SEMARAK ILMU PUBLISHING
202103268166(003316878-P)

Semarak International Journal of STEM Education

Journal homepage:
https://semarakilmu.com.my/journals/index.php/sijste/index
ISSN: 3030-5152

Online Teaching and Learning Technology Tools for Analytical-Numerical Methods in Engineering

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ARTICLE INFO

Article history:
Received 25 August 2024
Received in revised form 30 September 2024
Accepted 5 October 2024
Available online 10 October 2024

Keywords:
Online Teaching and Learning (TnL), Anayltical Numerical Method (ANM), SEM-AMOS

ABSTRACT

The COVID-19 pandemic has forced the synchronized and asynchronized teaching and learning (TnL) to sustain educational programs. It is difficult to change the modality of most STEM courses because the TnL of many laboratory skills does not transform to an online learning environment. The complication of virtual lab skills is the motivation of this paper to focus on the online Analytical Numerical Method course (ANM) integrated with technology tools and apps. The methodology of online TnL for Analytical numerical Methods involves the scientific and mathematical thinking skills in experimental approaches. These approaches employ varied education processes such as heutagogy, peeragogy, and cybergogy. Online ANM is looking for educator 4.0 tools to facilitate the outline of synchronous and asynchronous TnL activities. The apps and tools are suitable for most aspects of ANM course. The implementation strategies integrated Mathematics, IT and engineering. As expected, without STEM approaches and without online TnL technology tools, creating learner engagement through information and communication technology cannot be achieved. The result and discussion of SEM-AMOS model enhance online teaching and learning ANM based on student feedback, questionnaires and survey. Diagram, table and data presentation reveal an unexpected result supported by virtual lab and variants of virtual laboratory. This paper will provide a guidance to educator 4.0 practitioners to modify the current curriculum in line with the latest technological developments and requirements in online TnL.

1. Introduction

The COVID-19 pandemic has forced the rapid implementation of online learning to sustain Engineering Degree Programs especially in STEM-based Mathematics learning [1]. The COVID-19 pandemic presents a unique challenge and restrictions to be performed face to face or blended learning [2]. Traditional TnL of many laboratory skills does not transform to an online TnL approaches.

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https://doi.org/10.37934/sijste.2.1.1925

The process of transformation of TnL skill to compound the complication of virtual lab skills will be highlighted to support the changes in modality [3]. Most aspects of STEM courses including ANM are improving the methodology of virtual TnL using online technology tool, hardware, Education 4.0 software, cloud technologies and augmented reality in the educational process [1].

This paper highlights integrated methodologies, mathematical thinking, synchronous and asynchronous TnL activities, current pedagogies and process of implementation of online technology tools in ANM course. Mathematica software was selected as a case study of online TnL tools. ANM has implemented self-determined learning (heutagogy) for second year students at Universiti Teknologi Malaysia, higher education institutions in Malaysia. To support the huge memory requirement, the cloud environment is used to improve an instructor teaching and student's learning [4]. Dealing with the data analysis using SEM-AMOS model, student feedback, questionnaire and survey will produce the smart outcome based on the latest technological developments and requirements in online TnL.

2. Methodology: Integrated Mathematics, IT and Engineering

Online learning of ANM course combines the power of the video lecture, e-book, tutorial, assessments, Education 4.0 tools and some mathematical software. ANM course involves the combination of numerical methods, numerical analysis, software and hardware to support computational and simulation for solving engineering applications. Thus, the integrated mathematical thinking, IT and engineering are the requirements for learning ANM course [5]. The numerical method development begins with the fundamentals of mathematical modelling for solving some engineering applications. Next, use mathematical thinking to develop the algorithms and procedures. Implement a library of numeric algorithms of the mathematical software. Lastly, analyse the algorithms using numerical indicators such as execution time, convergence, stability, consistency, accuracy, number of iterations, and error estimations.

In addition, the transformation of numerical algorithm into the steps of procedures helps students develop the programming or coding at cloud environment. Many online technology tools are implemented in teaching ANM course, such as mobile application 3D Calculator, GeoGebra, MATLAB, Maple and Mathematica software. Moreover, Mathematica software is addressed on an online adaptive environment. Data analysis includes student feedback, lesson scores, time spent, the percentage of students who completed the course and the percentage of possible adaptive paths. Thus, the hypothesis of this research is that the improvement of student performance depends on the student satisfaction with the tool and its accessibility and reliability. Furthermore, factors determining the behavioural intention on TnL technology tools are not much depended on student perception and preference. A survey was conducted by randomly distributing an online questionnaire to virtual students. Data gathered from 430 surveys were received. The Structural Equation Modeling (SEM) and Analysis of Moment Structures (AMOS) were used to analyse the student feedback.

The application of mathematical thinking, visualization, structural design of problem-solving, analytical and critical thinking in the TnL process can be improved by implementing online technology tool [3,6]. Thus, the aim of this study is to understand the mathematical thinking skills when it comes to investigate online TnL tools in practice, the state of the art of the ANM course and to identify possible gaps [7].

3. Synchronous and Asynchronous TnL Activities

During COVID-19 pandemic, lecturer and students have been forced to adopt synchronous and asynchronous TnL [8]. There are 3 new strategies of TnL such as heutagogy, peeragogy, and cybergogy as extension of potential theory for online and distance education [9]. The strategies have required students to become more self-directed learning (heutagogy), deal with group discussion (peeragogy) use network connection (cybergogy) and education 4.0 tools [10]. This paper chooses Mathematica software to support online learning technology tools for ANM course in Engineering Program.

4. Implementation: Integrated with Technology Tools

The use of online tools, digital devices, platform and cloud reflect the significant presence of digital technology, including the methods of education and learning strategy of ANM course. Several innovation utilizing technologies involving learning management system (LMS), e-learning system, online practice questions, video conferencing, Education 4.0 tools such as Mathematica software, cloud-based memory allocation and desktop platform may help to minimize the education gap between students and lecturer [11]. In addition, several online technology tools in meeting the expectations of Education 4.0 such as Quizizz, Kahot, Mentimeter, Quizlet, Padlet, Socrative and Flipgrid have been used [12]. However, the largest and most highly visited online video-sharing service using cloud based is YouTube [5]. Thus, the huge memory allocation of Mathematica software and other Education 4.0 tools are also based on the cloud environment.

430 respondents for the questionnaires were collected from ANM students. The parameter of questionnaires includes student perception and preference (A), student satisfaction with software (B), accessibility and reliability (C) and the improvement of student performance (D). There are 2 parameters for A including the student experience with Mathematica (A1) and how often these students use Mathematica (A2). There are 3 parameters for B including level of difficulty (B1), exposure to hardware & operating system (B2) and software compatibility (B3). There are 3 parameters for C including the students' acceptability (C1), reliability (C2) and quality (C3). There is one parameter for investigating the performance improvement. SEM and AMOS were used to analyse the integrated parameters. The similar research methodology can be implemented to investigate the parameter A, B, C and D for other online technology tools such as GeoGebra, MATLAB and Maple.

5. Results and Discussion

The data analysis of online TnL technology tools based on Mathematica software was analysed by using SEM and AMOS. 430 questionnaires were analysed and the SEM-AMOS results can be visualized in Figure 1 and Figure 2. The path diagram of confirmatory factor analysis (CFA) can be illustrated in Figure 1. Figure 2 shows the parameter estimates of the CFA model such as student perception and preference (A), satisfaction with the software (B), student accessibility and reliability (C) and the performance of student improvement (D) for investigating the significance of nine selected questions (A1-2, B1-3, C1-3 & D) with 4 trait factors. SEM-AMOS focuses on the relationship between satisfaction with Mathematica software and the performance of student improvement in ANM course.

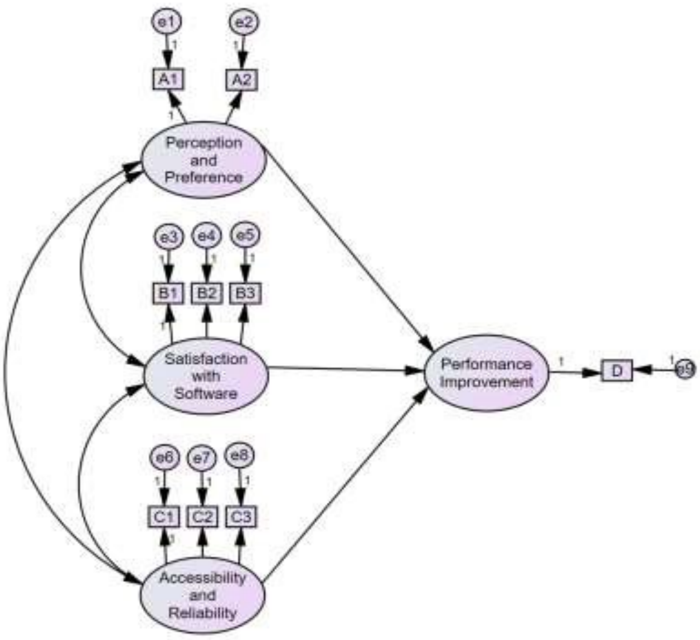

Fig. 1. The path diagram of CFA model

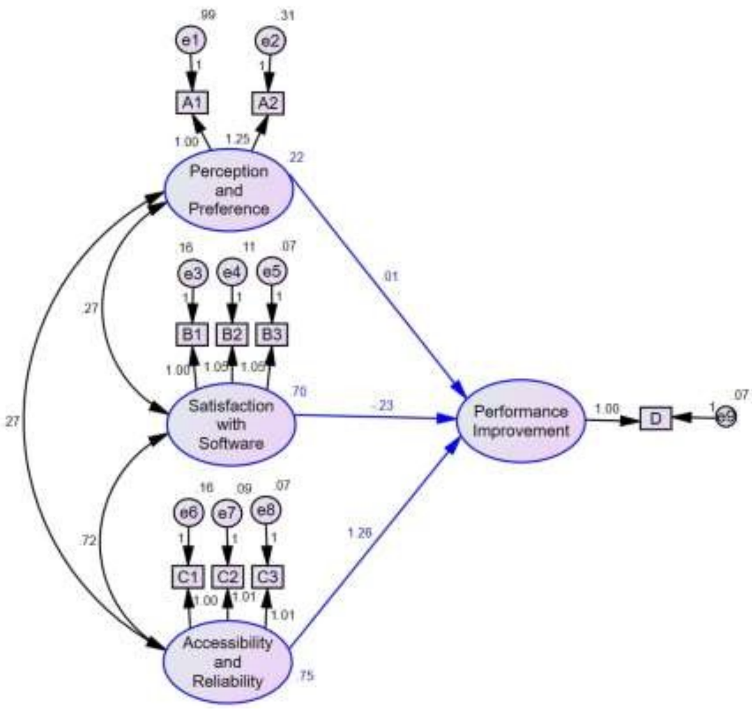

Fig. 2. The parameter estimates of the CFA model

The value of the weighted parameter for accessibility and reliability, performance improvement, satisfaction with software, perception and preference are shown in Table 1. The measurement indicators are standard error (S.E.), critical ratio (C.R.) and probability (P). The effect of student accessibility and reliability of software has high impact to their performance improvement. The maximum estimated value is 1.26. However, the significance of student perception and satisfaction of software was estimated at 0.01 and -0.23, respectively. This implies that both of these factors have low impact to improve student performance.

Table 1
The measurement indicators for accessibility and reliability, performance improvement, satisfaction with software, perception and preference

Regression Weights: (Group number 1 – Default model)			Estimate	S.E.	C.R.	P
Performance_Improvement	<---	Perception_and_Preference	.009	.083	.109	.913
Performance_Improvement	<---	Satisfaction_with_Software	-.228	.361	-.631	.528
Performance_Improvement	<---	Accessibility_and_Reliability	1.257	.338	3.717	***
A1	<---	Perception_and_Preference	1.000			
A2	<---	Perception_and_Preference	1.245	.203	6.140	***
B1	<---	Satisfaction_with_Software	1.000			
B2	<---	Satisfaction_with_Software	1.047	.031	34.241	***
B3	<---	Satisfaction_with_Software	1.054	.028	37.043	***
C1	<---	Accessibility_and_Reliability	1.000			
C2	<---	Accessibility_and_Reliability	1.013	.028	36.026	***
C3	<---	Accessibility_and_Reliability	1.014	.027	37.243	***
D	<---	Performance_Improvement	1.000			

Based on SEM-AMOS analysis, four-factor model of Mathematica was able to enhance online TnL of ANM course. How well-suited the data fit the hypothesis can be investigated by the score value of chi-square test statistic, root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), comparative fit index (CFI) and Tucker-Lewis Index (TLI) as shown in Table 2, Table 3, Table 4 and Table 5, respectively. Table 2 shows the Chi-square test statistics of SEM-AMOS model obtains 94.175, which proves that, Mathematica software is significant, acceptable and there is a positive associated between the other three factors for enhancing online TnL for ANM course. The SEM-AMOS model is efficient to integrate online tools and ANM. as reflected in the small value of RMSEA (≤0.10) as shown in Table 3. As an impact, the RMSEA shows that, the good performance of the SEM-AMOS for investigating the integration.

Table 4 shows the score for GFI and AGFI. The GFI (0.958) and AGFI (0.913) fulfil the requirement range between 0 and 1, which shows that, the SEM-AMOS is reasonably consistent with the data distribution. Thus, a good fit between the hypothesized model and covariance matrix contributes to be a good fit to the databased. Table 5 show the value for baseline comparison of CFI and TLI indicators. The CFI is 0.986 and TLI is 0.976 indicate the good fit model (>0.95). This result also shows that this model is a good fit to the databased.

Table 1
The Chi-Square test result

Result (Default model)	
Minimum was achieved	
Chi-squares	94.175
Degrees of freedom	22
Probability level	.000

Table 2
The RMSEA value for default model

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.087	.069	.105	.000
Independence model	.565	.552	.579	.000

Table 3
The value of GFI and AGFI for default model

Model	RMR	GFI	AGFI	PGFI
Default model	.012	.958	.913	.468
Saturated model	.000	1.000		
Independence model	.549	.198	-.003	.158

Table 4
Baseline comparison of CFI and TLI for default model

Model	RMR	GFI	AGFI	PGFI
Default model	.012	.958	.913	.468
Saturated model	.000	1.000		
Independence model	.549	.198	-.003	.158

6. Conclusion

In conclusion, the SEM-AMOS and its performance indicators provide positive evidence for the significant relationship between the online TnL tool, Mathematica software and the student performance improvement for Engineering Program via ANM course. Diagram, table and data presentation reveal SEM-AMOS result to modify the current curriculum and design effective online learning environment. Although there is no substitute for face-to-face TnL, this is an innovative solution to minimize the loss of learning exposure during a COVID-19 outbreak. Online technology tools may help to minimize the educational gap between students and lecturers in maintaining TnL for ANM course during this unprecedented circumstance.

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