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Brain Compatible e-Learning: A Trend for Effective Conceptual Understanding of Physics among TVET Institution Students in Malaysia

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Abstract
This article focuses on brain-compatible e-learning as an initiative to provide effective conceptual understanding of Physics among *Technical and Vocational Educational and Training* (TVET) institutional students in Malaysia. TVET institutions usually focus more on improving students' technical skills to produce skilled graduates to meet the industry needs. Thus, to strengthen the theoretical learning, this study tested the brain-compatible e-learning strategy in improving the Physics conceptual understanding of TVET students. The study respondents are 40 of Manufacturing Engineering Diploma students from a skills institution located in the north of Peninsular Malaysia who are on average of 18 to 25 years old and have an equivalent science achievement background. The study was conducted quantitatively using the Heat and Temperature Conceptual Understanding Test Instrument. The reliability of the instrument was tested by Kuder Richardson 20 coefficient and the value was 0.963. While the validity of the instrument and e-module was also obtained from several Physics' experts and Information Technology lecturer. The data collection was done in six months and was tested through the one-way repeated measure ANOVA test. The results showed that there was insignificant difference between all pairs of mean score. However, there was an increment of post-test mean score compared to pre-test mean score. Therefore, based on the result, it can be concluded that the brain-compatible e-learning was successfully enhanced the Physics conceptual understanding among TVET institution students. However, to give more effective impact in improving the conceptual understanding among TVET institutions students in Malaysia, improvements to the e-module should be made according to students need and practices.

Keywords: TVET Students, Brain Compatible E-learning, Physics Conceptual Understanding

Introduction

Technical and vocational education and training (TVET) education in Malaysia is conducted at various levels of education including secondary schools, polytechnics, community colleges and skills training institutes. Through the Malaysian Education Development Plan 2015-2025 (Higher Education), the government has laid the foundation for TVET to achieve excellence in educational pathways that provide attractive job opportunities and career options as well as prospects for further education. TVET Malaysia underwent a transition aimed at preparing its graduates to meet industry demands and support economic growth (Bakar, 2019). As a result, TVET institutions frequently collaborate closely with relevant industries to ensure that their curricula satisfy the needs of the industry and employers' demands today. Students are exposed to real-world problems while getting practical experience through this collaboration.

To fulfil this desire, the teaching methods used by TVET instructors play an important role in ensuring effective learning in order to produce quality TVET graduates. Conventional teaching methods is less effective in helping students to understand a topic (Yong, 2015; Douglas and Chiu, 2009; Subari et al., 2019). On the other hand, interesting and interactive teaching methods such as through the implementation of experiments, demonstrations and problem-solving sessions can help in strengthening the understanding of concepts in a learning. However, engaging and dynamic teaching strategies, such as using experiments, demonstrations, and problem-solving sessions, can support learning by improving students' comprehension of the material. Farrah and Itmeizeh (2021) mentioned that many educational institutions nationwide have integrated the internet into their teaching and learning procedures since the introduction of online learning. Academic accomplishment tests indicate that brain-based learning has a major influence on pupils' academic achievement in addition to internet-based learning (Kristanto et al., 2021). Amnah et al (2010) claims that gamification projects and elements can be applied to brain-based learning to increase learning efficacy.

Twelve brain-based learning principles were introduced by Caine and Caine (1991); Sousa (1995); Jensen (1998), based on research. These concepts have been divided into three primary brain-compatible elements: calm and sensitivity (*relaxed alertness*), orchestration of various enriched experiences (*orchestrated immersion*), and active processing (*active processing*) such as Figure 1.

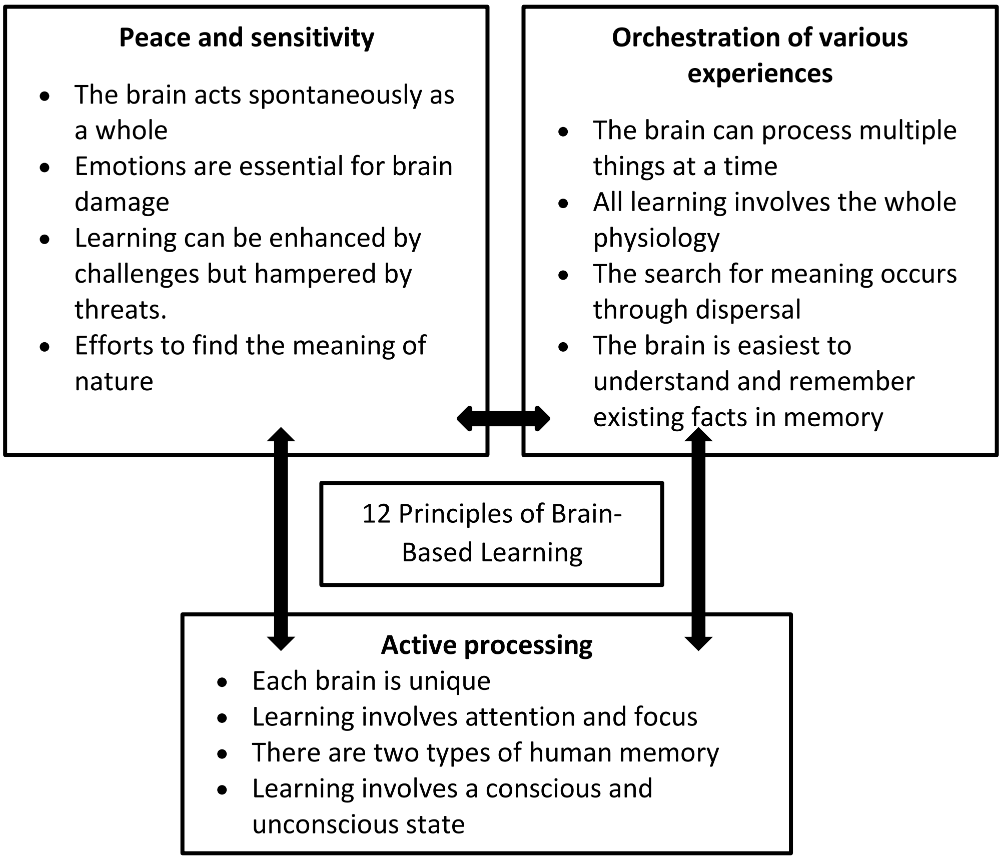

Figure: *Principles of Brain-based Learning*

Conversely, Sperry and Ornstein conducted research on the human brain in the 1960s and 1970s. According to Sperry (1975), the human brain can be divided into the left and right hemispheres, which have different functions and are connected by the corpus callosum, which is accountable for information transmission. Therefore, in an effort to generate more efficient and meaningful learning, this brain-compatible e-learning technique takes into account both left and right brain activity (Figure 2).

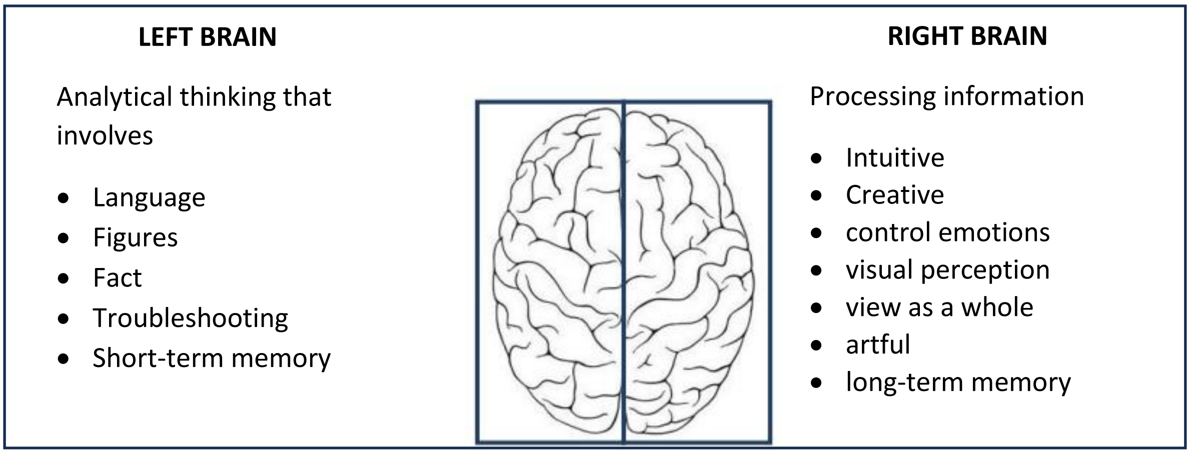

Figure 2: *Right brain and left-brain function (Sperry, 1961)*

Mazlin and Iksan (2018) claims that when new insights into brain function-based learning strategies are gained from research on brain function, teaching and learning undergo a revolution. Gaining knowledge about the functioning of the brain can assist educators and educational institutions in promoting student achievement. According to Kumala et al (2018), brain-based learning involves teaching students how to understand and recall knowledge in a way that is similar to how the brain naturally learns. To ensure student involvement, ongoing efforts are being made to enhance the curriculum's design, the way it is taught, and the atmosphere in which students learn as a whole. This includes the use of elements such as simple module content, interactive media, visual design and even gamification.

To this end, e-learning modules that are compatible with the human brain have been created and evaluated to enhance students' conceptual grasp of physics. Even though practical learning experiences are frequently given priority in TVET programs, the focus on learning application might aid students in connecting the theoretical ideas of physics with real-world situations that they may come into in their technical professions. Integrating the idea of physics with practical disciplines might lead to a more thorough comprehension. For instance, a student enrolled in an automotive field could learn about heat and temperature concepts in relation to vehicle mechanics. Rohayu et al (2021), states that conceptual knowledge refers to students' capacity for effective problem-solving through thought and action. This assertion is corroborated by Taqwa and Taurusi (2021), who assert that mastery of concepts is the primary prerequisite for resolving physics-related issues in daily life and school assignments (Entwistle & Peterson, 2004 in Cai et al., 2021). Therefore, it will be easier for a student to apply the notion of physics in his daily life if he can grasp it adequately.

Literature Review

Students of skill institutions or TVETs are trained to be skilful in new skill areas or to supplement existing skills to boost work capacity and productivity (Timire & Teis, 2019). Learning in skill institutions is an alternative to academic-based learning, concentrating more on technology for career demands (Abu Samah et al., 2022). As technology advances, today's students require reasonable and germane learning approaches to augment their knowledge and conceptual acquaintance (Mazlin & Iksan, 2018). It is imperative since students' learning motivation is boosted by an exciting learning climate due to the presence of elements that can encourage their learning (Filgona et al., 2020).

Based on earlier studies, brain-based learning with gamification positively influences students' academic achievement (Kristanto et al., 2021). Aktekin et al (2018) reported that valuable games are used to obtain high academic performance and inspiration and enhance classroom dynamics. In higher education, the introduction of games in learning has begun to develop. Through the games, one can overcome some of the limitations of traditional face-to-face pedagogy. Furthermore, Banikowski and Mehring (1999) put forward a game-based learning theory that suggests a commitment to performing tasks while playing will further stimulate brain function for active learning. Thus, knowledge retention is boosted by helping the brain to transform information from short-term to long-term memory. Whereas Ofori et al (2020), as cited by Elkhamisy and Wassef (2021), pointed out that using games in learning lets students recall and apply what they have comprehended in an interactive, entertaining and competitive way. Hence, it inspires the interest and probability of students of institution skills in exploring and mastering knowledge.

In addition to gamification, the project elements in e-learning also positively move learning, primarily for skilled institution students. It aligns with Jeon et al (2014), who commented that the study of project-based learning approaches (PBPs) focuses more on engineering. In line with the notion of the 21st century and students of skill institutions, project-based learning (PBP) becomes an alternative approach that delivers students autonomy to analyse challenges in real-world problems (Baharuddin et al., 2009; Mispuah, 2015). Therefore, according to Abdul Malek and Iksan (2014) in the record, Ubaidillah et al (2020), *'Hands-on'* and *'Minds-on'* skills can be developed through a PBP approach where students can translate ideas, mould their minds and capacities, consequently making learning task planning run smoothly and more focused.

Hassan and Osman (2014); Basir et al (2017b) recorded that PBP is an efficacious teaching and facilitation (PdPc) method for upgrading academic achievement and delivering a satisfactory learning impact on students. Furthermore, many analyses have confirmed the advantages of GST over traditional learning methods. Through PBP, the outcomes of group discussions to find solutions to teachers' questions will constitute characteristics such as social skills, meaningful learning, and communication skills (Rubani, 2016). Besides, Nasohah et al (2015) also supported the idea by emphasising that PBP is a more structured and systematic teaching and learning implementation process striving to achieve at least 95 per cent of the learning objectives according to the standards set. Therefore, the researcher considers that e-learning is compatible with the gamification element, and the project is one of the learning strategies that need to be applied in the skill institution to support efforts to intensify the conceptual understanding of Physics students.

Furthermore, Paristiowati et al (2020), in their research about integrating learning strategies, noted that flipped classrooms and brain-based learning stimulate the impact on critical thinking skills in studying Chemistry. The study was performed quantitatively involving 70 randomly selected Grade 11 students. Flipped classroom is a learning strategy that addresses the issue of learning time in the classroom. This is possible since the flipped classroom strategy uses texts, learning videos, and tests given by educators online, and students need to learn the teaching material before attending classes. Hence, it indicates that students outside the classroom learn the topic beforehand at the convenience of the student's place and time. In class, learning is only achieved by discussing and understanding problems. Accordingly, the time for educators to deliver lessons can be saved and used to carry out activities to master understanding of a subject topic (Sobral, 2021). In addition, the study by Paristiowati et al (2020) verified that the use of the flipped classroom and brain-based learning furnishes a distinct learning experience where students study in class and outside of the classroom. Therefore, this can improve the student's critical thinking and understanding skills. Learning strategies in a flipped classroom align with e-modules, where one can implement learning flexibly without time limits and learning locations.

On the other hand, Sitepu et al (2019) conducted a study on the level of conceptual understanding among students of skills studies. The study was accomplished qualitatively at SMK Andalusia 1 Wonosobo on ten respondents with a written test involving six essay questions. The findings established that the conceptual understanding of students' skills still needs to be enhanced and requires priority on conceptual understanding-based learning. In addition, Gurcay and Gulbas (2018) have examined the factors influencing the relationship between learning approaches, logical thinking abilities, and understanding of heat, temperature and internal energy concepts. They conducted the research on 120 students of Anatolian High School quantitatively. The study data confirmed that logical thinking ability is indispensable to enable meaningful learning for students to comprehend heat, temperature, and internal energy concepts better. They also concluded that this method is better than traditional teaching approaches. Accordingly, the researcher considers brain-compatible e-learning a reasonable suggestion for implementing suitable learning methods in TVET institutions. Brain-compatible e-learning is a learning method that considers the best brain function for more effective learning.

Methodology

This quantitative study used a quasi-experimental approach with a time series design for one group of respondents. The absence of a control group did not affect the study findings because the researcher did not analyse the difference in the effects of the intervention by comparing it with conventional methods. Implementing several times postal tests in the time series design is integral in improving the internal validity of the study's results. This ensures that internal validity is protected from factors other than treatment, such as test effects, fatigue and maturity (Gravetter & Forzano, 2018 in Rogers & Revesz, 2020). Table 1 shows the experimental quasi-study procedure with the time series design for one group of study.

Table 1
Time Series Design for One Group

R	O1	X	O2	O3
	Week 1	Week 2-14	Week 15	Week 21

Indicators:

R	=	Experimental Group
O1	=	Pre-test
O2	=	Post-test
O3	=	Advanced post-test
X	=	e-module learning intervention

The sample was 40 students from the Diploma in Engineering Programme of a TVET institution in the North of Peninsular Malaysia selected through purposive sampling techniques. Purposive sampling is required as random sampling of students is impossible because students have been placed according to class and meet specific criteria (Andrade, 2021).

Next, the learning process using e-modules developed using the Google Sites platform based on the ADDIE Learning Model resulting from the brainchild of Dick and Carry (1996). ADDIE stands for Analysis, Design, Development, Implementation and Evaluation. The ADDIE acronym explains that ADDIE implements five levels or elements of interrelated activities to guide the teaching implementation strategy or development of e-learning modules. Figure 3 shows the ADDIE Model as a guide for developing this e-module.

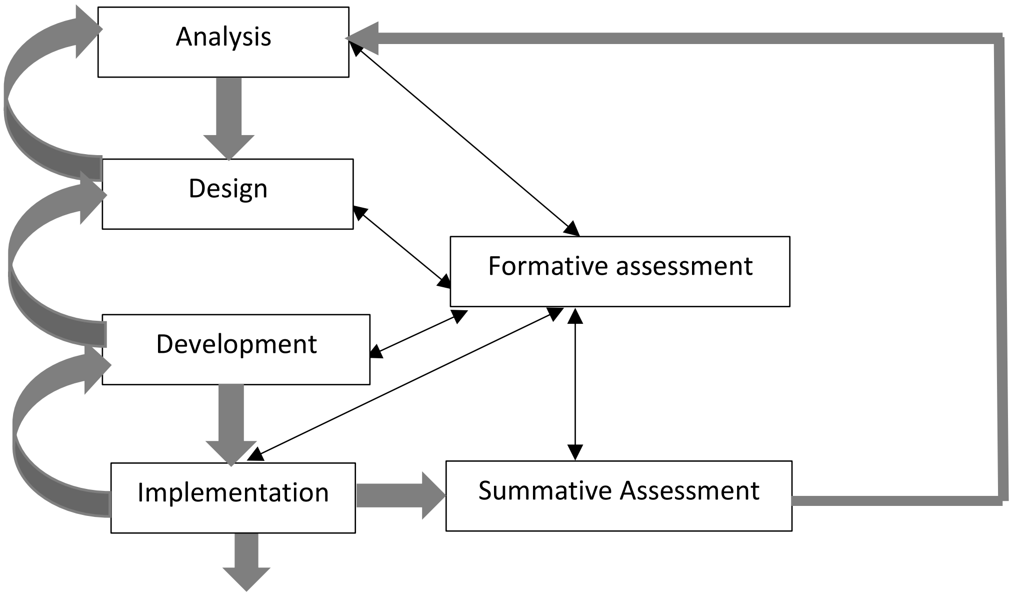

Figure 3: *Process in Designing e-Learning Module Based on ADDIE Theory*

Nonetheless, the development of an e-module adapted from the ADDIE Learning Model included consideration of the six central design phases, which are (i) Requirement Analysis, (ii) Declaring Objectives, (iii) Design media, (iv) Use of Materials / Media; (v) Assessment of Compatibility of Revision and (vi) Production, Implementation and Maintenance. The development of the module prioritised learning guidance using the Principles of Brain-Based Learning by applying elements (i) calm and sensitive conditions, (ii) orchestration of various experiences and (iii) active processing to the target group. The module's development also involved considering visual, audio and kinaesthetic aspects. The gamification element in e-modules was an interactive learning activity, while the project was a hands-on activity appropriate for TVET students. The gamification elements, such as Kahoot, Quizizz, and Word wall, in this e-module aim to improve students' conceptual understanding of physics. In addition, the Padlet application was also used as a medium of reflection for students. Figure 4, Figure 5 and Figure 6 show some of the elements found in the developed e-module.

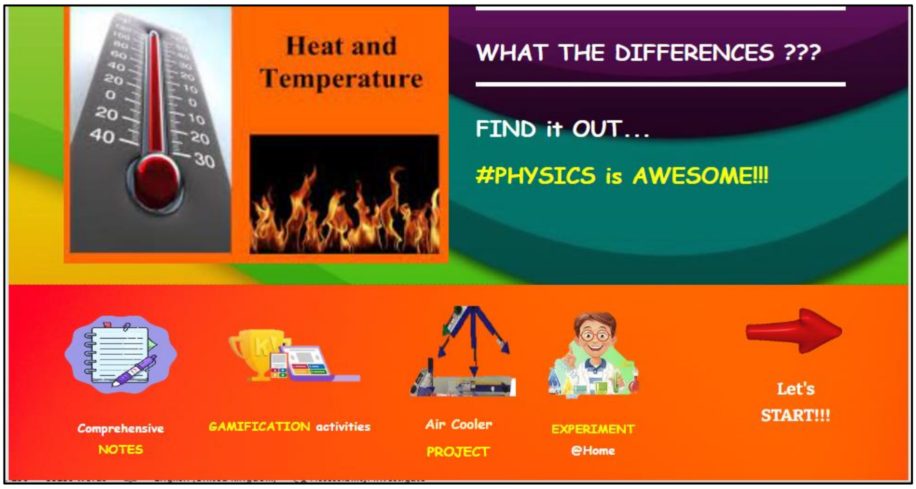

Figure 4: *Partially Content of Visual, Audio and Kinesthetics Elements in Physics e-Module*

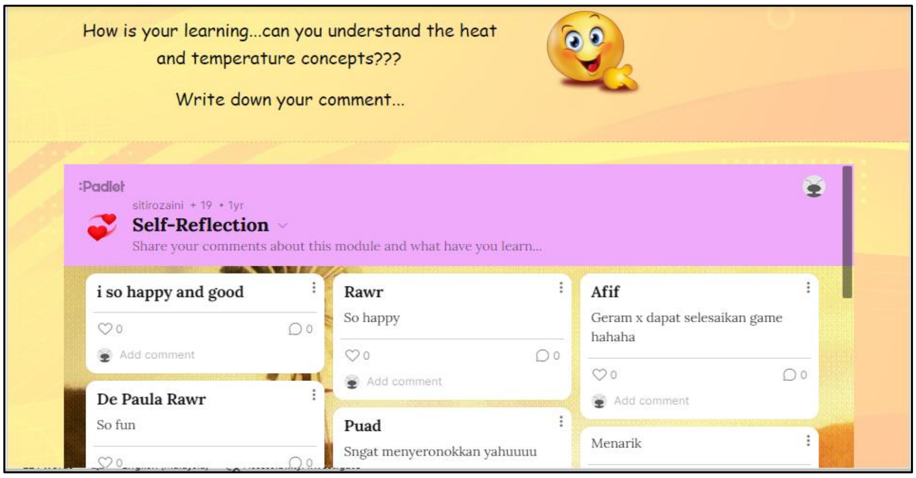

Figure 5: *Padlet Application as A Student Reflection Medium on Physics e-Module*

Figure 6: *Screenshot of the "Safe Me!!" Game on Physics e-Module*

In addition, students were given project assignments requiring them to apply their knowledge of heat and temperature concepts to the Solar Air Conditioning Project. The project preparation process allowed students to collaborate and acquire new creative ideas related to the concepts learned. This strategy encouraged transferring information to students' long-term memory systems. Figure 7 shows a demonstration video of the student project in the e-module. Figure 8 shows the students having a group discussion about the project establishment.

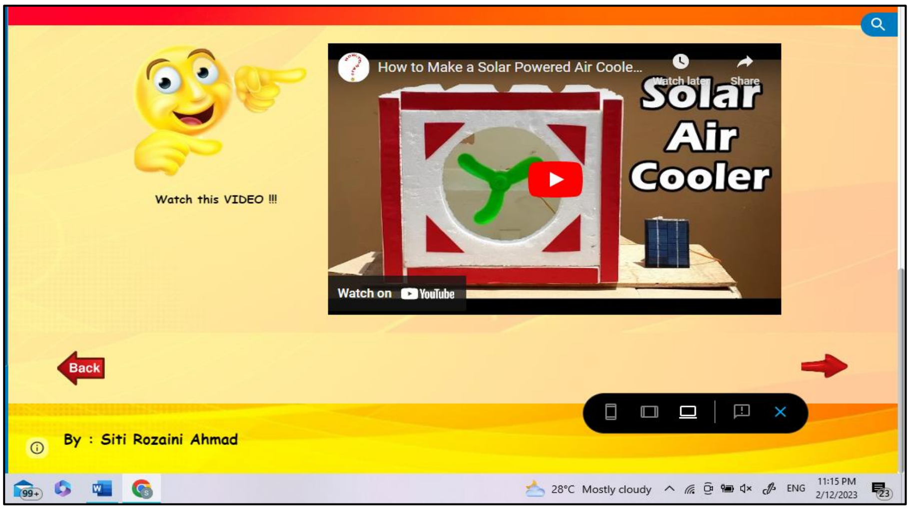

Figure 7: *Screenshot Video of Solar Air Cooler Project Demonstration in Physics e-Module*

Figure 8: *Overview of Project Discussion and Construction Activities by Students*

Next, Figure 9 shows the solar air conditioning project completed by the students. This project applied the concept of heat transfer or thermodynamics, where the cold air moves to warmer areas and produces a cold and cool atmosphere in the surrounding area. Through this project, students were better understood the concept of heat transfer in everyday life.

Figure 9**:** *Overview of the Solar Air Conditioner Project*

During the 6-month data collection period, students were tested with the Physics Conceptual Understanding Test three times: pre-test, post-test and advanced post-test. The collected study data was analysed using IBM SPSS 25 software through one-way repeated measure of the ANOVA test to test the effectiveness of this e-module-based learning.

Results and Discussion

The multivariate test results in Table 2 show that the main effect of test time on conceptual understanding is insignificant (Wilks' Lambda = 0.87, F (2, 38) = 2.75, *p* = .08, eta semi-squared, $\eta^2 = .13$).

Table 2
Multivariate Test Results for Mean Conceptual Understanding Score

Effects		Value	F	Degrees of Hypothetical Freedom	Degrees of Freedom of Error	Sig.	Partial Eta squared
Conceptual Understanding	Wilks' Lambda	.87	2.75	2.00	38.00	.08	.13

According to Cohen (1988), the eta squared value of .01 is small, .06 is medium, and .14 has a significant impact. The multivariate testing results with the semi-squared eta value $\eta 2 = .13$ obtained indicated that the effect of test time on conceptual understanding is substantial.

Univariate test findings for the internal variable of the subject supported the results of the multivariate test. The selection of the appropriate univariate test should first look at the assumption of sphericity by using the results of Mauchly’s Sphericity test. The result of Mauchly*’s* Sphericity test (Table 3) displaying values *p* = .84, i.e., greater than .05, indicated that the assumption of the matrix sphericity of the covariance is comply (Howell, 2008 as cited by Ahmad et al., 2021).

Table 3
Mauchly Conceptual Understanding Sphere Test Results

Impact over a period of time	Mauchly's W	Khi squared	Degrees of Freedom	Sig.	Epsilon Greenhouse Geisser/Huynh Feldt
Conceptual Understanding	.99	0.36	2	.84	0.99 / 1.00

The results of the univariate test based on the assumption of sphericity (as in Table 4) demonstrated that the main effect of the test time was insignificant for the conceptual comprehension test on e-module (F = 2.56, *p = .08*; $\eta 2 = .06$). The results of the multivariate test (Table 2) and the univariate test (Table 4) were insignificant and this showed that none pair test that had a considerable difference in the mean score of the conceptual understanding test. However, the Bonferroni test was conducted to confirm this result.

Table 4
Univariate Test Results for Conceptual Understanding Mean Score

Resources		Total squared type III	Degrees of Freedom	Mean Square	F	Sig.	Partial Eta squared
Conceptual Understanding	Assumption of Sphericity Complied with	48.75	2	24.38	2.56	.08	.06

Based on the results of the Bonferroni test (Table 5) it clearly showed that there is insignificant difference ($p > .05$) is present in all pairs of mean scores:

i. pre-test mean score with post-test mean score of conceptual understanding.
ii. pre-test mean score with an advanced post-test mean score of conceptual understanding.
iii. post-test mean scores with advanced post-test mean score of conceptual understanding.

The mean differences in these scores can be observed more clearly on the estimated marginal means obtained in Table 6.

Table 5
Bonferroni Test Results of Conceptual Understanding

	Conceptual Understanding	Mean Difference	Error	Sig.*
Pre-Test	Post-Test	-1.50	0.67	.09
	Advanced Post-Test	-0.38	0.72	1.00
Post-Test	Pre-Test	1.50	0.67	.09
	Advanced Post-Test	1.13	0.68	.31
Advanced Post-Test	Pre-Test	0.38	0.72	1.00
	Post-Test	-1.13	0.68	.31

Based on *estimated marginal means*
*. The mean difference is significant at level $p = .05$

In addition, one can note that the post-test mean score of conceptual understanding, which was 11.03, was reduced to 9.90 for the advanced post-test mean score of conceptual understanding (Table 6). Nevertheless, when observed, the results of the Bonferroni test (Table 5) authenticated that the mean pair of these scores had an insignificant difference. These results confirmed a retention in conceptual understanding after six weeks of intervention ending.

Table 6
Results Estimated Marginal Means Conceptual Understanding

Conceptual Understanding	Min	Error	95% Confidence Interval	
			Lower Limit	Upper Limit
Pre-Test	9.53	0.52	8.47	10.58
Post-Test	11.03	0.61	9.80	12.25
Advanced Post-Test	9.90	0.55	8.78	11.02

Overall, the results of the one-way ANOVA test of repeated measurements of this study data established an advancement and retention in students' conceptual understanding based on the mean increase in post-test scores after the intervention and retention in the mean of advanced post-test scores after six weeks of intervention ended. Retention in conceptual understanding after six weeks of the intervention ended implied that the mean increase in the score was due to the effect of the intervention. Accordingly, it proved that this brain-compatible e-module could improve the conceptual understanding of physics of TVET institution students.

Contribution

A brain-based learning approach can positively impact many, especially educators and students. Through the developed brain-compatible e-module, educators can convey a concept more clearly and effectively, and students can comprehend and master it more effortlessly. It will enrich the culture of knowledge among educators and students, further improving the quality of the teaching and learning approach.

In addition, the e-module developed based on this brain-based learning approach is an innovation in learning in TVET institutions, especially for theory-based learning courses. TVET institutions prioritise technical skills rather than generic skills such as Physics and Mathematics (Daryono & Rochmadi, 2020). Through this e-module, educators can apply a more stimulating learning culture outside the classroom, making the TVET institution students more engaged in learning theoretical courses.

Besides, the efficacy of e-module-based learning is due to its more flexible use without time and place limitations. Hence, this empowers students to study anywhere and anytime. Furthermore, this e-module is especially practical for TVET institution students as they hold limited learning time in class for theoretical courses. Typically, a longer time is allocated for hands-on learning of core courses. Nevertheless, through this e-module-based learning approach, students can revise a lesson to fathom and master Physics concepts.

Conclusion and Implications

Based on the results of this analysis, brain-compatible e-modules that applied gamification elements and projects could improve the conceptual understanding of Physics among TVET students. The researcher developed this brain-based learning approach based on the principles of the brain-based learning approach (12 principles), which were classified into three elements: a calm and sensitive state, a variety of enriched experiences, and active processing. Based on these elements, the e-module developed based on ADDIE Theory could spark interest and satisfy the needs of students to explore the module. Consequently, this lets students master a well-learned concept. Educators can modify and improve this e-module according to the course.

Further, to attend learning using this e-module, institutions should consider amplifying the internet network strength on campus so that students can access the e-module easily. In addition, educators need to attend In-Service Training to master teaching skills through e-learning methods. It is to produce more educators skilled in the brain-based and online learning approaches. Ultimately, this dynamic and more student-centred learning method will make students more imaginative and ingenious. This makes TVET graduates more open-minded and carry various technical and generic skills. Ergo, these measures will guarantee that graduates of TVET institutions are consistently relevant and welcomed by the industry.

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