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Regular Article

Exploring users' acceptance of electronic circuits simulation: Implications to teaching basic electronics

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ABSTRACT

This study explores the acceptance and use of electronic circuit simulation software among electronics students, teachers, and graduates, focusing on user interface design and computer literacy. Using the extended technology acceptance model and surveying 427 electronics enthusiasts in Cebu, Philippines. The study finds that the user interface design positively affects the perceived usefulness and ease of use of electronic circuit simulators. On the other hand, computer literacy positively affects perceived usefulness and ease of use. Additionally, the study shows that perceived ease of use directly affects attitude towards using the software, behavioral intention to use and actual system use. The results suggest that integrating innovative technologies like electronic circuit simulation software in teaching basic electronics is essential in enhancing the quality of education and producing competent graduates in the field. The study provides implications for theory and practice in vocational/technical education, especially in teaching electronics circuit designing in the applied electronics curriculum. Lastly, we put forward valuable insights into the curricular integration of ECS in teaching basic electronics, especially in developing economies.

1. Introduction

The use of technology in teaching, especially on subjects with complex and integrated system applications, has become an accepted approach for enhancing student learning. With the discovery of various digital technologies, the lectures and hands-on exercises given by the teachers using these digital tools form the most pivotal aspect of students' learning, especially among the most specialized engineering and technical courses (Estriegana et al., 2019). For example, simulation software improved the teaching and learning of digital electronics subjects with a methodology supporting self-paced learning during the COVID-19 pandemic, highlighting the key benefits for students (George, 2020). The paper added that tertiary education must provide relevant theoretical applications that could replicate the issues faced by the industries and the emerging concerns on aligning actual applications and digital simulations (Gonzales, 2022, p. 2022). In a way, technological intervention in universities will connect the foundations of students' learning to the current issues in the industry. In the context of electronics technology and teaching, the widely used digital tool for teaching basic electronics circuits is electronic circuit simulation (ECS). Technical and vocational education researchers have examined technology learning resources such as simulation software to understand the intricacies and delivery of technology-enhanced lessons with these tech-savvy tools (Akman & Turhan, 2017; Honey & Kanter, 2013; Patteti, 2021).

ECS is software that uses mathematical models and a set of programs that are capable of replicating, evaluating, and testing the behavior of an actual electronic circuit system. A review of significant contributions and discoveries of ECS started with circuits and systems and commenced with the earliest digital computers in the early 1950s (Pederson, 1984). In the last decade, ECS has become a handy tool for electronics enthusiasts with higher capabilities (i.e., sensors and actuators) to design and test complex electronic circuits on a cloud-based platform (Mayoof et al., 2021). In addition, there are massive options for ECS, from open source to paid licensing options. Simulation software allows circuit operation modeling and is a critical analysis tool before the actual operation of a circuit, thus making it a convenient tool in teaching basic electronics courses. Due to its highly accurate modeling capability, colleges and universities use technological innovation to teach technical, vocational, and electronics engineering programs, specifically designing and testing

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circuit diagrams (Santos et al., 2019). This digital tool for students and electronics technology professionals leads to economic advantages due to its cost-effective electronics project designs since the circuits can be tested for accuracy before buying spare parts for the actual project making. Although the field of teaching electronics technology has long developed digital learning software and systems, the users' learning processes don't occur quickly in natural settings. The fundamental questions surrounding the implementation of any technological assistance in teaching and learning hover around how the users accept and adopt the tool in classroom settings.

Investigating the acceptance of ECS technology has accompanied their implementation to uncover the variations of the behavioral aspects of their acceptance and usage. Reports derived from these behavioral scientific papers form part of psychological and even technical interventions to improve the systems of implementation and policy directions. A meta-analysis by Granić and Marangunić (2019) revealed that technology has proven to have dynamic associations of behavioral variables in the acceptance and use of different learning materials or software with antecedent variables and extended variants of Davis's (1989) Technology Acceptance Model (TAM). TAM propositions include the latent constructs of perceived ease of use (PEU) and perceived usefulness (PU) of a digital tool or software and determine the extent of the user's acceptance. At the onset of using the ECS among electronics students and enthusiasts, there is a need to consider the technical characteristics of the software, most specifically the computer literacy (CL) and user interface design (UID) in the context of its features and functions.

To put forward an explanation of how UID and CL potentially affect user acceptance, we examined emerging literature hypothesizing direct relationships between the UID and CL (e.g., Eraslan Yalcin & Kutlu, 2019; Iqbal & Sidhu, 2022; Salhoub et al., 2022) with the well-established latent variables in TAM. These were systematically presented in the hypothesis development section. This is to theoretically illustrate the grounding bases to extend TAM, specifically in using software such as ECS to delineate structures along the constructs UID and CL as antecedent variables of TAM. It is argued that the acceptance of ECS depends on basic computer skills and the software's design in simulating electronic circuits, especially on the ease of use, usefulness, attitude towards using, use behavior, and the actual use of the ECS. Also, this paper contributes to our understanding of the acceptance of ECS from a developing economy perspective.

The aim of the study is twofold, first is to investigate the structural relationships of the hypothesized paths using the covariance-based structural equation modeling (CB-SEM) methodology and to delineate the multigroup differences of users' acceptance from students in electronics-related courses and the working group in electronics related fields including teaching. The springboard to understand the structures of acceptance of ECS with the identified antecedent behavioral constructs is theoretically based on emerging literature (e.g., Altalbe, 2019; Kalayou et al., 2020; Sagnier et al., 2020; Tao et al., 2022; Zin et al., 2023; Álvarez-Marín et al., 2021). The paper seeks relations among the latent variables that explain the acceptance of electronic simulation packages (e.g., electronics workbench, NI Multisim, SPICE, Circuit Sims) with user interface design and computer literacy as the antecedent variables of Davi's (1989) TAM.

The rest of this paper is structured as follows. Section 2 presents the research model and hypotheses development, while Section 3 describes the methodology, including details about the study participants and the model fit thresholds of the CB-SEM. In Section 4, we present the results of the analyses. Section 5 discusses the results, while Section 6 discusses the implications of teaching basic electronics. Finally, in Section 7, we conclude the study and declare some points of limitations.

2. Research model and hypothesis development

Acceptance of a new system and technology has become a preliminary step for successfully implementing any system. Several theories were presented to explore the determinants of user acceptance of Information systems/technology IS/IT (Davis, 1989). The TAM developed by Davis (1989), adapted from Fishbein and Ajzen's theory of reasoned action (TRA), became the most widely cited theoretical framework dealing with behavioral intention and usage of IT (Rai et al., 2002). The model aims to explain key factors of user acceptance of information systems and predict the relative importance of the factors in the diffusion of technological systems (Davis et al., 1989). The model is an attempt to derive "the determinants of computer acceptance that is general, capable of explaining user behavior across a broad range of end-user computing technologies and user populations. As presented in Fig. 1, the model relates perceived usefulness, PEU, attitude towards using, and actual user behavior.

Several studies have attempted to extend and modify the TAM by proposing additional variables contributing to the acceptance of technological innovation. Venkatesh and Davis (2000) developed and tested a theoretical extension of the TAM called TAM2, which explained perceived usefulness and intention to use social influence and cognitive instrumental processes. Moreover, the present study extends the original TAM (see Fig. 2) by integrating a new construct that addresses the following variables: User Interface Design and Computer Literacy. Since the TAM supports the assumption that external factors influence ICT adoption, the TAM is regularly modified in research to reflect variables unique to regional and local contexts (Musa, 2006). It requires an understanding of the factors that influence the acceptance of ICT and its application in ECS, which can then be used to modify the TAM and address the unique characteristics of the population to be studied.

2.1. *The external factors: user interface design and computer literacy*

In this section, we convey theoretical underpinnings on how the acceptance and use of the ECS technology are affected by the system's user interface design (UID) and the user's computer literacy (CL), especially from a developing economy perspective. A more contextualized literature review was done to establish the UID and CL as latent constructs to have more interesting interactions using simulation software technologies.

Cho et al. (2009) defined UID as the perception of the structural design of the interface of an information system that presents the system's features and functions. The quality of the UID is a critical factor when developing and improving information software using customer feedback (McKnight et al., 1996). Thus, a sound user interface system, especially regarding how software is intended, its looks, and the availability of must-have features, leads to ease of use (Munoz et al., 2019). Moreover, Farhan et al. (2019) and Bailey et al. (2022) emphasized the importance of user interface in the development and testing of software for e-learning, which followed the insights from the results of the significance of the structural paths with the TAM constructs in the process of software development. Thus, in the context of ECS, a well-designed and organized interface can help students and electronics enthusiasts identify particular functions and features of the simulation software, leading to the eventual use of the system.

Emerging literature illustrated that UID quality is one of the critical elements in determining the system's usefulness, behavioral intention to use, and ease of use. For example, Eraslan Yalcin and Kutlu (2019) reported that the UID positively affects the student's intention to use a learning management system. Also, the acceptance of software based on augmented reality spaces provides evidence that a natural user interface with visual cues facilitates long-term learning and retention of specific actions of the users (Iqbal & Sidhu, 2022). In the case of inclusion to curricular innovations, the acceptance of the use of ECS will make students perceive that such an application to design electronic circuits is helpful for learning (Almaiah et al., 2016). In addition, a simple and flexible user interface with a good menu design with control toolbars will reduce the effort while using a system; they will perceive that the

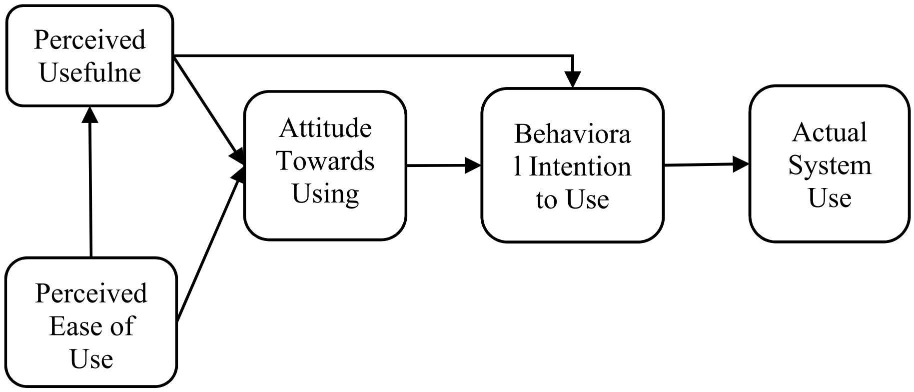

Fig. 1. The technology acceptance model (Davis, 1989).

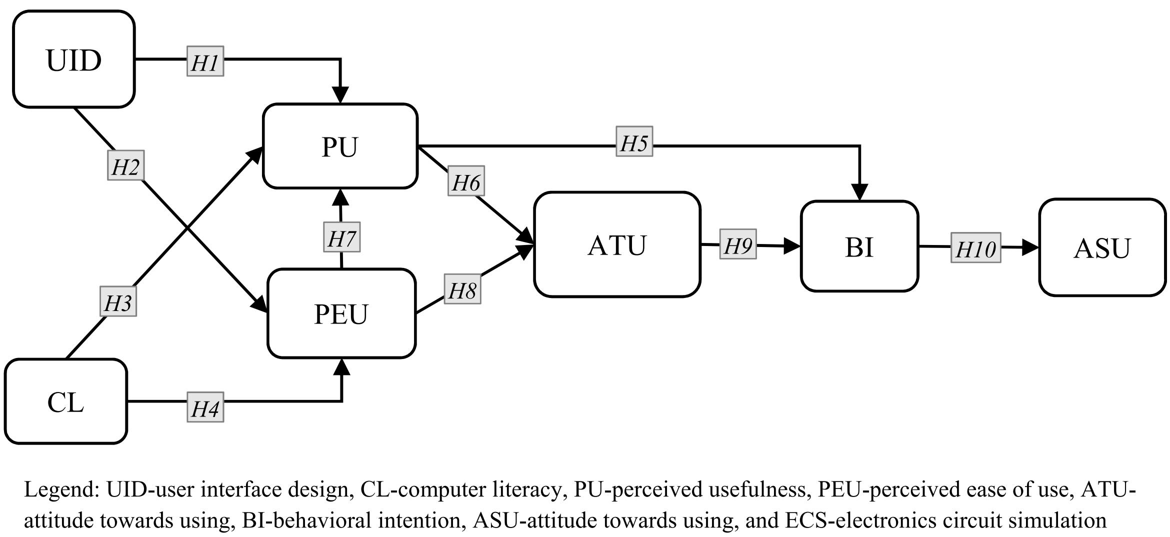

Fig. 2. The proposed model.
Legend: UID-user interface design, CL-computer literacy, PU-perceived usefulness, PEU-perceived ease of use, ATU-attitude towards using, BI-behavioral intention, ASU-attitude towards using, and ECS-electronics circuit simulation.

software (e.g., ECS) is user-friendly. Based on these arguments, we propose that 1) the UID positively affects PU **(H1)** and 2) the UID positively affects the PEU **(H2)**.

Computer literacy (CL) is referred to as the ability to use computer systems to word process documents, analyze data, develop small computer programs, browse the internet, and install the software (Idowu, Adagunodo, & Idowu, 2004). CL is considered the amount of computer knowledge required and the length of experience using computers with the necessary skill sets to carry out tasks (Mitra, 1998). From an experiential standpoint, researchers have found that CL is an essential antecedent of TAM constructs and ease of use (Nes et al., 2021; Rashid et al., 2021). Although the indicators of CL are more focused on basic computer knowledge, these skill sets may reflect more advanced expertise, which may include basic programming and logic gates that are fundamental in circuit designs among electronics enthusiasts.

Additionally, Salhoub et al., 2022 measure the user behavior of electronic services customers with the integration of computer self-efficacy in line with CL reporting significant relationships to perceived usefulness and PEU. It is empirical that CL can explain the part and overall variations of the PU and PEU in the context of ECS among electronics enthusiasts. Thus, we hypothesized that: 1) CL positively affects PU **(H3)** and 2) CL positively affects PEU **(H4)**.

2.2. *TAM in the context of ECS*

In this section, we discussed how TAM is widely used in evaluating the acceptance and use of simulation software like electronics circuit simulation (ECS). The latent constructs of Davis's (1989) TAM structure have been defined, given examples, and contextualized towards using different simulation software. We emphasized significant findings of recent studies that could support the proposed extended model in Fig. 2.

Perceived usefulness (PU) is the degree to which an individual believes that using a particular system would improve their work or design and that being useful is attributable to the capability of being used advantageously (Davis, 1989). Based on extensive empirical evidence of TAM-based literature, arguably, PU is a major factor affecting attitudes toward accepting and intention to use computer simulation applications similar to the ECS concept (e.g., building information modeling (BIM) and computer-aided designs (CAD)). For instance, Zhao et al. (2022) found a positive relationship among architectural, engineering, and construction professionals' usage of BIM technologies, specifically on their perceived usefulness and behavioral intention to use the system. The same significant results were revealed in the context of a basic design studio, a CAD architectural application software used in online teaching amidst the COVID-19 pandemic (Abu Alatta et al., 2022). Therefore, if students or electronics professionals perceive the advantages of using the ECS for self-study and hands-on circuit designing, their attitude toward using the software will be more positive. Hence, we hypothesized that: 1) PU positively affects the behavioral intention to use **(H5)** and 2) PU positively affects the ATU **(H6)**.

On the other hand, PEU refers to the degree to which an individual believes that using a particular system would be free of effort," where ease is defined as "freedom from difficulty or great effort" (Davis, 1989). PEU significantly affects PU and ATU in myriad contextual applications. Recent findings include PEU and PU as important factors in the acceptance and use of simulation software such as building information modeling (Bastan, Zarei, & Tavakkoli-Moghaddam, 2022), online learning and computer-based simulation systems (Rafique et al., 2018), non-immersive virtual reality (Mohamad et al., 2022), among others. Thus, if a user feels that a particular simulation software related to their field of specialization is easy to use, they will see it as a valuable tool in achieving their tasks, reflecting their attitude towards using the software. In these contexts, we believe that: 1) PEU positively affects PU **(H7)** and 2) PEU positively affects ATU **(H8)**.

Kaplan (1972) defined attitude as a tendency to respond to an event favorably or unfavorably. Generally, attitude towards using (ATU) is an appreciation of a person's overall affective response to use a software (Davis, 1989), while behavioral intention (BI) is the degree of a person's valuation to continue using the system (Venkatesh et al., 2003). BI is a latent construct derived from Ajzen and Fishbein (1980), which was operationally defined as the likelihood that a person will employ a specific application (i.e., ECS). The connection between ATU and BI implies that users tend to follow certain behaviors based on their positive attitude toward them. To explain further, BI is an individual's subjective probability of performing a specified behavior and is the primary determinant of actual usage behavior (Ajzen, 1985). It is defined as a behavioral tendency to keep using technology in the future; therefore, it determines the acceptance of technology (Alharbi & Drew, 2014). Examples of recent studies connecting significant positive relationships between ATU and BI are as follows: 1) Shahzad et al. (2022) in the context of the financial portal system, 2) Papakostas, Troussas, Krouska, and Sgouropoulou (2023) on the adoption of mobile augmented reality in education, and 3) Batucan et al. (2022) and Mailizar et al. (2021) in e-learning amidst COVID-19 pandemic. Premised on these arguments, we hypothesized that ATU positively affects the behavioral intention to use **(H9)**.

The most endogenous variable in the model is the actual system use (ASU). The ASU refers to the human conviction to accept and utilize various strategies to use the technology in an enterprise (also actual adoption) (Jnr & Petersen, 2022). The actual usage stemmed from the users' personality traits of being receptive, motivated, and aware of a particular technology such as ECS. Davis (1989) has identified ASU as the final path with a significant relationship with BI. In the context of students' attitudes towards massive open online courses (MOOCs), the work of Al-Rahmi et al. (2021) revealed a direct relationship with the significant path from BI to ASU. Thus, we hypothesized that BI positively affects ASU **(H10)**.

3. Methodology

3.1. Participants

A total of 445 electronics enthusiasts from the Central Visayas Region (Region 7), Philippines, participated and volunteered to complete the survey. We engaged enumerators, including instructors, students, and graduates from electronics-related programs across multiple universities in the region. Participation in the survey is voluntary due to the unknown population size of electronics enthusiasts in the region. An informed consent form was provided in the first section of the questionnaire with options to withdraw from the survey by informing the local ethics review committee. In the data quality audit of the responses, 18 were excluded due to duplication, missing data, and failure to hold the sincerity test. Thus, the final total number of valid respondents was 427, an acceptable number of cases for a structural model with seven latent constructs (Hair, 2009). The demographic distribution of the respondents can be seen in Table 1.

Table 1 presents the demographic characteristics of 427 respondents who are electronics enthusiasts. The sample comprises 229 males and 198 females, making up 53.6 % and 46.4 %, respectively. The age distribution highlights that most of the sample (78.7 %) falls in the age group of 18-23, with 336 individuals, most being students of electronics-related courses. Other age groups (i.e., from 24 to 49) are primarily electronics professionals comprising 21.30 % of the respondents. The ECS user type showed that the majority of the sample (62.8 %) consists of students of electronics-related courses, followed by individuals working in an electronics services company (24.3 %) and those teaching electronics-related subjects/courses (12.9 %). This data indicates the age distribution among electronics professionals and helps identify the target age group for industry-specific initiatives. Lastly, the category of ECS software used shows the software preferences among the sample, with Multisim being the most commonly used software, followed by Every Circuit and Circuit Sims. The table provides valuable insights into the demographics, ECS user type, and ECS software preferences among a sample of electronics professionals, which the industry and academia can use for further research and analysis.

3.2. Instrument

The final instrument is a 41-item survey questionnaire that measures the seven latent constructs in the research model. The indicators for each constructs were adopted from previously validated scales and various studies (i.e., Bhattacherjee & Sanford, 2006; Cigdem & Ozturk, 2016; Davis, 1989; Doll & Torkzadeh, 1988; Harrison & Rainer, 1992; Kollmann et al., 2009; Mathieson, 1991; Pituch & Lee, 2006; Taylor & Todd, 1995) that are relevant to the application of TAM and the antecedent variables in the proposed model. These indicators were contextualized to make them relevant to the acceptance and characteristics of ECS. The measurement is the five-item Likert with the following descriptors: (1) from very much to not at all, (2) from always to never, and (3) from very

Table 1
Demographic characteristics of the participants.

Category		Total n = 427	
		N	%
Sex	Male	229	53.6 %
	Female	198	46.4 %
Age	18-23	336	78.7 %
	24-28	51	11.9 %
	29-33	25	5.9 %
	34-49	15	3.5 %
ECS User Type	Student of electronics-related course	268	62.8 %
	Working in an electronics services company	104	24.3 %
	Teaching electronics-related subjects/courses	55	12.9 %
ECS software used (Multiple responses allowed)	Multisim (formerly Electronics Workbench)	382	89.5 %
	Every Circuit	136	31.9 %
	Circuit Sims	135	31.6 %
	DoCircuits	93	21.8 %
	SPICE	81	19.0 %
	Other ECS	106	24.8 %

high to very low. The details of the questionnaire and the source of various key measures are shown in Appendix A.

3.3. Data analysis

The study employed covariance-based structural equation modeling (CB-SEM) utilizing AMOS software (Version 26) to perform factor and path analysis on the final measurement model. Maximum likelihood was used as the discrepancy estimation method. Model validation was evaluated using regression weights (standardized) or factor loadings, average variance extracted (AVE), and composite reliability (CR), following the approach established by Fornell and Larcker (1981). To assess the model fit, various indices were employed. These are the Chi-square test, comparative fit index (CFI), Tucker-Lewis index (TLI), standardized root mean square residual (SRMR), and root-mean-square error of approximation (RMSEA), as recommended by Hair (2009). However, since the Chi-square test can produce significant results on large sample sizes, the study alternatively used the minimum discrepancy index of the Chi-square (CMIN/df).

Evaluating the strength and significance of the relationships between the latent variables, including their direct and indirect effects, aimed to gain insights into the underlying factors influencing the study's research question (Hair et al., 2014). The hypothesized relationships among the latent constructs were examined based on the existing literature gap and prior research studies. Structural equation modeling (SEM) allowed for the investigation of complex relationships and interactions among the variables (Byrne, 2016). By analyzing the model's fit indices, the study assessed the overall acceptability of the proposed model (Fornell & Larcker, 1981).

4. Results

4.1. Preliminary analysis

Table 2 shows the mean, standard deviation, and correlation across selected variables. The correlation coefficients are all significant at 0.01 (**) alpha levels. The highest correlation was found between ATU and UID ($r = 0.764$, $p < 0.01$), while the lowest correlation was found between PU and CL ($r = 0.372$, $p < 0.01$). All of the constructs meet the discriminant validity test since all the correlation indices of the study variable are <0.90 (Hair, 2009). Without considering other information to explain the structure, the results in zero-order correlations are used to establish the effects of multicollinearity or whether it affects the latent construct's contribution to the path model (Hair et al., 2014). However, it's important to note that interpreting the results does not account for potential multicollinearity or the effects of other variables but is useful in path modeling analysis to better understand the relationships between the variables.

A measurement model was implemented using confirmatory factor analysis (CFA), consistent with the theoretical foundation presented in the hypothesis development section, to confirm that the indicators used in the study empirically measure the intended construct. A parsimonious model was also sought to provide a more straightforward explanation of the phenomenon (Fan et al., 2016). The researchers adopted the criteria Hu and Bentler (1999) recommended to evaluate the CFA model. These criteria include (1) a $\chi2/df$ ratio of less than 3, (2) a root mean square error of approximation (RMSEA) of less than 0.060, (3) a standardized root mean square residual (SRMR) of less than 0.8, (4) a comparative fit index (CFI) of more than 0.9, and (5) a Tucker-Lewis index (TLI) of more than 0.9. Using these criteria, the researchers aimed to ensure that the measurement model had an adequate fit and could be used to test the study hypotheses.

4.2. Testing the measurement model through CFA

Table 3 presents the standardized loadings, composite reliability

Table 3
Construct reliability and convergent validity.

Constructs	Item Code	Standardized loadings	CR	AVE	Cronbach's Alpha
User Interface Design	UID7	0.825	0.930	0.654	0.930
	UID6	0.839			
	UID5	0.844			
	UID4	0.752			
	UID3	0.800			
	UID2	0.797			
	UID1	0.802			
Computer Literacy	CL7	0.630	0.921	0.629	0.926
	CL6	0.779			
	CL5	0.728			
	CL4	0.849			
	CL3	0.883			
	CL2	0.867			
	CL1	0.784			
Perceived Usefulness	PU5	0.817	0.904	0.655	0.912
	PU4	0.804			
	PU3	0.854			
	PU2	0.797			
	PU1	0.771			
Perceived Ease of Use	PEU7	0.767	0.904	0.574	0.907
	PEU6	0.792			
	PEU5	0.755			
	PEU4	0.778			
	PEU3	0.769			
	PEU2	0.736			
	PEU1	0.701			
Attitude Towards Using	ATU1	0.802	0.896	0.633	0.900
	ATU2	0.826			
	ATU3	0.799			
	ATU4	0.796			
	ATU5	0.753			
Behavioral Intention	BI1	0.856	0.938	0.753	0.938
	BI2	0.876			
	BI3	0.880			
	BI4	0.875			
	BI5	0.852			
Actual System Use	ASU1	0.761	0.921	0.701	0.927
	ASU2	0.828			
	ASU3	0.805			
	ASU4	0.898			
	ASU5	0.887			

Table 2
Zero-order correlations of the study variables.

Study Variable	UID	CL	PU	PEU	ATU	BI	ASU
UID	1						
CL	.457**	1					
PU	.575**	.372**	1				
PEU	.762**	.450**	.581**	1			
ATU	.764**	.419**	.628**	.722**	1		
BI	.619**	.452**	.633**	.572**	.630**	1	
ASU	.612**	.458**	.556**	.587**	.547**	.754**	1
Mean	3.90	3.45	3.98	3.72	4.05	3.79	3.50
Standard deviation	0.87	0.71	0.82	0.87	0.85	0.87	0.94

(CR), average variance extracted (AVE), and Cronbach's alpha of the final measurement model. Guided by Hair (2009), the cutoff scores implemented were: standardized loadings should be more than 0.7, and AVE must be greater than 0.5. The reliability of the questionnaire was measured based on the cutoff value of Cronbach's Alpha which must be greater than 0.7 (Hair et al., 2014). The overall measurement model showed very satisfactory fit measures of the χ^2/df (2.14), RMSEA (0.052), SRMR (0.039), CFI (0.942), and TLI (0.936). The consistency of the scales among the constructs is reliable, with Cronbach's alpha indices ranging from 0.900 to 0.938.

4.3. Testing the hypothesized paths through SEM

Causal relationships were tested in the structural model using AMOS 27 software with statistical support of coefficient of determination (R^2) and path coefficient. The result generated by structural modeling for the causal relationships of the proposed hypothesized model has shown in Table 4 and Fig. 3 with the significant values of all paths. All the obtained fit indices meet the suggested ranges: $\chi^2/\text{df} = 2.270$, RMSEA = 0.055, SRMR = 0.063, CFI = 0.934, and TLI = 0.929 (Hair, 2009).

Table 4 and Fig. 3 present the beta coefficients and the final study results, showing that seven paths are significant at $\rho < 0.001$, two paths are significant at $\rho < 0.01$, and one path is significant at $\rho < 0.05$. The data indicate that UID has a direct and positive effect on PU **(H1)** ($\beta = 0.247$; $\rho < 0.01$) and PEU **(H2)** ($\beta = 0.139$; $\rho < 0.001$). This finding is consistent with previous studies (e.g., Alharbi & Drew, 2014; Liu et al., 2010), demonstrating a significant positive relationship between user interface design and PEU in various technological contexts, including e-learning systems. Thus, it can be deduced that users will be more comfortable and find the ECS system easier to use, confirming that it is designed to be more user-friendly. Furthermore, computer literacy is found to have a direct and positive effect on PU **(H3)** ($\beta = 0.142$; $\rho < 0.05$) and PEU **(H4)** ($\beta = 0.139$; $\rho < 0.01$). Recent studies supported the result (e.g., Ndebele & Mbodila, 2022; Bingtan et al., 2022), which reported that users with higher computer literacy tend to perceive technology as more useful and easy to use, as they possess the necessary skills to interact with the system. Therefore, enhancing users' computer literacy may increase their acceptance and use of the ECS software.

Moreover, PU was found to have a direct and positive effect on BI **(H5)** ($\beta = 0.45$; $\rho < 0.001$) and ATU **(H6)** ($\beta = 0.27$; $\rho < 0.001$). This is consistent with the study of Kalayou et al. (2020). This shows that increased perceived usefulness leads to increased attitude and intention to use ECS. In addition, PEU was found to have a direct and positive effect on PU **(H7)** ($\beta = 0.45$; $\rho < 0.001$) and ATU **(H8)** ($\beta = 0.27$; $\rho < 0.001$). The result is similar to the study of Sánchez-Prieto et al. (2017), who indicate that PEU positively predicts PU and BI in the context of acceptance of mobile technologies. When the system is easy to use, users will find it very useful; therefore, they will have stronger intentions to use the ECS software. Also, ATU was found to have a direct and positive effect on BI **(H9)** ($\beta = 0.419$; $\rho < 0.001$). This finding is consistent with the Mailizar et al. (2021) study, which indicates that attitude significantly influenced the intention to use e-learning. The last path indicates that BI has a direct and positive effect on ASU **(H10)** ($\beta = 0.776$; $\rho < 0.001$). Thus, the finding of this study revealed that when the user has a high level of intention to use ECS will positively influence the actual system use.

Table 4
Hypothesis testing by structural equation modeling.

Hypothesis	Path	β	SE	CR	Label
H1	UID → PU	0.247**	0.084	2.937	Yes
H2	UID → PEU	0.139***	0.054	2.559	Yes
H3	CL → PU	0.142*	0.063	2.266	Yes
H4	CL → PEU	0.139**	0.054	2.559	Yes
H5	PU → BI	0.450***	0.067	6.718	Yes
H6	PU → ATU	0.270***	0.051	5.291	Yes
H7	PEU → PU	0.316***	0.092	3.43	Yes
H8	PEU → ATU	0.639***	0.055	11.665	Yes
H9	ATU → BI	0.419***	0.064	6.581	Yes
H10	BI → ASU	0.776***	0.049	15.748	Yes

5. Discussions

This study shows five important points of findings that possess higher and more significant relationships worthy of the discussion about the acceptance and use of the ECS as a tool in developing circuit designs. First, the findings of this study support the existing literature on the relationship between PU and BI **(H5)** in the context of technology adoption (e.g., Bailey et al., 2022; Bingtan et al., 2022). In the context of using ECS for developing circuit designs, the electronics enthusiasts in this study (students in electronics-related courses, instructors, and electronics professionals) perceive the ECS as convenient and efficient to use, leading to adopting it for developing circuit designs and projects. Thus if users believe that using the ECS is effortless and requires little effort to learn, and they believe that the ECS can help them to achieve their design goals, they are more likely to use the software. Recent studies have emphasized the importance of PU in adopting technology in various fields, such as healthcare (Zin et al., 2023) and CAD architectural application software used in online teaching (Abu Alatta et al., 2022), indicating its relevance in multiple contexts. Therefore, the findings of this study have practical implications for ECS developers, as they highlight the importance of designing user-friendly and efficient systems to increase user acceptance and adoption.

Secondly, the finding of a positive and direct effect between PEU and PU **(H7)** in the context of using ECS for teaching-learning basic electronics or circuit designing among electronics professionals is significant. The implication is that when users find the system easy to use, they are more likely to perceive it as useful in their learning or work-related tasks. Educators and developers of ECS software should prioritize user-centered design approaches that make the system easy to use and understand, especially for novice users. This can include providing clear instructions and intuitive user interfaces, allowing seamless navigation and interaction with the system. In other words, these findings can inform pedagogical practices in teaching basic electronics. Educators can help students develop a deeper understanding of circuit design pedagogical approaches and foster a more engaging learning experience vital for the next generation of innovators in the field (Honey & Kanter, 2013; Patteti, 2021). Using ECS software can also provide students with opportunities to develop practical skills relevant to their future careers in engineering or related fields. The positive relationship between PEU and PU highlights the importance of considering user perceptions when developing and implementing ECS software in basic electronics education.

Third, the study results indicate that PEU directly and positively impacts ATU **(H8)** in the context of ECS. This finding suggests that when users perceive the ECS software as easy to use, they are more likely to have a positive attitude towards using it for developing circuit designs. This finding is consistent with prior research by Martinho, Sobreiro, and Vardasca (2021) on online learning and Rafique et al. (2018) on mobile services, which found that users are more likely to adopt and have a positive attitude toward technology when it is perceived as easy to use. The importance of PEU in adopting and accepting technology is particularly relevant in a developing economy like the Philippines, where there may be varying levels of computer literacy and familiarity with technology. Therefore, ensuring that the ECS software is designed with an intuitive user interface and is easy to use can be crucial for its successful adoption and effective use in teaching basic electronics.

Fourth, ATU was found to have a positive and significant effect on BI **(H9)** to use ECS, implying that the more users develop positive attitudes towards ECS, the more they are inclined to use it. The result is consistent with the study by Estriegana et al. (2019) on acceptance of virtual learning laboratories; Akman and Turhan (2017) on acceptance of social

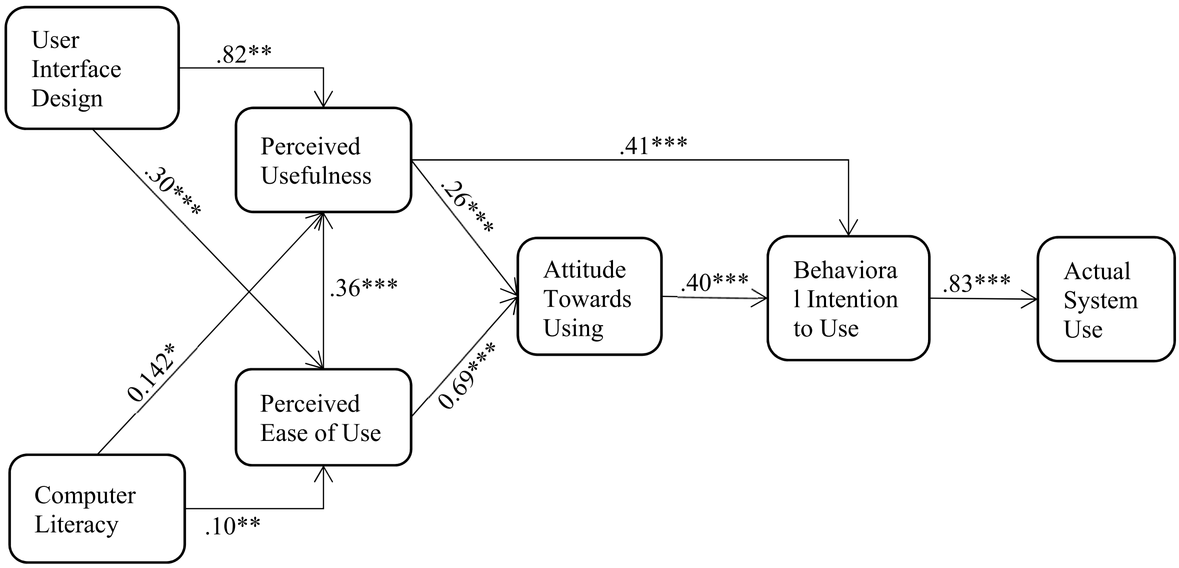

Fig. 3. The path coefficients of the final model.

learning systems; and Moreno, Cavazotte, and Alves (2017) on e-learning platforms, which demonstrated that attitude is a significant predictor of intention. Thus, this finding was not surprising, considering that attitudes can be shaped by the system's characteristics and usage of the system (Abu Alatta et al., 2022). Lastly, there is a positive and direct effect between BI and ASU **(H10)**. It means that users who intend to use ECS will positively affect the system usage. Like Batucan et al. (2022), the study concluded that individuals with higher behavioral intentions would positively influence their usage behavior.

6. Implications to teaching basic electronics

The results of the study have important implications for the teaching of basic electronics. Specifically, the results suggest that to enhance students' learning experience and outcomes, it is important to consider the design of the user interface of the ECS software used in teaching basic electronics. Given that the UID positively affects both the PU **(H1)** and PEU **(H2)** of the ECS software, educators and software developers should prioritize user-centered design approaches that make the system easy to use and understand for novice users. This can include providing clear instructions and intuitive user interfaces that allow seamless system navigation (Farhan et al., 2019). A more user-friendly ECS could enhance electronic hardware experimentation that are important in teaching basic electronics.

Additionally, the study highlights the importance of computer literacy (CL) in students' perceptions of the usefulness and ease of use of the ECS software. Therefore, educators should ensure students have the necessary computer literacy skills before introducing them to the ECS software. This can involve providing training sessions or tutorials on basic computer skills and software usage or incorporating such training into the basic electronics curriculum. Thus, the study put forward the importance of considering user perceptions and computer literacy when designing and implementing ECS software in basic electronics education. In preparing learning materials, it is crucial to incorporate an open-ended number of projects at varying levels of difficulty, enticing the students' different types of thinking (Gonzales, 2022, p. 2022). By doing so, educators can enhance students' learning experience and outcomes in basic electronics and equip them with the practical skills necessary for success in their future careers.

From the perspective of a developing economy like the Philippines, there may be unique challenges that need to be considered when implementing electronics circuit simulation (ECS) software in teaching basic electronics. For example, computer literacy levels among students and educators may vary widely, with some students having limited exposure to technology and computing (Batucan et al., 2022). This can pose challenges to the effective use and adoption of ECS software in the classroom in our effort to bridge the gap between theoretical classroom practices and work-related applications (Kondaveeti et al., 2021). Additionally, there may be limited access to technology and software, particularly in more remote areas. The results serves as an input to educational leaders in ensuring that all students have equal access to the ECS software and related resources. The UID of the ECS software may need to be tailored to the challenges posed by learners in developing economies. Developers may ensure that the language used in the software is easily understandable and accessible to students with limited English proficiency. Considering the specific challenges and contexts of developing economies is vital when designing and implementing ECS software in basic electronics education. By doing so, educators can ensure that the software is practical and accessible for all students and that they have the necessary skills and resources to succeed in their studies and future careers.

7. Conclusion

The present study investigates the acceptance and use of ECS software among electronics students, teachers, and professionals, with user interface design and computer literacy as antecedent variables of TAM. The proposed model provides a better understanding of the factors that affect the acceptance and use of ECS software, confirming all hypothesized paths with significant results. The findings showed that the ECS user interface design positively affects PU and PEU. The results suggest that PEU positively and directly affects attitude towards using the software, positively affecting behavioral intention to use and actual system use. Thus, the ECS is perceived as convenient and efficient, leading to its adoption for developing circuit designs and projects among students and electronics professionals.

Teaching basic electronics in developing economies like the Philippines is crucial for the country's economic growth. Basic electronics education provides students fundamental knowledge and skills in designing, troubleshooting, and repairing electronic systems and devices. With the country's increasing demand for electronic products and services, the need for skilled electronics professionals is also increasing. Hence, understanding the user's acceptance of innovative technologies like ECS software in teaching basic electronics is essential in enhancing the quality of education and producing competent graduates in the field. Using ECS software can provide students with a virtual laboratory experience, allowing them to design and simulate electronic circuits and apply their knowledge in practical applications.

Although the findings of this study contribute to the existing literature on the acceptance of ECS, some limitations must be acknowledged. The geographical limitation of the sample to the Philippines may restrict its broader applicability to a more diverse population. Hence, further research should aim for a larger and more varied sample to enhance the generalizability of the findings. Furthermore, future research can explore the experiences of electronics enthusiasts in small-scale electronics companies or those in the business incubation process to better understand their challenges in implementing ECS in their operations. It should be noted that these limitations do not affect the overall contribution of the study, which highlights the importance of user interface design and computer literacy in facilitating the acceptance and use of ECS software among electronics students and graduates in developing economies.

CRediT authorship contribution statement

Aderito G. Gonzales: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Gamaliel G. Gonzales:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – review & editing.

Declaration of competing interest

We declare that our university funded this study, and some of the respondents are authors' students. We acknowledge the potential conflicts of interest and affirm that they did not influence the research design, data collection, analysis, or interpretation of results. The study was conducted in adherence to ethical principles and scientific rigor. We declare that no financial or personal relationship could potentially bias our findings.

Appendix A. Constructs, Measurement indicators, and Sources

Construct	Code	Indicators	Sources
Perceived Usefulness (PU)	PU1	ECS improves the performance of my work [learning].	Davis (1989)
	PU2	ECS increases the productivity of my work [learning].	
	PU3	ECS enhances the effectiveness of my work [learning].	
	PU4	ECS makes easier for me to carry out my tasks.	
	PU5	I find ECS useful for my work [learning].	
Perceived Ease of Use (PEU)	PEU1	Learning to operate the ECS is easy.	Davis (1989)
	PEU2	I find it easy to get an ECS and to do what I want.	
	PEU3	I find interaction with an ECS clear and understandable.	
	PEU4	I find ECS flexible to interact with.	
	PEU5	It is easy for me to become skillful at using an ECS.	
	PEU6	Using an ECS enables me to accomplish my tasks more quickly.	
	PEU6	Overall, I find ECS easy to use.	
Attitude Towards Use (ATU)	ATU1	Using ECS in my work [learning] is a good idea.	Taylor and Todd (1995)
	ATU2	Using ECS in my work [learning] is a wise idea.	
	ATU3	Using ECS in my work [learning] will be pleasant.	
	ATU4	Using ECS would enhance my effectiveness in work [learning].	
	ATU5	Overall, I like the idea of using ECS in my job.	
Behavioral Intention to Use (BI)	BI1	I intend to use ECS to assist my work [learning].	Cigdem and Ozturk (2016)
	BI2	I intend to use functions of ECS to assist my work [learning].	
	BI3	I intend to use ECS as an autonomous tool in work [learning].	
	BI4	I would like to see ECS functions implemented further in other tasks.	
	BI5	I feel confident with ECS and would like to use it more effectively.	
Actual System Use (ASU)	ASU1	Overall, to what extent do you use ECS?	Mathieson (1991)
	ASU2	To what extent did you use ECS last month?	
	ASU3	To what extent did you use ECS last week?	
	ASU4	I use the ECS to share/seek solutions to problems in work [learning].	Pituch and Lee (2006)
	ASU4	I frequently use the ECS to supplement my work [learning].	
User Interface Design (UID)	UID1	ECS lay-out is a user-friendly.	Doll and Torkzadeh (1988)
	UID2	The ECS provides the precise information I need.	
	UID3	The information in the ECS is presented clearly.	
	UID4	The ECS is easy to use.	
	UID5	I am satisfied with the accuracy of the ECS.	
	UID6	The ECS provides sufficient information.	
	UID7	Overall, I am able to use the ECS.	
Computer Literacy (CL)	CL1	How would you rate your technical knowledge, i.e., your knowledge about specific languages, applications, platforms, and tools?	Bhattacherjee & Sanford, 2006; Kollmann et al., 2009
	CL2	How knowledgeable are you on using the following technologies: computers?	
	CL3	How knowledgeable are you on using the following technologies: word processing?	
	CL4	How thorough is your current knowledge on spreadsheets?	
	CL5	How confident are you in using the computer to write a letter or essay?	Harrison and Rainer (1992)
	CL6	How confident are you in getting software up and running?	
	CL7	How confident are you in moving the cursor around the monitor screen?	

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