Need Analysis for Development of Technology-Based Pedagogical Module for 3D Geometry: A Case Study in Malaysia

Analisis Keperluan Pembangunan Modul Pedagogi Geometri 3D Berasaskan Teknologi untuk Meningkatkan Kemahiran Visual Spatial

Rosnanie Ali[1], Faridah Hanim Yahya[2*], Noor Insyiraah Abu Bakar[3], Zainonie Ma'arof[4], Abdussakir[5]

[1]SMK Lawas, K.M 1.6, Jalan Trusan, 98850 Lawas, Sarawak, Malaysia
[2,3]Faculty of Human Development, Universiti Pendidikan Sultan Idris,
35900 Tanjung Malim, Perak, Malaysia
[4]SMK Seri Mahkota, Km 16, Jln Gambang, 25150 Kuantan, Pahang, Malaysia
[5]Department of Mathematics Education, Faculty of Tarbiya and Teacher Training
Universitas Islam Negeri Maulana Malik Ibrahim Malang

*Corresponding author: faridahhanim@fpm.upsi.edu.my

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ABSTRACT

The poor achievement of students in Mathematics, especially in 3D Geometry is due to their low Visual Spatial Skills. Relative research shows that a variety of teaching methods including hands-on activities with the application of technology can help to improve Visual Spatial Skills. Therefore, teachers need complete guidelines of suitable activities and technologies to be applied in their teachings. The purpose of this study is to identify the need for the development of a technology-based 3D Geometry pedagogical module to improve students' skills based on teachers' perceptions. This study applied a review method and used a questionnaire as the study instrument. The study sample consisted of 74 secondary school Mathematics teachers serving in Sarawak. In addition, the results show that there is a significant difference in performance expectancy and effort expectancy between teachers who served less than 15 years and more than 15 years. The mean score for these two of expectancies also shows a very high interpretation. Therefore, a teaching module for 3D should be designed to increase students' performance in Geometry.

Keywords: 3D geometry, technology, visual spatial skills, Mathematics, pedagogical module, teachers

ABSTRAK

Pencapaian pelajar yang membimbangkan dalam Matematik terutamanya di dalam bidang Geometri 3D adalah disebabkan Kemahiran Visual Spatial yang rendah. Kajian-kajian lepas menunjukkan kepelbagaian kaedah pengajaran guru yang terdiri daripada aktiviti-aktiviti seperti menjalankan aktiviti secara hands-on dengan pengaplikasian teknologi dapat membantu meningkatkan Kemahiran Visual Spatial. Oleh itu, guru memerlukan garis panduan yang lengkap berkaitan aktiviti serta teknologi yang sesuai diaplikasikan dalam pengajaran mereka. Tujuan kajian ini adalah untuk mengenal pasti keperluan pembangunan modul pedagogi Geometri 3D berasaskan teknologi untuk meningkatkan kemahiran pelajar daripada persepsi guru. Kajian ini menggunakan

kaedah tinjauan dan menggunakan soal selidik sebagai instrument kajian. Sampel kajian terdiri daripada 74 orang guru Matematik sekolah menengah yang bertugas di Sarawak. Dapatan kajian menunjukkan sebahagian besar guru (93.2%) bersetuju untuk membangunkan modul pedagogi berasaskan teknologi untuk meningkatkan kemahiran bagi topik Geometri 3D. Selain itu, dapatan juga menunjukkan terdapat perbezaan yang signifikan terhadap jangkaan prestasi dan jangkaan usaha di antara guru yang berkhidmat kurang daripada 15 tahun dan lebih daripada 15 tahun. Purata min bagi kedua-dua jangkaan ini juga menunjukkan inteprestasi yang sangat tinggi. Oleh itu, modul pedagogi geometri 3D perlu dibangunkan bagi meningkatkan pencapaian pelajar dalam geometri.

***Kata kunci**: geometri 3D, teknologi, kemahiran visual spatial, matematik, modul pedagogi, guru*

INTRODUCTION

Mathematics is one of the subjects that is given priority by the Ministry of Education (MOE). This is because, among the agenda in the first agenda of Malaysian Education Blueprint 2013-2025 is to benchmark the learning of Language, Mathematics, and Science with international standards. In connection with that, Malaysia has participated in the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA). Malaysia's participation in TIMSS and PISA is to make a comparison of Malaysia's achievements with other countries in international rankings. This is in sync with Malaysia's aspiration to be in the top third in international assessments such as TIMSS and PISA within 15 years. Therefore, TIMSS and PISA have been used as benchmarks that become the reference in deciding the level of achievement of Malaysian students in Mathematics and Science subjects compared to other countries in the international rankings. In fact, this also helps in carrying out improvements in the education system.

Figure 1 shows the inconsistent average Mathematics scores among Malaysian students since Malaysia's participation in 1999 to 2019. The report shows a drop of 4 points lower (461) in 2019 compared to the achievement in 2015 (465). This is the second-lowest achievement when compared to the scores obtained since Malaysia's participation in TIMSS in 1999. In fact, this average score is also below the average international score that has been established at 500.

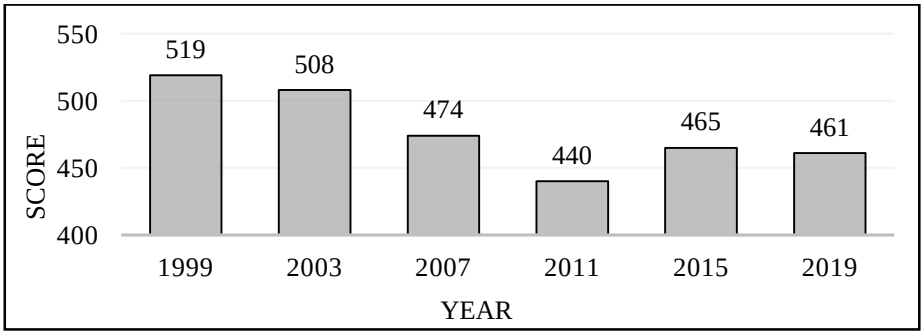

Figure 1: Malaysian average score in Mathematics TIMSS 1999-2019

Geometry is one of the domains of content which is assessed in TIMSS. Although the TIMSS 2019 report states that the content domain of the geometry topic scored the highest at 466 compared to the other domains, such as numbers, algebra, and probability, the average score is still at a moderate level compared to the national level benchmarks. The TIMSS report also stated the weakness of students in solving 3D Geometry topic questions at a high level where students need to make comparisons for a 2D shape that is converted to a 3D shape. The results showed that only 42.2% of students managed to solve the question correctly. This problem is similar to the research of Salleh & Salleh (2020). which states that the topic of 3D Geometry shapes is still a problematic topic for most students.

The ability of students to solve questions for this Geometry domain proves their weakness in mastering Geometry concepts (Wahab et al., 2018). The study of Abdullah et al. (2022) and Yahya et al. (2021) stated that the factors that contribute to the weakness and achievement of students in 3D Geometry are due to Visual Spatial Skills (VSS). VSS is the ability to rotate mentally, the ability to

describe mentally, the ability to transform mentally, and the ability to cut mentally (Bertoline & Weibe, 2007; Bertoline, 1998; Tsutsumi, 2004). VSS is also one of the important features of Mathematics education, especially for 3D Geometry topics. This is because the difficulty of learning 3D Geometry is often related to the weakness of VSS (Wahab et al, 2018). In fact, concepts in Geometry generally involve shapes and diagrams which require visualization skills (Ngirishi & Bansilal, 2019).

This failure is also influenced by the learning methods applied by teachers because the learning strategies implemented by teachers in the classroom will affect students in learning Geometry (Valtonen, Sointu, Kukkonen, Kontkanen, Lambert & Makitalo, 2017). Facing the technological flow in this 21st century, technological facilities play an important role in the effort to make the effectiveness of learning (Wahab, Ismail, Ismail & Majid, 2020). According to MOE (2017), Information and Communication Technology (ICT) can also be integrated according to the suitability of the topic to be studied in helping to improve students' understanding of the subject content. The various methods of teaching that integrate technology are important in helping to improve student understanding and achievement apart from encouraging student interest in learning Mathematics. This is because, the combination of teaching practices of Mathematics teachers with ICT is also suggested to improve student performance (Sarkar, Kadam & Pillai, 2020).

Unified Theory of Acceptance and Use of Technology (UTAUT)

The UTAUT model is a model that has been developed by Venkatesh et al. (2003). This model aims to explain the intention and behavior of individuals to use an IT system. In addition, this model consists of four main constructs, namely performance expectations, effort expectations, social influence, and convenience conditions. These four constructs are determinants directly related to usage intention and level of performance (Siraj, Abdullah & Rozkee, 2020). Therefore, the pedagogy module that will be developed is based on the UTAUT model.

In this study, performance expectancy is the component used to measure the level of teachers' confidence in which technology helps them in improving their performance or teaching strategies in teaching Mathematics related to the title of 3D Geometry. This is because the use of technology is expected to help teachers in designing teaching strategies that involve teaching methods and activities. Meanwhile, effort expectancy refers to the level of ease of use of technology with self-efficacy. Venkatesh et al. (2003) defined self-efficacy as a powerful determinant of individual behavior for the actual use of technology or intention to use technology.

Furthermore, social influence refers to the extent to which an individual trusts people who are important to him or her to use technology. Thus, in this study social influence implies that a teacher trusts individuals who are important to him/her in teaching such as colleagues. In addition, the state of convenience is a measurement of an individual's level of trust for the technical and organizational infrastructure that exists in supporting the use of technology in teacher teaching.

OBJECTIVE AND RESEARCH QUESTION

The objective of this study is to identify the need for the development of a technology-based pedagogy module for Spatial Visual Proficiency in the topic of 3D Geometry based on teacher perceptions. Therefore, a needs analysis was carried out to answer the following study questions:

1. What is the level of need for the development of a technology-based pedagogy module for VSS in the 3D Geometry topic based on teachers' perceptions?
2. What is the performance expectancy and effort expectancy of teachers to use technology-based pedagogy modules for VSS in 3D Geometry topics?
3. Is there a significant difference in the level of acceptance dan intention to use technology between teachers with a period of service below 15 years and more than 15 years?

RESEARCH HYPOTHESIS

H_1: There is a significant difference in the mean score for performance expectancy between teachers with service periods below 15 years and more than 15 years.
H_2: There is a significant difference in the mean score for effort expectancy between teachers with service periods below 15 years and more than 15 years.
H_3: There is a significant difference in the mean score for attitude towards using of technology between teachers with service periods below 15 years and more than 15 years.
H_4: There is a significant difference in the mean score for social influence between teachers with service periods below 15 years and more than 15 years.
H_5: There is a significant difference in the mean score for facilitating conditions between teachers with service periods below 15 years and more than 15 years.
H_6: There is a significant difference in the mean score for self-efficacy between teachers with service periods below 15 years and more than 15 years.
H_7: There is a significant difference in the mean score for behavioral intention between teachers with service periods below 15 years and more than 15 years.

RESEARCH METHODOLOGY

This study is using the Design and Development Research (DDR) approach based on Richey and Klein (2007). This DDR approach includes three phases: needs analysis (Phase I), design and development (Phase II), and assessment (Phase III). However, this study will only involve a needs analysis in order to obtain information regarding the level of need for the development of a technology-based pedagogy module for Visual Spatial Skills in 3D Geometry. Needs analysis is one of the methods used to identify the gap between the current situation and the desired situation (Kaufman & English, 1957; Pratt, 1994; Witkin, 1997).

The needs analysis phase involved as many as 74 (n = 74) Mathematics teachers who teach in secondary schools in Betong Division at Sarawak. The Betong division includes 2 areas, which are the Saratok area and the Betong area, which consists of 13 secondary schools in total. Table 1 below shows the number of respondents involved for each school. This sample consists of 37 teachers who have served under 15 years and 37 over 15 years. The sample was determined using a purposive sampling technique. Respondents involved have been identified and are representative of the population to be studied (Richey & Klein, 2007; Noraini Idris, 2009). Therefore, the selection of these Mathematics teachers was based on the justification that they have the same characteristics as Secondary school Mathematics teachers in Malaysia.

Table 1: Number of respondents based on school

School	No. of respondent
1. Sekolah Menengah Kebangsaan (BM) Saratok	6
2. Sekolah Menengah Kebangsaan Agama Saratok	5
3. Sekolah Menengah Kebangsaan Kabong	6
4. Sekolah Menengah Kebangsaan Kalaka	5
5. Sekolah Menengah Kebangsaan Saratok	6
6. Sekolah Menengah Kebangsaan Pusa	7
7. Sekolah Menengah Kebangsaan Spaoh	4
8. Sekolah Menengah Kebangsaan Ulu Layar	6
9. Sekolah Menengah Kebangsaan Beladin	6

continued

10	Sekolah Menengah Kebangsaan Saribas	7
11.	Sekolah Menengah Kebangsaan Datuk Patinggi Kedit	6
12.	Sekolah Menengah Kebangsaan St. Augustine	5
13.	Kolej Vokasional Betong	5

The study for the needs analysis phase was carried out through a survey method, which is using the needs analysis survey questionnaire instrument. This survey questionnaire consisted of 30 questions. In addition, this research question is divided into five sections, A (Demographic Information), B (Teachers' Perceptions Regarding the Practice of Teaching Methods), C (Teachers' Perceptions of KVS in Teaching), D (Teachers' Acceptance and Usability of Technology), and E (The Need to Develop a Technology-Based Pedagogy Module for VSS for 3D Geometry). All items in Sections B, C, and D used a 7-point Likert scale: 1 (Strongly Disagree), 2 (Disagree), 3 (Somewhat Disagree), 4 (Neutral), 5 (Somewhat Agree), 6 (Agree), and 7 (Strongly Agree).

A total of three Language, Technology, and Mathematics experts who have served more than 5 years in their respective fields were involved to validate the instrument. The study instrument was assessed from the aspect of content validity to ensure that the items in the questionnaire were aligned with the study questions. In fact, their comments and suggestions were also used to make improvements to the questionnaire. In addition, a pilot study was also carried out to test the reliability of the instrument. Through this pilot study, the reviewer was able to improve the questions that were not suitable for the research question. Therefore, the pilot study was conducted on 30 respondents consisting of secondary school Mathematics teachers. The results of the reliability test analysis of the pilot data have shown a high Cronbach's alpha value of 0.97 which indicates a "very good" correlation strength. Thus, the 30 teachers involved with the pilot test will not be involved in the actual study for the analysis phase.

RESULTS AND DISCUSSION

A. Demographic

Table 2 shows the demographic information of the sample. A total of 74 teachers have taken part as respondents in the needs analysis study. As for the level of education, as many as 59 people (79.7%) have a diploma, 14 people (18.9%) have a bachelor's degree and only 1 of them (1.4%) have a diploma. In addition, 37 people (50.0%) are teachers who have served 15 years and under, and 37 people (50.0%) have served more than 15 years. However, in ICT proficiency level, only 1 of them (1.4%) is very good, 22 of them (29.7%) are good, 47 of them (63.5%) are moderate and 4 of them (5.4%) are poor.

Table 2: Respondent demographic information (n=74)

Item	Details	Frequency	Percentage (%)
Level of Education	Diploma	1	1.4
	Degree	59	79.7
	Masters	14	18.9
Period of service in Education	1 – 5 years	12	16.2
	6 – 10 years	9	12.2
	11 – 15 years	16	21.6
	16 – 20 years	16	21.6
	More than 20 years	21	28.4

continued

Lavel of skills using ICT	Very Poor	0	0.0
	Poor	4	5.4
	Moderate	47	63.5
	Good	22	29.7
	Very Good	1	1.4

B. Research Question 1

What is the level of need for the development of a technology-based pedagogy module for VSS in the 3D Geometry topic based on teachers' perceptions?

Table 3 shows that most teachers (54.1%) have referred to any pedagogy modules for improving teaching of the 3D Geometry topics in secondary schools. In addition, respectively (50.0%) have referred and never referred to any technology modules for improving the teaching of 3D Geometry topics in secondary schools. In addition, most teachers (67.6%) had never heard of technology-based 3D geometry pedagogy modules to improve VSS. Therefore, most of them (93.2%) considered that there is a need to develop a technology-based pedagogical module to improve VSS for 3D Geometry topics. In fact, the study of Musa et al, (2022) which encourages the development of modules that cover the field of Mathematics learning that will be a guide for teachers in learning. However, the majority of teachers (82.4%) stated that they did not have enough materials to use technology-based pedagogical modules to improve VSS for 3D Geometry topics at school. This is aligned with the TIMSS (2019) report which states that the lack of resources such as computer software or applications for Mathematics learning has impacted teaching.

Table 3: The needs to develop a technology-based pedagogical module

Details		Frequency	Percent (%)
1. Have you ever referred to any pedagogical modules for improving teaching of 3D Geometry topics in secondary schools?	Yes	40	54.1
	No	34	45.9
2. Have you ever referred to any technology modules for improving teaching of 3D Geometry topics in secondary schools?	Yes	37	50.0
	No	37	50.0
3. Have you ever heard of a technology-based pedagogical module for 3D geometry topics to improve VSS?	Yes	24	32.4
	No	50	67.6
4. Do you feel the need to develop a technology-based pedagogical module for the topic of 3D Geometry to improve VSS?	Yes	69	93.2
	No	5	6.8
5. Do you have enough materials to use technology-based pedagogy modules for 3D Geometry topics to improve VSS in schools?	Yes	13	17.6
	No	61	82.4

C. Research Question 2

What is the performance expectancy and effort expectancy of teachers to use technology-based pedagogy modules for VSS in 3D Geometry topics?

Table 4 shows the interpretation of mean that will be applied to answer review questions 2 and 3. Interpretation of mean is determined based on range on scale from 1.00 to 2.20 which is very low interpretation until 5.81 to 7.00 which is very high interpretation (Ahmad, Awang & Ahmad, 2017).

Table 4: Interpretation of mean

Range of Scale	Interpretation of Mean
1.00 – 2.20	Very Low
2.21- 3.40	Low
3.41-4.60	Moderate
4.61-5.80	High
5.81-7.00	Very High

Performance expectancy is used to measure teachers' confidence level whether technology helps them improve their performance or teaching strategies in Mathematics teaching that are related to the 3D Geometry topic (Venkatesh, 2003). Based on Table 5 the highest mean score is 6.04 (SD=0.691) for the item "using technology to improve my teaching quality for 3D Geometry topics". Whereas, the item that has the lowest mean score is the item “I feel that teaching Mathematics for 3D Geometry topics through the use of technology is useful in my teaching” with a mean score of 5.89 (SD=0.694). Overall, table 3 shows that all items have high min scores with an average min score of 5.98 (SD=0.687). Therefore, this clearly shows that teachers’ performance expectations are very high for teaching 3D Geometry topics with technology. The findings of this study are agreed by the study of Morchid (2019) which states that learning that applies the use of technology such as the use of mobile phones is indeed helpful in learning. In fact, the findings of this study also show a very high performance expectation of teachers to use technology in learning. In addition, the results of the study Wijaya, T. T. et al. (2022) which also states that Indonesian Mathematics teachers choose to use digital textbooks because they think that such technology-based materials help in improving the quality of learning in the classroom.

Table 5: Mean score for perfomance expentancy

	Details	SD	Mean	Interpretation
1.	I feel that teaching Mathematics for 3D Geometry topics through the use of technology is useful in my teaching	0.694	5.89	Very High
2.	The use of technology in teaching Mathematics for 3D Geometry topics helps to facilitate the teaching and learning process is more effective.	0.692	6.01	Very High
3.	The application of technology has been able to improve the quality of my teaching for the topic of 3D Geometry.	0.691	6.04	Very High
4.	My teaching performance will be better in Mathematics for 3D Geometry topics by using technology.	0.672	5.99	Very High
	Average	0.687	5.98	Very High

In addition, Venkatesh et al. (2003) defines effort expectation as a measurement of individual behavior for actual use of systems or intentions to use systems. In this study, the system referred to the technology used. Table 6 shows the teachers' acceptance of the effort expectation for the technology-based pedagogy module for 3D Geometry. The highest min scores are item "My interaction in teaching Mathematics for 3D Geometry topics using technology will become easier to understand" and item "I found that teaching for 3D Geometry topics using technology is easier" with mean score 5.97 (SD=0.758) and 5.97 (SD=0.793) respectively. Overall, all items showed high min scores with a mean min of 5.97 (SP=0.801) and this clearly indicates a very high effort expectancy for teaching 3D Geometry topics using technology. This shows that effort expectancy influences teachers in using technology in learning. This finding is parallel to the study of Chun, T. W. & Yunus, M. M. (2023) which also showed a high interpretation score for effort expectancy. In fact, the study of Kim, J. & Lee, K. S-S. (2022) agreed that Mathematics teachers in the Philippines think that your intention to use digital textbooks depends on the ease of using digital textbooks. In addition, teachers also agreed that technology can help facilitate students' learning in understanding geometry concepts (Abd Fattah et al, 2021).

Table 6*:* Mean score for effort expentancy

	Details	SD	Mean	Interpretation
1.	My interaction in teaching Mathematics for the topic of 3D Geometry using technology will be easier to understand.	0.758	5.97	Very High
2.	The use of technology makes it easier for me to become more proficient in teaching 3D Geometry topics.	0.851	5.96	Very High
3.	I found that teaching 3D Geometry topics using technology is easier.	0.793	5.97	Very High
	Average	0.801	5.97	Very High

D. Research Question 3

Is there a significant difference on level of acceptance and intention to use technology between teachers with a period of service below 15 years and more than 15 years?

T-tests have been conducted to identify whether there is a significant difference in the mean scores for level of acceptance and intention to use technology between respondents who have served 15 years or less and more than 15 years. Table 7 shows the findings that have been obtained based on the analysis that has been run.

For the performance expectation (H1), the mean for the period of service below 15 years and more than 15 years are 5.93 (SD=0.658) and 6.03 (0.630), respectively. In addition, the p-value obtained is 0.501 ($p > 0.05$). Besides, the mean period of service of 15 years and below and more than 15 years for effort expectancy (H2) are 5.97 (SD=0.673) and 5.96 (0.808) respectively. Meanwhile, the p-value obtained is 0.959 ($p > 0.05$).

Next, for the attitude towards the using of technology (H3), the mean obtained by teachers who served below 15 years is 5.26 (SD=0.801) which is lower than the mean of teachers who served more than 15 years which is 5.40 (SD=0.596). In addition, the p-value obtained is 0.413 ($p > 0.05$). Besides, for social influence (H4), the mean for teachers below 15 years of service is 5.02 (SD=1.222) which is also lower than the mean for teachers beyond 15 years of service which is 5.59 (SD=0.940) with a p-value of 0.026 ($p > 0.05$).

For the facilitating conditions (H5), the mean for periods of service below 15 years and more than 15 years are 4.64 (SD=1.200) and 4.97 (1.182) respectively. In addition, the p-value obtained was 0.233 ($p > 0.05$). Moreover, the mean period of service below 15 years and more than 15 years for self-efficacy (H6) were 4.47 (SD=1.212) and 4.79 (0.904), respectively. Meanwhile, the p-value obtained was 0.196 ($p > 0.05$).

Next, for behavioral intention (H7), the mean of teachers with below 15 years of service is 5.49 (SD=1.085) which is lower than the mean of teachers with more than 15 years of service, which is 5.77 (SD=0.864). In addition, the p-value obtained is 0.225 ($p > 0.05$). From the t-test results, it was found that there was only a significant difference in the mean score for social influence (H4) between service periods below 15 years and more than 15 years.

In conclusion, this result is in line with the Izkair, A. S., and Lakulu, M. M. (2023) study conducted in a foreign country which shows that experience is significant to social influence (H3). However, the results of this study also show that experience is significant with performance expectancy (H1) and effort expectancy (H2).

Table 7: Summary of the results for t-test

	Service Period in Education	**N (n=74)**	**Mean**	**Standard Deviation**	**p-value**	**Siginificant**
H1: Perfomance Expectancy	Less than 15 years	37	5.93	0.658	0.501	NO
	More than 15 years	37	6.03	0.630		
H2: Effort Expectancy	Less than 15 years	37	5.97	0.673	0.959	NO
	More than 15 years	37	5.96	0.808		
H3: Attitude towards using of technology	Less than 15 years	37	5.26	0.801	0.413	NO
	More than 15 years	37	5.40	0.596		
H4: Social Influence	Less than 15 years	37	5.02	1.222	0.026	YES
	More than 15 years	37	5.59	0.940		
H5: Facilitating Conditions	Less than 15 years	37	4.64	1.200	0.233	NO
	More than 15 years	37	4.97	1.182		
H6: Self-Efficacy	Less than 15 years	37	4.47	1.212	0.196	NO
	More than 15 years	37	4.79	0.904		
H7: Behavioral Intention	Less than 15 years	37	5.49	1.085	0.225	NO
	More than 15 years	37	5.77	0.864		

CONCLUSION

This study aims to identify the need for the development of technology-based pedagogical modules for Visual-Spatial Skills for 3D Geometry topics based on teacher perceptions. The study results show that teachers consider the need to develop a technology-based pedagogical module to improve VSS for 3D Geometry topics. In fact, performance expectancy and effort expectancy have a very high interpretation. This shows a positive expectancy towards the use of technology in 3D Geometry learning. In addition, the study results also show that the teacher's service period has a significant relationship with social influence. In relation, the results of this study will be used by the researcher to continue the phase 2 DDR study to develop a technology-based 3D geometry pedagogy module and then continue phase 3, which is the module evaluation. Therefore, the results of this study will be a reference for other researchers to get information related to the need for technology in learning and teaching Mathematics, especially the topic of 3D Geometry. In fact, teachers may also get benefits from the module that will be developed to be used as a reference in applying technology in learning 3D Geometry topics as well as improving the practice of teaching methods in Mathematics.

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