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STUDENT ACCEPTANCE STUDY OF PHET SIMULATION WITH AN EXPANDED TECHNOLOGY ACCEPTANCE MODEL APPROACH

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ABSTRACT
Phet simulation is a computer-based practicum simulation medium that helps to increase students' engagement and understanding through concept visualization. Even though there have been numerous studies on the Technology Acceptance Model (TAM) related to Phet simulation, the TAM study of Phet simulation combined with certain learning methods is rarely observed. We propose an advanced version of TAM by including the external variables of system quality, user characteristics, and instructor. This study is a quantitative design with a descriptive, explanatory type. This model was tested using an online questionnaire disseminated to 49 students who finished taking basic natural sciences subjects using Phet simulation based on problem-based learning. The result showed that system quality has an effect on perceived usefulness, perceived ease of use has an effect on behavioral intention of use, behavioral intention of use has an effect on actual usage, and there is no relationship between instructor quality on perceived usefulness. Grit on perceived ease of use, learner anxiety, and perceived usefulness on the behavioral intention of use. These findings have implications regarding user acceptance of Phet simulation combined with certain learning methods, specifically problem-based learning.
Keywords: *Student Acceptance, Technology Acceptance Model, Phet Simulation, Problem-Based Learning.*

1. Introduction

The world has experienced revolution and advanced change related to information and communication technology (ICT) and the internet in all sectors, specifically in the education sector (Alsalhi et al., 2019; Castéra et al., 2020; Muhaimin et al., 2019). The advancement of information technology describes how teachers use technology in the classroom to respond to innovation and uphold their professional credentials (Ottested et al., 2018). Technology integration is the use of technology to support classroom learning implementation (Reigeluth & Joseph., 2002). The introduction of new teaching methods is made possible by ICT innovation, which modifies routines for classroom instruction and traditional teaching methods. ICT develops and contributes a vital role in education reformation and become an important part of academic programs.

Several studies reported positive impact of using ICT by teachers for better student learning (Awang et al., 2018; Habibi et al., 2018). Natural science teachers often consider the importance of technology integration during learning process (S. K. Howard et al., 2015). Moreover, they are more confident when using technology in the classroom due to the impact of ownership and experience of the technology (Yerdelen-Damar et al., 2017). The has implications for the use of natural science teacher technology, they take advantage of technology-based simulations to ease students' understanding of natural science concepts (Almasri, 2022).

Natural science education must include laboratory instruction because without engaging in scientific laboratory activities, it will be difficult to comprehend scientific theories. Virtual laboratories can be used as an alternative to carrying out computer-based laboratory practicums in which they offer simulations in the form of designs and ways of working that are similar to actual experiments (real environment) to provide practical experience to students (El Kharki et al., 2021; Kapilan et al., 2021). The lack of practical tools and learning media, or their limitations owing to infrastructural and financial constraints, can be resolved by using computer simulations

(Darrah et al., 2014). Model-oriented approaches to teaching natural science, especially with interactive simulations, have increased student engagement and understanding (Bo et al., 2018). Simulation has the potential to help students understand modeling as a fundamental scientific epistemic activity (Campbell et al., 2015). The simulation through a virtual laboratory can be conducted using Phet simulation media.

PhET, a simulation project in the field of Physics Education Technology, operates on the web and is affiliated with the University of Colorado (Finkelstein et al., 2005). PhET interactive simulation can be used worldwide and across educational levels from elementary school to higher education institutions for science and mathematics learning topics. The PhET interactive simulation project offers over 160 interactive simulations developed using Java, Flash, or HTML5. These simulations are accessible online at no cost through the PhET website (http://phet.colorado.edu) and can also be used offline by downloading the application (Correia et al., 2019; Moore & Perkins, 2018).

In the Basic Natural Science Concepts course in the Islamic Elementary School Teacher Education department, Universitas Islam Lamongan, the lecturers have used technology in the learning process by presenting a virtual laboratory through the implementation of Problem-Based Learning (PBL) using PhET simulations. The use of this type of media is certainly not without reason. Phet simulation supports learning science content through exploration and discovery (Moore & Perkins, 2018). Phet simulation is a learning medium by utilizing computer technology. Phet also provides various experiments if inadequate laboratory tools and materials are available (Astuti & Handayani, 2018). The study’s results revealed that problem-based learning (PBL) with information and communication technology greatly increased students' basic competence in science learning (Ulva, 2017). As we know that the PBL learning model provides a problem-solving process that is guided by the teacher to assist students in understanding subject concepts through problem-solving solutions (Haji et al., 2015). Applying the PBL learning model helps students think more critically, assimilate knowledge, and instill responsibility in themselves, all of which help students grow as thinkers (Malan et al., 2014).

Research findings show that when teachers teach "electrical circuits", they use PhET in class to help students visualize the concept (Kriek & Stols, 2010). PhET media makes watching, reading, understanding, and remembering learning more enjoyable (Rahmadita et al., 2021). When the characteristics of the students and the subject matter being studied are taken into account and matched with appropriate media, the implementation of an approach will become more effective (Mahardika Arsa Putra & Tri Agustiana, 2021).

It doesn't matter what pedagogical technique is used, the most important thing lies in students' involvement, satisfaction, and acceptance of the learning process. To measure student acceptance of the learning process, especially in problem-based learning (PBL) using PhET simulations, the Technology Acceptance Model (TAM) approach is very important. ICT will be successful in learning when using the TAM approach (Adam, 2017). TAM consists of perceived ‘usefulness and 'perceived ease of use' and this approach was first introduced by (Davis, 1989). In that time, the TAM component had grown to include both behavioral intention and actual use (Davis & Venkatesh, 1996). According to the TAM approach, technology acceptance is mainly driven by two main factors: usability and convenience. In addition, perceived usefulness is influenced by external variables such as system quality (Mtebe & Raphael, 2018) and instructor quality (Ouajdouni et al., 2021). Meanwhile, perceived ease of use is influenced by two dimensions: learner anxiety and user persistence (Duckworth et al., 2007).

This research is conducted to examine and test the TAM (Davis & Venkatesh, 1996) with an extended design to study user acceptance of Phet simulation based on Problem Based Learning. To fill the different gap, we identify the literature about user acceptance of STEAM-Problem Based Learning Phet simulation by adding external variables from TAM such as system quality (Mtebe & Raphael, 2018), instructor quality, learner anxiety (Ouajdouni et al., 2021), users’ grit (Duckworth et al., 2007).

2. Literature Review

Technology is the application of knowledge and practical skills to design, manufacture, and use tools, machines, systems, or devices that aim to solve problems, fulfill needs, or improve human living conditions (Chen, 2023). The use of technology to transfer and access information, as well as facilitate communication between individuals or between organizations (Chande, 2023; Okumus, 2013). Utilization of technology in learning and training, as well as use of technology to support work and business processes (Gunasekaran & Nath, 1997; Mwantimwa, 2019). for example e-learning systems, online course platforms, human resource management applications. Education and understanding of the use of technology, including the ability to use digital tools and platforms (Dian et al., 2023; Haleem et al., 2022). Utilization of technology to create more sustainable and environmentally friendly solutions (Agus et al, 2023). Technology continues to develop and become an integral part of everyday life, having a significant impact on the way we work, learn, communicate and life as a whole. A good understanding of technology allows us to take maximum advantage of its potential and, at the same time, consider its impact on society and the environment.

Phet Simulation PhET Interactive Simulations, often referred to simply as "PhET", is an educational project that develops and provides a variety of interactive simulations in science and mathematics subjects. The primary goal of PhET is to provide educational tools that enable students to understand complex scientific concepts through imaginative virtual experiments (Flegr et al., 2023). Here are some of the main characteristics of PhET Interactive Simulation, interactive and visual, exploratory and visual experiments, diverse disciplines, support for independent and group learning, free and open source, supported by educational research, available in various languages, awards and recognition (Salame & Makki, 2021). PhET provides simulations that users can play and interact with directly. This simulation uses attractive graphics and visual elements to help students understand scientific concepts in a more concrete way (McElhaney et al., 2015). PhET simulations allow users to conduct virtual experiments, change variables, and observe how those changes affect the system. This provides students with the opportunity to actively explore scientific concepts.

PhET covers various fields of science such as physics, chemistry, mathematics, biology and other sciences. Each simulation is developed to address specific concepts within that field. PhET simulations can be used by students independently for self-exploration or in a classroom context as a group learning tool. They can be used inside or outside the classroom as a supplement to lessons. PhET provides all their simulations for free and as open source. This allows teachers and learning developers to access and use these simulations at no cost. PhET simulations are based on educational research and designed to support effective learning concepts (Fikriyati et al., 2023; Fuadi et al., 2023). They often involve the principles of constructivism, where students construct their own understanding through direct experience. To support global users, PhET provides simulations in multiple languages, enabling easier access for students worldwide and PhET has received numerous awards and recognition for its contributions to supporting science and mathematics education. Their simulations are frequently used by teachers around the world (Inayah & Masruroh, 2021).

3. Research Methods

This research is quantitative study with explanatory descriptive design. An online questionnaire consisting of 40 statements was given to 49 students of Islamic Elementary School Teacher Education students, semester III, academic year of 2022/2023 at the Universitas Islam Lamongan. They were recruited after taking Basic Natural Science Concept courses using a Phet simulation based on Problem Based Learning. The data gathered from an online questionnaire is intended to validate the research hypothesis.

Each item in the questionnaire is derived from a scale that has been validated in previous studies. TAM attitude scale towards use, behavioral intention of use (Alharbi & Drew, 2014; Davis & Venkatesh, 1996), perceived ease of use (Davis, 1989; Sagnier et al., 2020), and perceived usefulness (Davis, 1989; Urbach et al., 2010). In this study, external factors of TAM are assessed using various instruments, including the quality of the e-learning system (Mtebe & Raphael, 2018), instructor quality, users' grit (Ouajdouni et al., 2021), which are measured using a 7-point Likert scale: 1: Strongly disagree, 2: Disagree, 3: Somewhat disagree, 4: Neutral, 5: Somewhat agree, 6: Agree, and 7: Strongly agree (Taherdoost, 2019). Additionally, Grit (Duckworth et al., 2007) is measured as an external instrument using a 5-point scale: 1: Not at all, 2: Not much, 3: Somewhat, 4: Mostly, 5: Very much (Pornel & Saldaña, 2013) as depicted in Figure 1.

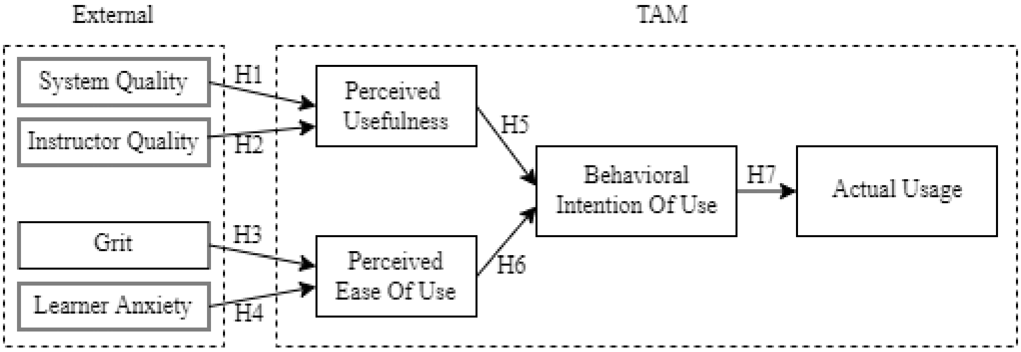

Fig. 1. Research Model

The research data was analyzed using a structural equation model (SEM) with the AMOS version 24.0 software. The comprehensive research model was evaluated based on the following criteria: Normed Chi-Square (X^2/df) ≤ 3.00, Adjusted Goodness of Fit Index (AGFI) ≥ 0.80, Comparative Fit Index (CFI) ≥ 0.90, Incremental Fit Index (IFI) ≥ 0.90, Root Mean Square Error of Approximation (RMSEA) ≤ 0.08, and Normed Fit Index (NFI) / Tucker Lewis Index ≥ 0.90 (Jr., Black, Babin, & Anderson, 2014).

4. Results and Discussions

Data Analysis dan Model Testing

This research was reviewed and evaluated using a structural equation model (SEM) with the assistance of AMOS. The test results are presented in two stages as follows:

First Phase

This is the results of the first full model SEM analysis based on the goodness of fit criteria. The following data are obtained:

Table 1 - The Result of SEM Comprehensive Model Testing in The First Phase

Criteria	Cut of Value	Result	Evaluation
X^2 Chi-square	< 593.7614	1229.266	poor
Probability	≥ 0.05	0.000	poor
CMIN/DF	≤ 2.00	1.885	good
RMSEA	≤ 0.08	0.136	poor
GFI	≥ 0.90	0.527	poor
AGFI	≥ 0.90	0.462	poor
TLI	≥ 0.95	0.403	poor
CFI	≥ 0.95	0.446	poor

Data source: Researchers data analysis result, 2022

Table 1 indicates that the model fails to meet the goodness of fit criteria, as only the CMIN/DF criterion fulfills the requirement with results of 1.885 ≤ 2.00. The $\chi 2$ value is 1229.266, which is greater than the Chi-square table value of 593.7614 (significant at the 0.00 probability level). Moreover, the RMSEA value is 0.136, GFI is 0.527, AGFI is 0.462, TLI is 0.403, and CFI is 0.446. Thus, it can be concluded that the model's overall fit falls into the poor or not good category. This conclusion is based on the model's feasibility requirements, where most of the goodness of fit criteria are not satisfactory. Therefore, based on the results of the first phase of analysis, a complete model analysis for the second phase is necessary.

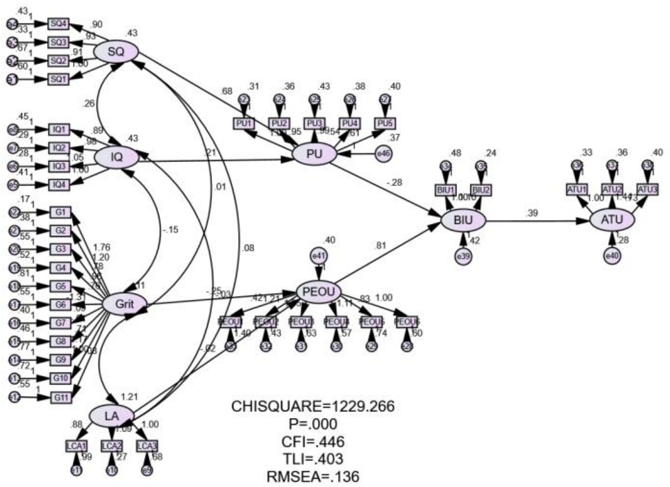

Fig.1. The Result of SEM Comprehensive Model Testing in the First Phase
Data source: Researchers data analysis result, 2022

Second Phase

This is the results of the first full model SEM analysis based on the goodness of fit criteria. The following data are obtained:

Table 2 - The Result Of SEM Comprehensive Model Testing In The Second Phase

Criteria	Cut of value	Result	Evaluation
X^2 Chi-square	< 237.5948	294.665	moderate
Probabilitas	≥ 0.05	0.198	good
CMIN/DF	≤ 2.00	1.072	good
RMSEA	≤ 0.08	0.039	good
GFI	≥ 0.90	0.729	moderate
AGFI	≥ 0.90	0.654	moderate
TLI	≥ 0.95	0.942	moderate
CFI	≥ 0.95	0.951	good

Data source: Researchers data analysis result, 2022

Table 2 demonstrates that the model has successfully met the goodness of fit criteria. The prediction model with the obtained data shows no significant difference. It can be observed that the $\chi 2$ value for goodness of fit is 294.665, which is greater than the chi-square table value of 237.5948 (not significant at the 0.198 probability level). Additionally, CMIN/DF is 1.072, RMSEA is 0.039, GFI is 0.729, AGFI is 0.654, and TLI is 0.942. Therefore, it can be concluded that the model's feasibility is in the good category. This conclusion is based on the model's feasibility requirements, which have mostly fulfilled the goodness of fit criteria. As a result, the second phase of the comprehensive SEM model analysis has been successful in fitting the model by eliminating the indicators PEOU1, PEOU6, PU2, PU7, IQ1, IQ2, G1, G2, G8, G9, G11, and LCA1.

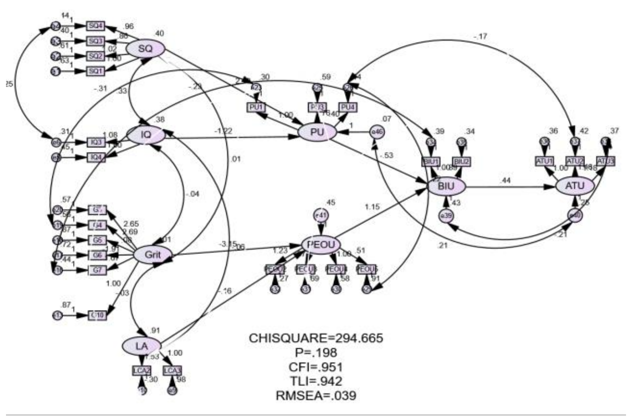

Fig. 2. The Result of SEM comprehensive model testing in the first phase
Data source: Researchers data analysis result, 2022

Hypothesis Testing

The hypothesis was tested by comparing the statistical boundary conditions, with a probability value (P) of <0.05. If the results of the data analysis meet the above requirement, it can be concluded that the hypothesis is accepted. The results of the hypothesis analysis are as follows.

Table 3 - Research hypothesis test results

Hypothesis	Statement			Estimate	S.E	C.R	P	Supported or not
H1	SQ	→	PU	0.681	0.299	2.275	0.023	Supported
H2	IQ	→	PU	0.209	0.247	0.844	0.399	Not supported
H3	Grit	→	PEOU	-0.246	0.424	-0.581	0.561	Not supported
H4	LA	→	PEOU	-0.21	0.108	-0.196	0.844	Not supported
H5	PU	→	BIU	-0.279	0.210	-1.333	0.182	Not supported
H6	PEOU	→	BIU	0.810	0.371	2.182	0.029	Supported
H7	BIU	→	ATU	0.387	0.159	2.426	0.015	Supported

Note. SQ= system quality; IQ= instructor quality; LA= learner anxiety; PU = perceived usefulness; PEOU = perceived ease of use; BIU = behavioral intention of use; ATU= actual usage

Table 3 reveals that the Technology Acceptance Model (TAM) components towards PhET simulation based on Problem-Based Learning indicate a positive and significant relationship between system quality and perceived usefulness (H1).This finding supports the results of previous studies (Cidral et al., 2018; Faizah & Khairiyah, 2021; Faqih & Jaradat, 2015). Undoubtedly, if students consider that the Phet simulation based on Problem Based Learning has a good quality system, they tend to find the system useful for them.

The analysis did not reveal a significant effect between instructor quality and perceived usefulness (H2). This outcome aligns with the findings of previous studies that also did not find a significant impact of instructor quality on perceived usefulness (Haji et al., 2015; Moore & Perkins, 2018; Ulva, 2017), but contradicts with the findings of the study by (Bakar et al., 2023; Lathifah et al., 2023). This shows that the quality of the instructor does not influence the perceived usefulness of using Phet simulation based on Problem Based Learning.

Several research results show that grit affects the emotion of fulfillment towards academic success (Amirudin et al., 2022; Datu & Fong, 2018; Fatimah et al., 2023; J. M. Howard et al., 2019). This study intends to analyze grit as a factor affecting perceived ease of use. The study results in Table 3 indicate that grit does not have a significant effect on perceived ease of use (H3). These findings suggest that while grit may influence academic success, it does not impact students' perceived ease of use when utilizing Problem-Based Learning-based PhET simulations.

The statistical results in Table 3 demonstrate that learner anxiety does not have a significant effect on perceived ease of use (H4). This finding aligns with the conclusions of previous studies that also reported no significant impact of learner anxiety on perceived ease of use (Abdullah et al., 2016; Faqih & Jaradat, 2015; Purnomo & Lee, 2013), and contrary to the results of existing research (Al-Gahtani, 2016; Komalasari & Yakubu, 2023; Nikou & Economides, 2017; Pratiwi & Warlizasusi, 2023). Anxiety tends to be a factor of acceptance of technology. Nonetheless, in this study, the PhET simulation application was accessed via the website using mobile phones, which led to students not feeling anxious while operating the PhET simulation.

In accordance with earlier studies (Çivril & Özkul, 2021; Kamble et al., 2019; Mohammadi, 2015; Rodríguez Lera et al., 2021; Wu & Chen, 2017), perceived value has a beneficial impact on behavioral incentive to utilize. This goes against what was just said. The results of this study show that perceived usefulness has no discernible influence on usage behavior motivation (H5). With this in mind, it can be stated that students' behavioral motives for using problem-based learning-based PhET simulations are not significantly impacted by perceived utility.

According to Table 3, this research suggests that behavioral intention to use is positively impacted by perceived ease of use (H6). The result presented here contrasts with those of other investigations (Alharbi & Drew, 2014; Faqih & Jaradat, 2015; Rodríguez Lera et al., 2021) and is in alignment with the findings of earlier studies (Kamble et al., 2019; Mohammadi, 2015; Sagnier et al., 2020; Wu & Chen, 2017). This finding shows that taking into consideration perceived ease of use, students have a behavioral intention to utilize the Phet simulation based on problem-solving instruction. Although earlier research did not discover any significant connection between behavioral intention to use and actual utilization (Arifin et al., 2023; Ashrafi et al., 2022; Damayanti et al., 2023; Firdaus et al., 2023). Table 3 shows that the investigation's finding that behavioral intention to use had a significant impact on actual usage (H7) is consistent with that finding. which is consistent with and supports previous studies (Estriegana et al., 2019; Faqih & Jaradat, 2015; Kamble et al., 2019; Mohammadi, 2015; Wu & Chen, 2017).

5. Conclusion

Reviewing the previous Phet simulation-based research literature provides valuable insights towards its practical use in learning. Even though there have been many studies on TAM on the use of Phet simulation, studies on the level of acceptance of Phet simulation combined with certain learning methods are rarely observed. In this study, we included new factors in TAM to comprehensively understand the acceptance or rejection of using Problem Based Learning-based Phet simulation, namely system quality, instructor quality, grit and learner anxiety.

These findings suggest that the Technology Acceptance Model (TAM) is an appropriate theoretical framework for understanding user acceptance of Problem-Based Learning-based PhET simulations. In addition, system quality as an external factor of TAM plays an important role in increasing the acceptance of this technology by students. Therefore, science activities must be designed to utilize scientific practices and combine digital laboratories with appropriate learning methods.

This research has certain limitations concerning the sample size and the homogeneity of respondents, as they were solely drawn from the PGMI study program at Unisla. Additionally, the study did not specifically investigate the influence of demographic characteristics, such as age, gender, and experience, on student acceptance of PhET simulations. Consequently, the researcher suggests that this model should be evaluated by a broader range of users in different contexts to further examine its effectiveness. Future studies can enhance the explanatory power of the model by exploring various variables that might influence the adoption of technology, combined with different learning methods, and incorporate them into the model.

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