. [10] expressed that the use of textbooks and lecture methods can decrease the desire to learn among TVET students'. Therefore, they implemented the Massive Open Online Course (MOOC) to help increase learning interest among TVET students. In addition, the United Nations Educational Scientific and Cultural Organization (UNESCO) [11] had introduced the VR-head set for mechanical engineering to create virtual learning. Rollings and Adam [12] affirmed that technology integration in teaching and learning TVET help to support students' intellectual skills. However, based on previous studies, there has been no interactive application development that stimulates thinking skills using real industrial cases. All the above studies have put a great emphasis on the important of integrating technology in teaching and learning TVET. However, there are still insufficient studies conducted on interactive application development that stimulates thinking skills using real industrial cases.

2. Conceptualisation of STIPSS

The main purpose of STIPSS development was to assist TVET students to improve their industrial thinking and problem-solving skills (Fig. 1). This application was built using Android-based flash and it could only be accessed through smartphones. This interactive pedagogical tool consisted of 18 cases and 54 questions that were designed based on real industry cases. The content of the application was based on Sternberg [13] Successful Intelligence Theory. This theory discusses three categories of intelligence, namely analytical intelligence, practical intelligence and creative intelligence. These 18 cases were based on (i) Analytical, practical and creative thinking intelligence cases (verbal construct - verbal based cases and solutions), (ii) Analytical, practical and creative thinking intelligence cases (quantitative construct-numerical based cases and solutions) and (iii) Analytical, practical and creative thinking intelligence cases (figural construct-cases and solutions based on figures, logos, symbols, and charts). Its 54 questions were specifically designed to measure students' analytical, practical and creative thinking skills. Students were able to view the total points scored for each category upon the completion of all six respective questions. Positive written reinforcements such as "bravo", "good", and "well done" were displayed together with the scores. In addition, the activities were planned according to several constructive alignments and outcome-based education frameworks. These frameworks measured the learning outcomes, learning activities and feedback automatically.

Figure 1 shows the flowchart for STIPSS users. This flowchart is a step-by-step manual with measurement features that also shows the score for each construct. Each construct comprised of 6 cases and 18 questions that assess a user's analytical, practical and creative thinking skills. Below is the example of one of the cases that were used in the constructs.

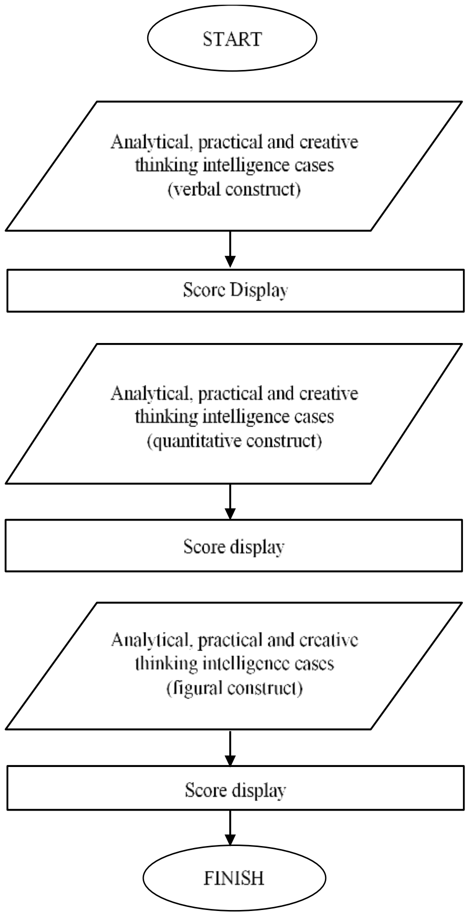


Fig. 1. Flowchart for STIPSS users (13).

Case 1

Mr. Mina is a supervisor working in a construction company and has served for 12 years. He is recognized as an honest person and has excellent work performance. Nevertheless, he has recently learned of the frauds committed by his employer, especially involving foreign workers.

His employer has repeatedly taken advantage of them by not paying their wages fairly. There are also foreign workers who do not have valid work permits and travel documents. Although Mr. Mina knew about it, he could not do anything because he had been warned to shut up.

Question 1.1

Identify the best statement that described the mistakes made by Mr. Mina's employer.

- Focuses on only getting profits.
- Treats foreign workers dishonestly.
- Violates laws involving foreign workers by taking advantage of and threatening the workers.
- Disobeys the Standard Operational Procedure (SOP) for recruiting foreign workers.

Question 1.2

What is the main effect that may occur to Mr. Mina's employer if the situation persists?

- The company will be blacklisted.
- The credibility of his employer will be affected.
- The employer will be subjected to disciplinary actions.
- The employer will be subjected to legal actions.

Question 1.3

Mr. Mina does not want to be terminated. Predict the appropriate action that Mr. Mina can take in order to avoid the risk of being terminated.

- Make a police report at the nearest police station.
- Lodge a complaint with the Labour Department.
- Prosecute his employer immediately.
- Publicize on social sites.

3. STIPSS Development

The Android-based Smart Thinking and Industrial Problem Solving Stimulator (STIPSS) adopted a 4-D model [5, 14]. The procedure is described in Fig. 2.

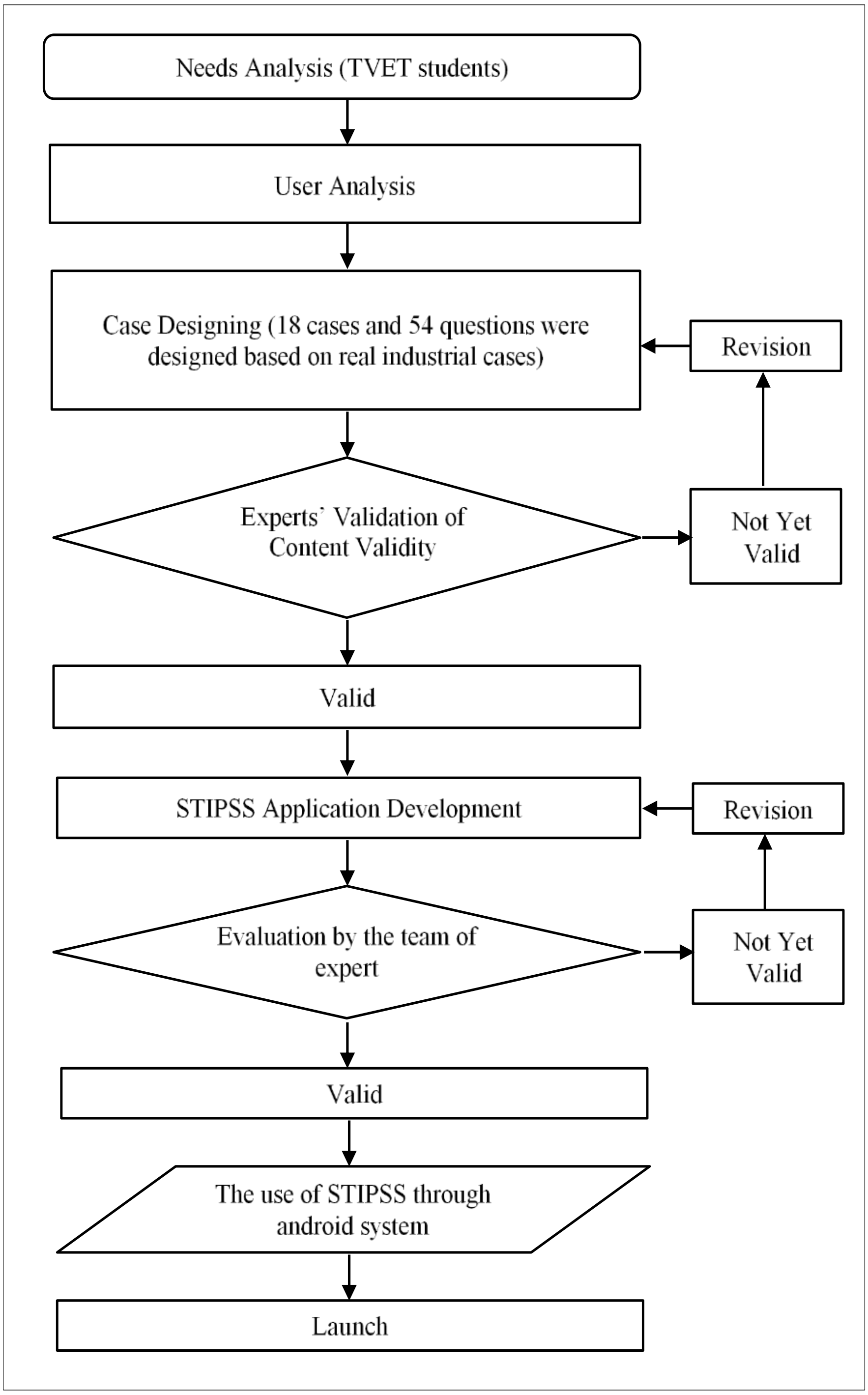


Fig. 2. Smart thinking and industrial problem-solving stimulator development flowchart (13).

Based on Fig. 2, the development of STIPSS involved three phases: Needs analysis, user analysis, and content validity. In the first phase, needs analysis was conducted to record TVET students' thinking skills ability. The 120 students took the Sternberg Triarchic Ability Test (STAT) aimed to test their thinking skills. The test results were categorised into three - low, medium, and high thinking-skills levels. Based on the needs analysis, 67.5% of TVET students (n = 81) possessed low analytical thinking skill, 71.67% (n = 86) had low practical thinking skill and 68.3% (n = 82) demonstrated low-level creative thinking skill. The result showed that TVET students needed tools to stimulate their thinking skills. The conducted needs analysis could also assist researchers in creating possible real-world industrial problems for TVET students to solve.

User analysis was conducted to ensure that the 18 developed industrial cases could stimulate all types of thinking skills and constructs that were stipulated by Sternberg [13] namely the verbal, quantitative, and figural. At this stage, the researchers designed the 18 industrial cases based on real-world problems in the workplace. This phase also required the researchers to examine STIPSS users' (TVET students) background.

Next, STIPPS was evaluated by several experts to justify its content validity and reliability. If the cases had high validity and reliability, the researchers could continue developing STIPSS application. If it was otherwise, the researchers would have to revise and improve all the cases. When the development process for STIPSS was completed, a group of experts evaluated STIPSS for its information, interaction and presentation design (graphics, font, colour, audio, animation, and button). The experts' approval would determine the readiness of launching STIPPS to Android users.

STIPPS was unique in the sense that the 18 industrial cases were real-life cases. The research by Harman et al. [15] has shown that using real-life cases in medicine study could encourage students to think critically. They also observed an increase in students' ability to investigate cases and to solve problems.

The cases employed in STIPSS revolved around workplace sexual harassment, workplace safety practices, corruption, financial irregularities, abuse of power, fraud, work ethics, work procedures and others. The assessment items were organized to measure three types of thinking skills accurately. Individually, the experts checked each case and item and some improvements were made to specific cases based on the experts' comments and suggestions.

Following each assessment item, four choices of responses were provided and constructed based on the principles of good item building [16]. The functionality of the key answer and distractors were carefully assessed by a panel of ten experts. The technical and vocational teachers' opinions were also taken into account. Their feedback was collected to further improve STIPSS in order to ensure that the content of STIPSS was relevant for the vocational students in Malaysia.

In addition to being a meaningful learning resource for students, STIPSS can also be used as a case-oriented pedagogical tool for teachers. Apart from that, the case-based learning method can be applied to other subjects in schools in order to stimulate students' thinking and problem-solving skills.

4. Research Questions

There are four research questions as mentioned below:

4.1. What is the mean value for each industrial case?

4.2. What is the reliability of STIPSS?

4.3. What is the value of the Intraclass Correlation Coefficient (ICC) among the experts?

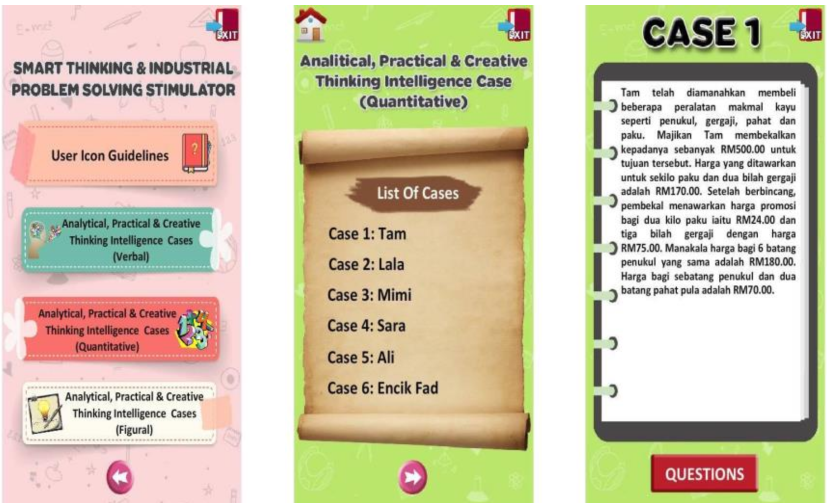
4.4. What are the experts' opinions about STIPSS?

5. Evaluation process by experts

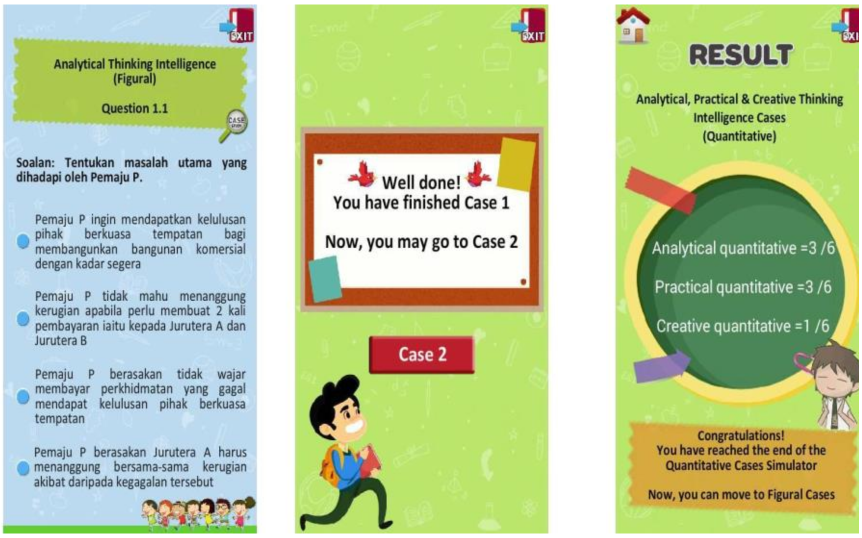
5.1. Panel of experts

The valuation process of STIPSS was conducted in Malaysia in which, a panel of evaluators that consisted of ten academic experts from Malaysian public institutions of higher learning was formed. Their fields of expertise were psychology, curriculum and instruction, linguistic, educational management, instructional design and mathematics education. On top of that, all of them had university teaching experience and had at least 10 years of research experience. The evaluation process took six hours to complete. All the 18 cases and 54 items were discussed and were given ratings between 1 (very weak) to 10 (excellent). The evaluators also provided comments and suggestions through an interview to improve this application.

One of the advantages of STIPSS is that TVET students will be able to identify the three levels of thinking skills. Furthermore, the scores will inform the students about their dominant thinking skills. Based on the students' test scores, TVET educators may diversify their teaching activities and methods. The industrial cases used in the application could also provide an opportunity for students to experience workplace problem-solving situations. Figure 3 is the screenshot of the STIPSS application.



(a) **(b)** **(c)**



(d) **(e)** **(f)**

Fig. 3. Screenshot from STIPSS.

6. Evaluation Results

6.1. Descriptive analysis

Table 1 presents the mean value and standard deviation for each case that had been evaluated by the panel of 10 experts. The mean value ranged from 7.60 to 9.60. Based on the mean values, it was clear that all the 18 industrial cases in STIPSS had good ratings from the experts. This indicated that all the cases were valid to be implemented in the interactive application.

Table 1 Mean value for each case.

Case	Mean	Standard deviation	*N*
Case 1	8.60	.699	10
Case 2	8.30	1.050	10
Case 3	8.90	.738	10
Case 4	9.30	.823	10
Case 5	7.70	2.312	10
Case 6	9.40	.699	10
Case 7	8.70	.675	10
Case 8	7.60	2.503	10
Case 9	9.60	.699	10
Case 10	8.80	1.229	10
Case 11	8.70	.675	10
Case 12	8.90	.738	10
Case 13	8.90	.738	10
Case 14	8.70	.823	10
Case 15	9.20	.632	10
Case 16	9.20	.632	10
Case 17	9.20	.789	10
Case 18	9.40	.699	10

6.2. Reliability of STIPSS

Table 2 represents the reliability of the 18 developed industrial cases. Miller et al. [16] suggested that the reliability index in a test is satisfactory if it is about 0.7. According to Creswell [17], the alpha index value of 0.7 and above is good for data with 10 or more items. Based on the table, the industrial cases are of high reliability.

Table 2. Reliability values for entire cases.

Cronbach's Alpha	Cronbach's alpha based on standardized items	*N* of items
.915	.948	18

6.3. Intraclass Correlation Coefficient (ICC)

A panel of 10 experts was appointed to provide their ratings for STIPSS before it could be used in the later experimental study. There was a high degree of reliability between them (Table 3). The average measure for ICC was .915 with a 95% confidence interval from .812 to .194 (F (9, 153) = 11.71, p < .000). In short, there was a near-perfect agreement among the panel of experts on the 18 industrial case simulations.

Table 3. Intraclass correlation coefficient.

	Infraclass Correlation[b]	95% confidence interval		*F* Test with true value 0			
		Lower bound	Upper bound	Value	*df*1	*df*2	Sig
Single measures	.373[a]	.194	.682	11.717	9	153	.000
Average measures	.915[c]	.812	.975	11.717	9	153	.000

A two-way mixed-effects model where people effects are random and measures effects are fixed.
a. The estimator is the same, whether the interaction effect is present or not.
b. Type C intra-class correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.
This estimate is computed assuming the interaction effect is absent; we were unable to estimate it otherwise.

6.4. Panel of experts' opinions about STIPSS

Below were the opinions expressed by the experts (*E*) on STIPSS:

- "STIPSS is a good pedagogical tool to stimulate analytical, practical and creative thinking skills among TVET students" (*E*1).
- "STIPSS is a good pedagogical tool to stimulate thinking skills, but improvements should be made to the 8th case. For example, the sentence should be clearer, more concise and solid" (*E*4).
- "I love STIPSS because it is carefully and systematically developed, but I propose for the characters' name to be neutral and unbiased to any race" (*E*6).
- "I found STIPSS to be carefully developed and the learning outcomes are always in line with learning activities and interactive assessments" (E7).

- "Overall, STIPPS is successfully constructed based on three types of thinking skills. On top of that, the use of multimedia elements has made STIPSS more interesting. This was done by integrating the latest technologies through android apps"(E8).
- "For me, STIPSS is interesting as a 21st-century pedagogical tool, but researchers need to be careful when building cases. Make sure the sentence structure is simpler, compact and organized for the users to understand the cases" (E10).

7. Discussion

The high standard set for the TVET program requires instructors to develop competency-based world-training programs that can provide students with pivotal knowledge and skills. Apart from that, today's TVET students must also be equipped with 21st-century skills that can help them succeed in life and at work. In addition to current TVET curriculum, these skills hold a significant value in increasing students' employability and life satisfaction. Some of the skills needed in the workplace are thinking skills and problem-solving skills. This agrees with Reeve's study [4], which stated that the TVET program should integrate these skills into the TVET program curriculum.

The findings demonstrated that the lowest mean value (7.60) as shown in the 8th case. This was because the names in the case were closely related to a certain ethnicity. Therefore, the names were changed to avoid biasness. The experts also commented that the sentences were too long and this could lengthen the amount of time needed by the users to fully understand the context of the cases.

Furthermore, the case-based simulation should be made of materials that could train students to analyse data and to have a better grasp of the issues brought forward. The materials should also encourage users to relate current problems with their personal experience and to make swift decisions when presented with untried situations [18-20]. Meanwhile, most cases obtained a mean value of up to 9.60. A high mean value indicated that the majority of the experts gave positive feedbacks that evidence indicated that the cases could be used as a pedagogical tool to enhance students' thinking skills. This finding was in line with Saleewong et al. [21] study in which, their study had shown that case simulation is used in the curriculum as much as 45% in medicine study, 28% in education, 18% in business modules and 9% in science subjects to stimulate student thinking. It is expected that there will be a higher implementation of case-based teaching and learning method among TVET students especially when teachers are exposed to STIPSS. This exposure can increase teachers' awareness of the use of real-life cases as a pedagogical tool.

In addition, based on the ICC's findings, all experts had an overall high level of agreement on the reliability of STIPSS. This was caused by the STIPSS systematic and thorough construction process that was based on the education design. As mentioned by Sharma [18] and Aldoobie [22], the development of an educational design that involves a systematic process can help designers or instructors in shaping and creating attractive, instructional materials efficiently and effectively. An advantage of using a teaching design model is that the design of the lesson will meet the needs of the students and achieve the learning [22]. One of the panel members agreed with this, saying that STIPSS learning outcomes were in line with the interactive learning and assessment activities. Additionally, the majority of the experts affirmed that integrating multimedia element in the development of STIPPS as well as making the application smartphone-compatible had made STIPPS be more appealing, interesting and attractive to the younger generations. In addition, the incorporation of such material had also catered the TVET students' future employability needs [18].

Graphics, text, audio, colours and animation were used to attract students' attention in solving all 18 industrial cases. As mentioned by Jingjit [23], learning with multimedia stimulations such as sounds, graphics and texts can accelerate students could also gain progression. Students' also gain transferrable technological knowledge through the animation; this skill can be used in new situations [25]. Barak et al. [24] stated that animation does not only increase students' motivation but also their students' attention in learning. Besides animation, colours could also influence the learning process and to enhance humans' memory performance.

The integration of android technology in the education system is seen as a new alternative in improving the thinking and problem-solving skills of TVET students. The University of Hawaii had adopted the use of technology in its online learning [26]. Some of the advantages of technology-incorporated learning are students become better at time management, self-discipline and motivated. This corroborates the idea by Duckworth and Seligman [27], who indicated that self-discipline exceeds IQ in predicting student academic performance. In other words, students with disciplined minds are more likely to succeed in an advanced technology environment [28]. For example, in STIPSS, TVET students will have to complete all industrial cases to obtain their scores for each thinking skill.

The use of case stimulation in STIPSS is a unique step to stimulate TVET students to think and solve problems. This agrees is in agreement with Creevy et al. [29] who described the use of cases in teaching have given a new dimension to TVET instructors by promoting thinking skills based on facts of the cases [30]. In addition, STIPPS helps to promote active learning among TVET students. As mentioned by Popil [31], the use of case stimulation can promote active learning, increase problem-solving skills and hone high-level thinking skills. Case analysis is also useful in developing ethical decision-making skills [32].

8. Conclusion

Creativity is part of thinking skills, which is important in problem-solving, especially when students are required to create a new product to solve a situation. Thinking skills involves imagination and the ability to deliver new and unique ideas. Many of today's innovations are the result of human's creativity. Some teaching strategies that promote thinking skills are analysing, comparing and differentiating, defining, explaining, evaluating and solving analytical problems. Some of the common teaching strategies that can promote thinking skills include brainstorming, creating, designing, simulating, imagining, innovating, and solving problems. Furthermore, thinking skills can be applied through hands-on activities in TVET workshops. In addition, the ability to solve problems can be obtained through reading and using inductive and deductive reasoning according to the circumstances. It is recommended that future studies be conducted to ascertain the effectiveness of STIPPS to enhance TVET students' thinking skills. This study confirms that STIPSS had high validity and reliability values hence this pedagogical tool could be used in future experimental studies. The 18 industrial cases in STIPPS had obtained a high mean value that reflected the high validity rate in each industrial case. Investigation on students' views about the use of STIPPS could also shed light on the usability of STIPPS in the long run and ways to improve.

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