Determinants of Intention to Use Simulation-Based Learning in Computers and Networking Courses: An ISM and MICMAC Analysis

Shahla Asadi, Jordan Allison, Mohammad Iranmanesh, Masood Fathi, Mahmood Safaei and Faisal Saeed*

***Abstract* — Simulation-based learning (SBL) presents a wide variety of opportunities to practice complex computer and networking skills in higher education, employing various platforms to enhance educational outcomes. The integration of SBL tools in teaching computer networking courses is useful for both instructors and learners. Furthermore, the increasing importance of SBL in higher education highlights the necessity to further explore the factors that affect the adoption of SBL technologies, particularly in the field of computer networking courses. Despite these advantages, minimal effort has been made to examine the factors that impact instructors' intentions to use SBL tools for computers and networking courses. The main objective of this study is to examine the factors that affect instructors' intentions to utilize SBL tools in computer networking courses offered by higher education institutions. By employing Interpretive structural modeling (ISM) and Matriced' Impacts Croise's Multiplication Appliquee a UN Classement (MICMAC) analysis, the research attempts to provide an in-depth understanding of the interdependencies and hierarchical associations among twelve identified factors. Results showed that system quality, self-efficacy, technological knowledge, and information quality have high driving power. This study offers valuable perspectives for higher education institutions and for upcoming empirical studies and aids in comprehending the advantages of using SBL tools in teaching and higher education.**

***Index Terms*— Digitalization, Intention to use, ISM, learning, MICMAC, Simulation-based, Technology adoption.**

I. INTRODUCTION

HIGHER education is witnessing a transformation and has constantly embraced advanced technologies. The integration of advanced technologies in higher education has revolutionized learning performance and has had a substantial influence on education consequences, offering students access to new resources, fostering collaboration and communication, and enhancing critical thinking and problem-solving abilities [1]. Due to advancements in technology in higher education settings, the significance of computer networks is amplified. Computer networks aid in seamless communication, network infrastructures, data transfer, and collaboration across devices, systems, and users [2]. The traditional methods of teaching in higher education for computer networking frequently encounter challenges in providing a comprehensive understanding of complex networking concepts to learners [3]. Particularly, the absence of practical and hands-on experience can hinder learners' knowledge, lower their performance, and their retainment of essential principles in networking [4]. Furthermore, relying only on theoretical training can restrict learners' understanding, hindering their capability to implement knowledge proficiently in actual situations [5] therefore, practical practice plays an essential role in spanning the gap between theory and practice in computer network education.

Simulation-based learning (SBL) has emerged as an innovative technology to enhance computer networking teaching and learning. Overall, SBL refers to the utilization of simulation software, tools, and serious games to enrich training and learning practices. SBL settings, including virtual reality, computer network simulation, and intelligent systems, embody "interactive digital learning environments that replicate authentic processes or situations . . . permitting learners to experiment with their hypotheses regarding the impact of input variables on desired outcomes" [6]. SBL provides secure and immersive environments for students to practice their practical skills [7]. SBL integrates intellectual, technical, and collaborative capabilities into an environment that reflects real-life scenarios, enabling students to engage as they would in practical settings while feeling safe to learn from their mistakes [8]. Additionally, SBL has emerged as a valuable tool for instructors to evaluate and suggest feedback on the performance of learners in technical skills and decision-making, in a personalized and efficient manner [9]. Campos et al [10] asserted that learning approaches based on SBL software and tools are appealing to academic and industrial collaborators.

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These collaborators realize SBL is an effective method to educate their learners and forthcoming employees. Fig.1 shows the published articles retrieved from Google Scholar using the search term "simulation-based learning" over the past twelve years. The findings reveal an approximately threefold increase in the number of studies on SBL in Google Scholar.

The higher education sector is currently experiencing a substantial shift due to sophisticated technologies, including computer networking [11]. Kaewwit and Chulajata [12] acknowledged that the present educational environment needs the employment of information technology to facilitate the procedure of learning. Thus, to improve the networking knowledge of learners, the use of simulation networking tools is considered crucial for learners' understanding and visualization of computer network courses. Allison [2] revealed the significance of network simulation tools in enhancing the teaching and learning of computer networks, specifically by utilizing the Cisco Packet Tracer. The author emphasized that practical and hands-on activities are crucial to be employed along with any theory session. The mix of theoretical and practical methods aids learners in understanding computer networking principles and their components.

Despite the significance of SBL in higher education, particularly in the field of computers and networking, SBL tools have not been fully integrated as an essential practical approach in networking courses [2]. While prior studies mostly focused on investigating SBL tools and their design patterns [12-14], few have investigated the factors that impact the intention of instructors to use SBL in computer networking courses. Thus, it is essential to realize the factors that impact instructors' intention to use SBL, which is critical for effectively incorporating this promising technology into the educational context.

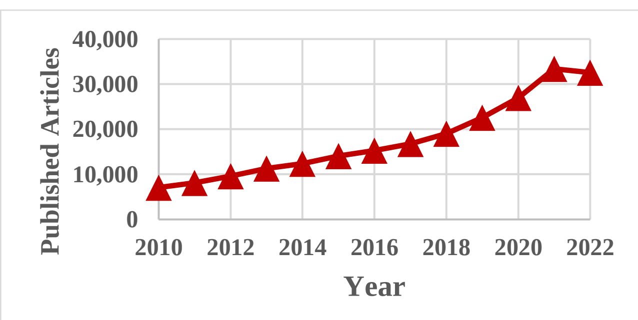

Fig. 1. The progression of the term "simulation education" in Google Scholar.

Our study examines the difficulties encountered by conventional teaching approaches in computer networking and the increasing significance of practical, experiential learning for effective education. SBL is being used to address this issue, and our research seeks to enhance the comprehension and use of SBL in the field of computer networking. For this reason, this study initially conducted a systemic literature review to identify the determinants of SBL. Then, interpretive structural modeling (ISM) [15] and MICMAC analysis [16] were employed, where both are widely recognized approaches for discovering interdependencies and hierarchical interrelations among factors. The ISM approach offers the benefit of being a scientific methodology initiated by the professionals' opinions and practical knowledge. Hence, this study seeks to tackle the following objectives.

- To identify the factors impacting instructors' intention of using SBL for computers and networking courses.
- To determine interactive and hierarchical relationships between these factors through ISM and MICMAC analysis.

The novelty of the work lies in investigating the factors that impact instructors' intention to use SBL from the perspective of computer networks and simulation, which have received limited investigation. By examining these factors, this study will aid higher education institutions in the development of effective strategies to promote the widespread use of SBL for enhancing the teaching and learning experience. This will enable institutions to remain competitive in the educational sector by embracing potential simulation tools. Moreover, this study represents one of the pioneering research efforts employing the ISM method to rank the determinants of SBL and to verify the contextual relationships among determinants. Additionally, a hierarchical structural model has been constructed using an ISM approach to determine the prioritization and interrelationships among these factors. The study offers effective information and guidance for educational managers in effectively managing and implementing SBL strategies in enhancing the teaching of computer networks and empowering instructors to create dynamic and effective learning environments. In addition to investigating factors influencing instructors' intention to use SBL in computer networking, our work presents an innovative approach by considering the influence of current improvements in simulation technologies. According to the responses provided by the participant's demographic information, we examined the incorporation of the Cisco packet tracer, a widely used software in SBL environments. The objective of this broader scope is to offer a thorough comprehension of how advancing technologies might improve the efficiency of SBL in computer networking education.

II. FACTOR IDENTIFICATION

This study performed a Systematic Literature Review (SLR) to provide a comprehensive understanding of the factors that impact instructors' intention to use SBL for computers and networking courses. SLR is a robust methodology for synthesizing research findings and establishing an in-depth understanding of a research topic [17]. In this study, we followed guidelines proposed by Moher, and Liberati [18] for the SLR to ensure a comprehensive examination of subjects and content and to ensure reliability in outcomes.

For the search process, we used the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)"

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protocol by Moher, and Liberati [19]. The search string in Scopus consisted of a combination of the following terms: "Simulation-based learning" OR "SBL" OR "Simulation in learning" AND "Computer" OR "Networking" OR "Computer networking" in the title, abstract, and keywords sections of articles. A total of 507 articles were identified from the screening. In the next stage, we removed duplicate articles and applied inclusion and exclusion criteria from the Scopus database. Articles outside the publication range of 2012 to April 2023 were deleted, resulting in 359 remaining articles. We excluded Conference Reviews, Book, Editorial, and Letter articles, leaving 351 remaining articles. To ensure inclusivity, our focus was exclusively on empirical publications that examine the factors influencing simulation-based learning (SBL) through the use of simulation tools in education. To alleviate any potential bias, a comprehensive screening process was put into effect.

We only considered articles in the past ten years, as updates in technology and simulation tools mean that articles older than ten years may be greatly outdated. Indeed, Pieper et al (2014) suggest that review papers older than five years have a high risk of being outdated. Next, we filtered based on the subject area and excluded non-English articles, resulting in 301 records in Scopus for analysis. Fig. 2 illustrates the details of the study selection procedure using the PRISMA approach. The utilization of the PRISMA approach guaranteed that the study selection process was transparent and traceable, hence reducing possible biases and strengthening the reliability of the SLR.

VOSViewer software was used to provide bibliometric insights within the literature. Bibliometric analysis is a quantitative approach to exploring and assessing scientific publications and other forms of written communication. It involves analyzing the structure and content of publications, as well as their citations, to provide insights into scientific research and communication patterns [20].

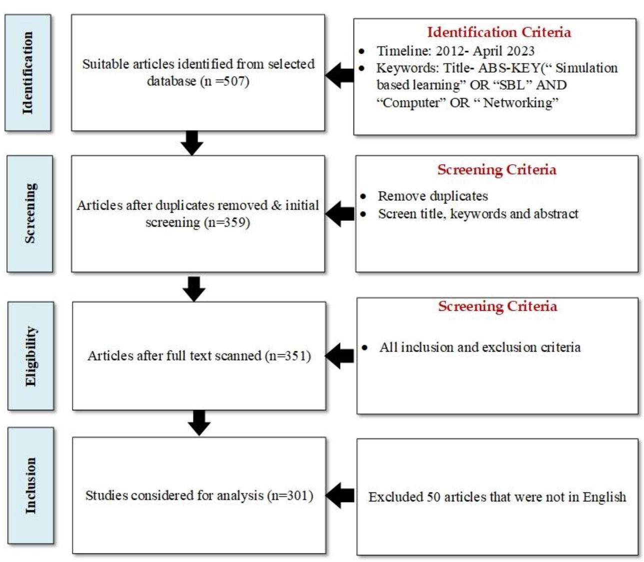

Fig. 2. Procedure for Selecting and Excluding Articles in SLR.

The reason for using all three methodologies is based on their complementary capabilities for obtaining a full understanding of the issues present in the research. Systematic Literature Review (SLR) provides a comprehensive examination of the current research, while Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) enhances the simplicity and transparency of reporting. In addition, bibliometric analysis provides a quantitative aspect for fuller comprehension. Every method contributes a distinct viewpoint, thus augmenting the strength and comprehensiveness of the literature review.

The use of different approaches corresponds to our dedication to accuracy and inclusion, offering a detailed examination of the factors being considered. A combination of these techniques enhances the depth and dependability of the literature review.

As displayed in Fig. 3, the terms simulation-based learning, students, computer-aided instruction, computer simulation, human, education, learning systems, and teaching were the most frequently utilized keywords in the abstract, keywords, and literature of those articles included in the SLR.

The result and analysis of the SLR approach led to the recognition of twelve factors that impact instructors' intention to use SBL for computers and networking courses, namely: self-efficacy (SE), perceived usefulness (PU), perceived enjoyment (PEN), personal innovativeness (PI), technological knowledge (TK), performance expectancy (PE), system quality (SQ), information quality (IQ), perceived ease of use (PEOU), social influence (UA), facilitating conditions (FC), and improves productivity (IP). Table I demonstrates the significance of these factors, as identified by previous studies. The explanations of the twelve identified factors are presented in the sub-sections below.

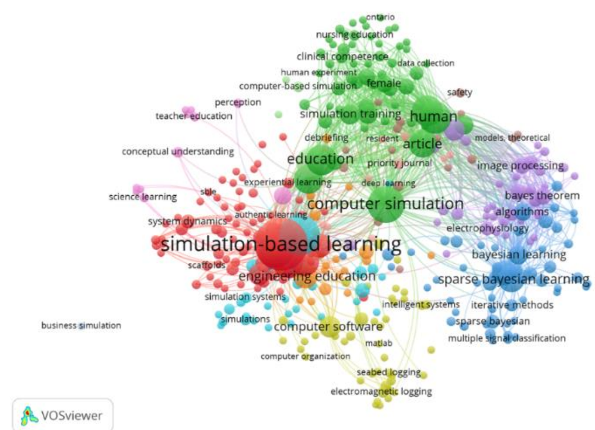

Fig. 3. Co-occurrence of authors' keywords for SBL.

A. Self-efficacy (SE)

Self-efficacy (SE) can be defined as a positive and forward-looking perception that individuals believe they hold the necessary skills, ability, and competence to attain some objective successfully [21]. Prior studies demonstrate that SE is among the most significant factors that impact SBL usage in higher education [22, 23]. People who have a strong perception of self-efficacy can overcome challenges and obstacles through their effort and self-skills [24]. Several studies prove that SE is a significant contributor to understanding and achievement, which evolves depending on the experiences of individuals [25]. SE can boost individuals' success and self-assurance by positively affecting their ability to take responsibility, which is a crucial aspect in guaranteeing excellence and inhibiting wrong beliefs [26]. The importance of SE in computer and networking courses, such as Cisco Packet Tracer (CPT) and GNS3, as SBL tools in higher education, lies in its ability to empower and enhance instructors' practical experience in teaching computers and networking principles.

PU can be identified as a person's perception that the usage of a technological system will remarkably increase a person's performance [27]. PU is indicated by an individual's belief that using a technological system can aid ongoing developments in their individual and professional performance. Consequently, PU aids in clarifying the extent to which technology develops the individual's performance productivity, or effectiveness in the workplace [28]. Numerous studies have acknowledged that when users recognize technology as applicable and valuable, the likelihood of having a positive intention to use it is high [29, 30]. Previous studies strongly support the positive effect of PU on students' perception of the use of SBL [31, 32]. When it is perceived that SBL tools like Cisco Packet Tracer and GNS3 are relevant to enhance student learning and can assist students in achieving learning objectives and increasing their understanding of complex networking concepts, the likelihood of adopting and using these tools will be increased.

B. Perceived usefulness (PU)

PU can be identified as a person's perception that the usage of a technological system will remarkably increase a person's performance [27]. PU is indicated by an individual's belief that using a technological system can aid ongoing developments in their individual and professional performance. Consequently, PU aids in clarifying the extent to which technology develops the individual's performance productivity, or effectiveness in the workplace [28]. Numerous studies have acknowledged that when users recognize technology as applicable and valuable, the likelihood of having a positive intention to use it is high [29, 30]. Previous studies strongly support the positive effect of PU on students' perception to use SBL [31, 26]. When it is perceived that SBL tools like Cisco Packet Tracer and GNS3 are relevant to enhance student learning and can assist students in achieving learning objectives and boost their understanding of complex networking concepts, the likelihood to adopt and use these tools will be increased.

C. Perceived ease of use (PEOU)

PEOU indicates the extent to which a person believes that utilizing a certain system would need minimal attempt [50], which is a significant factor that leads to the rapid approval of new and innovative technology-based applications [51]. Past findings have confirmed that PEOU impacts a user's intention to use new technology [52, 53]. This relationship has been empirically confirmed in several technological areas including augmented reality [54], m-learning [52], Internet of Things services [55], and SBL [56]. When individuals identify technology as simple to use, they are prone to have more positive attitudes toward using that technology [57]. Accordingly, PEOU is a critical factor in influencing a user's intention to use novel technology. Therefore, we assume that if instructors perceive SBL tools, such as Cisco Packet Tracer, GNS3, OPNET, OMNET++, or other networking tools, as easy to use, they will be more inclined to embrace SBL tools in their teaching.

TABLE I. INFLUENCING FACTORS ON INTENTION TO USE SBL TOOLS IN PREVIOUS STUDIES

Researcher	**Factors**											
	SE	**PU**	**EN**	**PI**	**TK**	**PE**	**SQ**	**IQ**	**PEOU**	**SI**	**FC**	**IP**
Lemay, Morin [31]				√					√			
Lu and Lin [32]		√	√	√								
Pardiñan and Loremia [33]		√		√			√	√	√			
Hung, Kao [34]	√			√								
Ah-Fur, Chien-Hung [35]		√		√					√			
Zulfiqar, Zhou [36]		√	√						√			
Juera [37]		√							√			
Bamufleh, Hussain [38]				√		√				√	√	
Lin, Wang [39]		√	√	√								
Christensen, Hillaire [40]	√											

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Yeşilyurt, Ulaş [41]	√							
Chiu, Chen [42]								√
Bürgi [43]								√
Al-Mamary [44]							√	
Alyoussef [45]							√	
Khan, Hameed [46]						√		
Norström [47]		√						
Meirovitz, Russak [48]		√						
Al Mulhem [49]				√				
Su and Chao [50]			√	√	√	√	√	

D. Perceived Enjoyment (PEN)

According to Kim and Drumwright [58], PEN refers to the inherent motivation that arises from the pleasure and enjoyment experienced while using a system. Numerous studies have extended the Technology Acceptance Model (TAM) theory by including PEN, which has typically been deemed as a fundamental hedonic factor [59]. In the context of e-learning, Hunde, Demsash, and Walle [60] disclosed that health students intend to utilize e-learning systems when they perceive e-learning systems as more enjoyable and pleasurable. PEN enhances performance since it improves focus on tasks, leading to increased intrinsic and extrinsic motivation in students [61]. Similarly, PEN may promote the adoption of flexible intellectual approaches, as well as interest and motivation to learn [62]. Thus, in the present study PEN has substantial importance in determining instructors' intention to use SBL tools for computer and networking, such as Cisco Packet Tracer, GNS3, OPNET, OMNET++, and other networking tools. When instructors perceive the learning procedure as enjoyable and pleasurable experiences, they are more likely to be interested and involved in using simulation-based tools for their students.

E. Information quality (IQ)

Information quality (IQ) refers to the precision, completeness, simplicity, clarity, effectiveness, and trustworthiness of information that can meet the users' demands and preferences [63]. The IQ is the level of relevance timeliness, security, and presentation of information based on the users' requirements [64]. The highest IQ can be seen in its capability to generate vast amounts of information both within and beyond the organization [65]. Academic literature has revealed a positive relationship between IQ and users' intention towards the use of e-learning [66], augmented reality [67], and virtual reality in learning [68]. Therefore, it is necessary to prepare information that is precise, complete, relevant, and up to date with users' needs, while presenting it in a successful manner. In this regard, the importance of IQ on instructors' intention towards using SBL tools including Cisco Packet Tracer, GNS3, OPNET, OMNET++, or other networking tools, cannot be neglected. Instructors and students require information about these SBL tools to comprehend how they could be used to help enable students to enhance their practical knowledge and learning experience.

F. System quality (SQ)

System quality (SQ) refers to the "adaptability, availability, reliability, response time, and usability of the system and these are related to the technical characteristics of the system" [69]. According to Widodo [70], SQ is a measure of an information system's technical aspects and is regarded as a functional assessment, including reliability, responsiveness, and flexibility. It signifies the users' perception of the information system's technical service level. Previous studies have found that SQ is the important factor impacting students' satisfaction with using e-learning systems [71, 72]. Moreover, SQ has been identified as a significant predictor of students' intention to use e-learning systems [73, 74]. In the context of the present study, investing in the improvement of SBL tools in terms of functionality, performance, and relevance to networking scenarios can have a positive impact on instructors' intention to use these tools and they will be more eager to use SBL tools in their teaching practice.

G. Performance expectancy (PE)

Performance expectancy (PE) is described as the extent to which an individual supposes that employing a system will leads to enhanced job effectiveness and performance [75]. Venkatesh, Morris [75] referred to PE as an important and basic construct that has a direct influence on intention to use and actual use of technology and has been confirmed as the

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most influential indicator of intention to use. This indicates that individuals are more liable to accept emerging technology if they believe that it will enhance their job performance and success [76]. The consequences of research conducted on technology acceptance for learning have shown that when students or instructors find technology valuable and useful in learning, their intention to engage with new technology increases significantly [77, 78]. Adopting new technologies and tools in learning will improve learners' performance, effectiveness of learning and productivity [79]. Accordingly, SBL tools usage will lead to enhanced learning outcomes and performance. When instructors and learners perceive that SBL is valuable and beneficial for improving their networking skills, they are more inclined to adopt and engage SBL tools in their teaching and learning.

H. Technological knowledge (TK)

Technological knowledge (TK) is described to the degree to which an individual has information and required knowledge about using systems and new technology in a special field [80]. For understanding the various applications and technologies in higher education, it is required for both instructors and students to have knowledge about technology to use for their educational performance and improve outcomes [81]. Bhuasiri, Xaymoungkhoun [82], highlighted the importance of TK in education. They revealed that TK, such as students' computer skills and knowledge about using innovative technologies, is a significant driver of e-learning success in developing countries. This finding was supported by Hailegebreal et al [83] and Dery et al [84], who stated that students with TK are more likely to use ICT compared to those with poor TK. Therefore, acquiring TK through instructors is necessary to ensure learning tools are used to accelerate effective learning and teaching. In the context of SBL, Liu [85] asserted that if students have TK, they are more inclined to use GNS3 tools in the complex subject of networking. Thus, for students and educators who are working practically with SBL tools such as Cisco packet tracer or GNS3, it is crucial to be trained and obtain TK for using these essential tools effectively to enhance understanding and improve performance.

I. Personal Innovativeness (PI)

Agarwal and Prasad [86] suggested that in the context of information technology, personal innovativeness (PI) is theorized to display the consequences of individuals' perceptions regarding new information technology. The PI pertains to individuals' openness to modifying their current circumstances and their ability to embrace risks [87]. Moreover, Noh et al. [88] defined PI as an individual trait that significantly influences consumers' adoption and acceptance of technology. According to Hirschman [89], innovativeness implies an individual's inclination to explore and discover innovative methods for utilizing an existing innovation. Previous studies in terms of consumer behavior have consistently emphasized the significance of PI [90]. Jo [91] found that PI has a considerable impact on individuals' continuance intention toward the smart factory. Therefore, the PI is an attractive and fundamental construct to discover and has an influence on the intention toward utilization technologies like SBL tools for simulation and networking.

J. Social influence (SI)

Social influence is "the degree to which an individual perceives that important others believe he or she should use the new system" [75]. It has been confirmed that individuals are influenced by the perspectives of peers, colleagues, friends, and relatives to adopt technology [90]. Based on the UTAUT theory, SI is a robust predictor of the intention to use new technology [92]. Previous studies have extensively investigated the impact of the SI construct in several contexts and found that SI is an important driver of individuals' intention towards adopting technology [50, 93, 94]. In the educational context, recent literature confirmed that students are influenced by individuals whose opinions they value, leading to the adoption of new technology and direct effect on behavior intention [95, 96]. In the context of SBL tools for networking simulation, if colleagues and other instructors can use tools successfully and achieve positive results, instructors are more likely to be influenced by their opinions, and thus, they are more inclined to use these tools in their networking teaching.

K. Facilitating condition (FC)

Facilitating conditions (FC) refers to "to which extent people believe that an organizational and technical infrastructure exists to support the system" [75]. Indeed, the utilization of SBL tools require specific knowledge, skills, and proficiency. Individuals would be more inclined to adopt the technology if they gain the necessary supporting devices, knowledge, and resources [97].

In the educational setting, FC implies the presence of instructional support, administrative aid, and alignment between the latest technology advancement and further tools that operators frequently utilize [98]. Several studies conducted in distinct contexts have constantly verified the significant positive influence of FC on both intentions to use and the actual adoption of information technologies [44, 45, 50]. We therefore expect that FC will play a crucial role in impacting instructors' intention to use SBL tools. Since SBL tools such as Cisco Packet Tracer, MATLAB, and GNS3 are advanced and require specific resources and technical support, when FC are beneficial, instructors are more likely to use these supported tools. This ultimately leads to increased motivation and engagement with these tools.

L. Improves productivity (IP)

Improves productivity (IP) implies how students actively contribute to educationally purposeful performances [99]. Jones, Mortimer [100] has emphasized the significance of improved productivity in higher education. One crucial way to improve learning productivity and quality is promoting the

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integration of technologies in educational institutions [101]. IP can be viewed from the learning outcomes aspect, where the result is not just based on knowledge enhancement, and developed thinking skills, but also comprises transformations in attitudes and behavior happen after the learning process [102]. Therefore, the integration of SBL in higher education will enhance instructors' intention to use these tools for computer networking subjects. Through dynamic, practical learning, actual application, and real simulation, students can use SBL tools to improve their productivity and creativity in understanding computer networking, resulting in enhanced learning effectiveness which is what instructors would want for their students.

III. RESEARCH METHODS

The primary aim of this study is to identify the factors that impact instructors' intention to use SBL tools in their networking and computer courses. To identify relationships between these factors, this study employed ISM technique, which is one of the most widely utilized interactive learning methods for analyzing qualitative data [103]. Warfield [104] proposed the ISM method, which primary seeks to use the knowledge and practical expertise of experts to systematically evaluate a complex system in terms of its foundational aspects and to construct a multi-tiered structural model to enhance comprehension and analysis.

There are several methods, including DEMATEL, fuzzy DEMATEL, or SVNS-DEMATEL, that have been used by previous scholars for identifying interrelationships in their studies [105-108]. DEMATEL, fuzzy DEMATEL, and SVNS-DEMATEL are methodologies that predominantly attempt to identify the interrelationships inside a system. These techniques have a substantial emphasis on the quantitative aspects and address uncertainties at various levels [109]. DEMATEL employs a matrix-based approach for evaluating dependencies [110], while fuzzy DEMATEL utilizes fuzzy logic to tackle uncertainties in the data [111]. SVNS-DEMATEL develops the approach by incorporating a condition vector to adjust for dynamic relationship factors throughout time [109]. On the contrary, ISM (Interpretive Structural Modeling) is mostly qualitative, giving importance to expert opinions and collaborative brainstorming to create a structural model of the key components of a system [109]. DEMATEL techniques offer an analytical strategy that emphasizes relationships, while ISM prioritizes a qualitative understanding through expert insights and interactive learning approaches. The selection between them is dependent upon the particular characteristics of the research and the intended level of evaluation. In our study we employed the ISM approach since ISM is acknowledged as a highly effective interactive learning approach for analyzing qualitative data. While our study involves qualitative data, the application of ISM (Interpretive Structural Modeling) provides a robust framework for efficiently collecting and utilizing the knowledge and practical competence of experts through collaborative brainstorming. Previous research consistently indicates that ISM is a well-established and robust decision-support analytic tool for uncovering contextual relationships among specific elements [112-114]. It clarifies challenges or issues by demonstrating contextual relationships among specific components. Due to its ability to enhance comprehension and assessment, ISM has been widely used across multiple domains [115].

In the initial stage, the questionnaire was evaluated and validated by experts to ensure the relevance of the twelve factors derived from the literature review. Lynn [116] recommended that it is desirable to involve a minimum of three experts while emphasizing that more than ten experts is unnecessary. Thus, a panel of three experts with extensive expertise in the fields of computer and networking validated the derived factors. Based on the feedback provided by the experts, the questionnaire was modified and improved before being distributed to the respondents.

The sample of expert participants differs in several studies, typically involving five to fifteen experts [117, 118]. In the second stage, in November 2022, twenty qualified experts in the field of computers and networking from the School of Computing and Engineering at the University of Gloucestershire participated in the study. We directly visited the experts and communicated via email regarding the purpose of this study. Based on their readiness and unanimous agreement, the ISM questionnaire (Attached in the supplementary materials) was sent to them via email. Furthermore, this study obtained ethical approval from the institution to conduct questionnaires with the experts.

The demographics of survey participants were as follows: 60% of the respondents were men, and 40% were women. Despite working for the same institution, participants originated from a variety of backgrounds, including England, Iraq, Iran, Tunisia, Bangladesh, Pakistan, India, and China. Regarding education, 60% held a PhD, and 35% held a master's degree. Furthermore, the experts boasted several years of experience in teaching computer networking and cybersecurity, with 60% having accumulated over 5 years of experience and 35% having 3-5 years, and 5% having less than 3 years. In terms of experience of using SBL tools, most respondents exhibited awareness and experience in using SBL tools ranged from 95% using Cisco Packet Tracer, followed by to 5% using GNS3 Cisco VIRL and Boson NetSim.

Fig.4 displays the steps for the ISM methodology applied in this study. For the data analysis of the respondents' answers, we utilized Microsoft Excel and MATLAB software.

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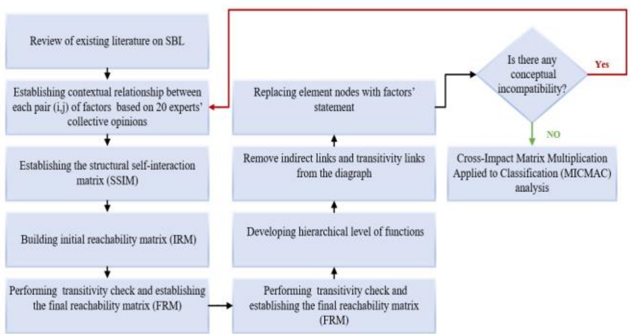

Fig. 4. Procedures for implementing ISM.

IV. RESULTS

The preliminary step for employing the ISM method involved identifying the drivers of SBL through a comprehensive and complete literature review. After finalizing twelve variables as determinants of SBL use, expert opinions were required regarding identifying the interrelationship between these factors. The initial step of implementing ISM was to develop the contextual relationship among the SBL drivers based on the opinions of twenty experts. For creating the "structural self-interaction matrix (SSIM)" the following four symbols were used to realize the relationship between two parameters 'i' and 'j'. Table II signifies the results of the SSIM in this study. For instance, the PI-IQ note is symbolized as O in Table I, implying both functions PI and IQ are independent.
V: Parameter 'i' causes Parameter 'j'.
A: Parameter 'i' is caused by Parameter 'j'.
X: Parameter 'i' and 'j' cause each other.
O: Parameter 'i' and 'j' are unrelated.

In the next step of ISM method, an initial reachability matrix (IRM) was created by converting the V, A, X, O symbols with binary numbers '0' and '1' in SSIM based on the subsequent rules:

- Where the symbol 'V' is depicted in cell (i, j) in the SSIM, the subsequent values in the IRM for cells (i, j) and (j, i) are set as '1' and '0' respectively. Conversely, if the symbol 'A' is found in cell (i, j) of the SSIM, the initial IRM assigns '0'to cell (i, j) and '1' to cell (j, i).
- In cases where the symbol 'X' is occurred in cell (i, j) in the SSIM, both the values in the IRM for cells (i, j) and (j, i) are set as '1'.
- When the symbol 'O' is observed in cell (i, j) in the SSIM, both the values in the IRM for cells (i, j) and (j, i) are designated as '0'.

Table III demonstrates the results of the IRM by converting the SSIM symbols. For instance, revisiting the PI-IQ note which symbolized as 'O' in table SSIM, both values for PI-IQ and IQ-PI are set as 0 in the initial IRM.
The final reachability matrix (FRM) is another step in the ISM method, which involved the transitivity rule based on the IRM. The transitivity rule suggests that if parameter X causes parameter Y and parameter Y cause Z, then X could inadvertently cause parameter Z. Table IV exhibits FRM results, in which '1*' implies the existence of the transitivity rule. In this table, driving power and dependence power of each variable are calculated by summing up rows and columns respectively. For instance, in relation to Table III, SE does not directly cause the variable SI. Nevertheless, SE leads to the variable TK, where SE-TK entry is assigned '1' in the IRM table. Furthermore, TK leads to SI in the IRM with the value of '1', which indicates SE indirectly leads to the variable SI with a '1*' in the FRM matrix (Table IV).
The next step in implementing the ISM approach includes hierarchy extraction. To discover the hierarchy of respected variables, a partitioning level is conducted. This procedure was obtained by determining the reachability and antecedent set for each variable from the FRM, as shown in Table IV. The reachability set of a particular factor encompasses the factor itself along with all another factors that it influences. On the other hand, the antecedent set of a particular factor consists of the factor itself and all of the other factors that influence it. The intersection of the two sets variables (antecedent and reachability set) is regarded as the intersection set. The hierarchy levels are classified based on the extraction level, where the factor has the same reachability set and intersection set and has been designated as the uppermost factor in the hierarchy extraction in the ISM method according to Warfield [104].
By repeating this process (while excluding the factors discovered in the prior iteration), the hierarchic levels of remaining factors are iteratively determined. Table V illustrates the hierarchical levels of the factors presented in this study.
After comprehending the hierarchy of respected variables (refer to Table V) and making use of the IRM, an interpretive hierarchical structural model was generated graphically (Fig. 5). In the context of the interpretive hierarchical structural model, a lower level signifies greater significance or influence on the intention to use SBL. Among the twelve identified factors for the intention to use SBL, the placement of SQ at level 1 indicates it is the most important factor in comparison to other factors. Meanwhile, PEOU at level 5 indicates it is the least important factor in comparison to factors placed at lower levels. PEOU was extracted first in Table V and is at the highest level in Fig. 5, constituting the most dependent factor in the hierarchical structural model. Factors PE, PU, FC, and IP are placed at the next level of the structural model. The remaining seven factors of SBL are positioned at the lowermost levels of the structural model.

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TABLE II. SSIM

Functions	SE	PU	EN	PI	TK	PE	SQ	IQ	PEOU	SI	FC	IP
Self-efficacy (SE)		V	V	V	X	V	O	O	V	O	V	V
Perceived usefulness (PU)			A	O	O	V	A	O	O	O	A	X
Perceived enjoyment (PEN)				O	A	O	A	A	V	O	O	V
Personal innovativeness (PI)					X	O	O	O	O	O	V	V
Technological knowledge (TK)						V	O	O	V	V	V	V
Performance expectancy (PE)							A	A	X	O	O	V
System quality (SQ)								V	V	V	V	V
Information quality (IQ)									V	V	V	V
Perceived ease of use (PEOU)										O	O	O
Social influence (SI)											O	V
Facilitating condition (FC)												X
Improves productivity (IP)												

TABLE III. INITIAL REACHABILITY MATRIX

Functions	SE	PU	EN	PI	TK	PE	SQ	IQ	PEO	SI	FC	IP
Self-efficacy (SE)	1	1	1	1	1	1	0	0	1	0	1	1
Perceived usefulness (PU)	0	1	0	0	0	1	0	0	0	0	0	1
Perceived enjoyment (PEN)	0	1	1	0	0	0	0	0	1	0	0	1
Personal innovativeness (PI)	0	0	0	1	1	0	0	0	0	0	1	1
Technological knowledge (TK)	1	0	1	1	1	1	0	0	1	1	1	1
Performance expectancy (PE)	0	0	0	0	0	1	0	0	1	0	0	1
System quality (SQ)	0	1	1	0	0	1	1	1	1	1	1	1
Information quality (IQ)	0	0	1	0	0	1	0	1	1	1	1	1
Perceived ease of use (PEOU)	0	0	0	0	0	0	0	0	1	0	0	0
Social influence (SI)	0	0	0	0	0	0	0	0	0	1	0	1
Facilitating condition (FC)	0	1	0	0	0	0	0	0	0	0	1	1
Improves productivity (IP)	0	1	0	0	0	0	0	0	0	0	1	1

TABLE IV. FINAL REACHABILITY MATRIX

Functions	SE	PU	EN	PI	TK	PE	SQ	IQ	PEOU	SI	FC	IP	Driving power	*Rank*
Self-efficacy (SE)	1	1	1	1	1	1	0	0	1	1*	1	1	10	1
Perceived usefulness (PU)	0	1	0	0	0	1	0	0	1*	0	1*	1	5	5
Perceived Enjoyment (PEN)	0	1	1	0	0	1*	0	0	1	0	1*	1	6	4

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Personal innovativeness (PI)	1*	1*	1*	1	1	1*	0	0	1*	1*	1	1	10	1
Technological knowledge (TK)	1	1*	1	1	1	1	0	0	1	1	1	1	10	1
Performance expectancy (PE)	0	1*	0	0	0	1	0	0	1	0	1*	1	5	5
System quality (SQ)	0	1	1	0	0	1	1	1	1	1	1	1	9	2
Information quality (IQ)	0	1*	1	0	0	1	0	1	1	1	1	1	8	3
Perceived ease of use (PEOU)	0	0	0	0	0	0	0	0	1	0	0	0	0	6
Social influence (SI)	0	1*	0	0	0	1*	0	0	1*	1	1*	1	6	4
Facilitating condition (FC)	0	1	0	0	0	1*	0	0	1*	0	1	1	5	5
Improves productivity (IP)	0	1	0	0	0	1*	0	0	1*	0	1	1	5	5
Dependence power	3	11	6	3	3	11	1	2	12	6	11	11		
Rank	4	2	3	4	4	2	6	5	1	3	2	2		

TABLE V. HIERARCHICAL EXTRACTION.

Function	**Reachability Set**	**Antecedent Set**	**Intersection Set**	**Extraction level**
Iteration 1				
SE	SE, PU, PEN, PI, TK, PE, PEOU, SI, FC, IP	SE, PI, TK	SE, PI, TK	
PU	PU, PE, PEOU, FC, IP	SE, PU, PEN, PI, TK, PE, SQ, IQ, FC, SI, IP	PU, PE, FC, IP	
PEN	PU, PEN, PE, PEOU, FC, IP	SE, PEN, PI, TK, SQ, IQ	PEN	
PI	SE, PU, PEN, PI, TK, PE, PEOU, SI, FC, IP	SE, PI, TK	SE, PI, TK	
TK	SE, PU, PEN, PI, TK, PE, PEOU, SI, FC, IP	SE, PI, TK	SE, PI, TK	
PE	PU, PE, PEOU, FC, IP	SE, PU, PEOU, PI, TK, PE, SQ, IQ, SI, FC, IP	PU, PE, FC, IP	
SQ	PU, PEN, PE, SQ, IQ, PEOU, SI, FC, IP	SQ	SQ	
IQ	PU, PEN, PE, IQ, PEOU, SI, FC, IP	SQ, IQ	IQ	
PEOU	PEOU	SE, PU, PEN, PI, TK, PE, SQ, IQ, PEOU, SI, FC, IP	PEOU	*1*
SI	PU, PE, PEOU, SI, FC, IP	SE, PI, TK, SQ, IQ, SI	SI	
FC	PU, PE, PEOU, FC, IP	SE, PU, PEN, PI, TK, PE, SQ, IQ, SI, FC, IP	PU, PE, FC, IP	
IP	PU, PE, PEOU, FC, IP	SE, PU, PEN, PI, TK, PE, SQ, IQ, SI, FC, IP	PU, PE, FC, IP	
Iteration 2				
SE	SE, PU, PEN, PI, TK, PE, SI, FC, IP	SE, PI, TK	SE, PI, TK	
PU	PU, PE, FC, IP	SE, PU, PEN, PI, TK, PE, SQ, IQ, SI, FC, IP	PU, PE, FC, IP	*2*
PEN	PU, PEN, PE, FC, IP	SE, PEN, PI, TK, SQ, IQ	PEN	
PI	SE, PU, PEN, PI, TK, PE, SI, FC, IP	SE, PI, TK	SE, PI, TK	
TK	SE, PU, PEN, PI, TK, PE, SI, FC, IP	SE, PI, TK	SE, PI, TK	
PE	PU, PE, FC, IP	SE, PU, PI, TK, PE, SQ, IQ, SI, FC, IP	PU, PE, FC, IP	*2*
SQ	PU, PEN, PE, SQ, IQ, SI, FC, IP	SQ	SQ	
IQ	PU, PEN, PE, IQ, SI, FC, IP	SQ, IQ	IQ	
SI	PU, PE, SI, FC, IP	SE, PI, TK, SQ, IQ, SI	SI	
FC	PU, PE, FC, IP	SE, PU, PEN, PI, TK, PE, SQ, IQ, SI, FC, IP	PU, PE, FC, IP	*2*

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IP	PU, PE, FC, IP	SE, PU, PEN, PI, TK, PE, SQ, IQ, SI, FC, IP	PU, PE, FC, IP	*2*
Iteration 3				
SE	TSE, PEN, PI, TK, SI	TSE, PI, TK	TSE, PI, TK	
PEN	PEN	TSE, PEN, PI, TK, SQ, IQ	PEN	*3*
PI	SE, PEN, PI, TK, SI	SE, PI, TK	SE, PI, TK	
TK	SE, PEN, PI, TK, SI	SE, PI, TK	SE, PI, TK	
SQ	EN, SQ, IQ, SI	SQ	SQ	
IQ	EN, IQ, SI	SQ, IQ	IQ	
SI	SI	TSE, PI, TK, SQ, IQ, UA	SI	*3*
Iteration 4				
SE	SE, PI, TK	SE, PI, TK	SE, PI, TK	*4*
PI	SE, PI, TK	SE, PI, TK	SE, PI, TK	*4*
TK	SE, PI, TK	SE, PI, TK	SE, PI, TK	*4*
SQ	SQ, IQ	SQ	SQ	
IQ	IQ	SQ, IQ	IQ	*4*
Iteration 5				
SQ	SQ	SQ	SQ	*5*

Note: SE: Self-efficacy; PU: Perceived usefulness; PEOU: Perceived ease of use; PI: Personal innovativeness; TK: Technological knowledge; PE: Performance expectancy; SQ: System quality; IQ: Information quality; SI: Social influence; FC: Facilitating condition; IP: Improves productivity; PEN: Perceived enjoyment.

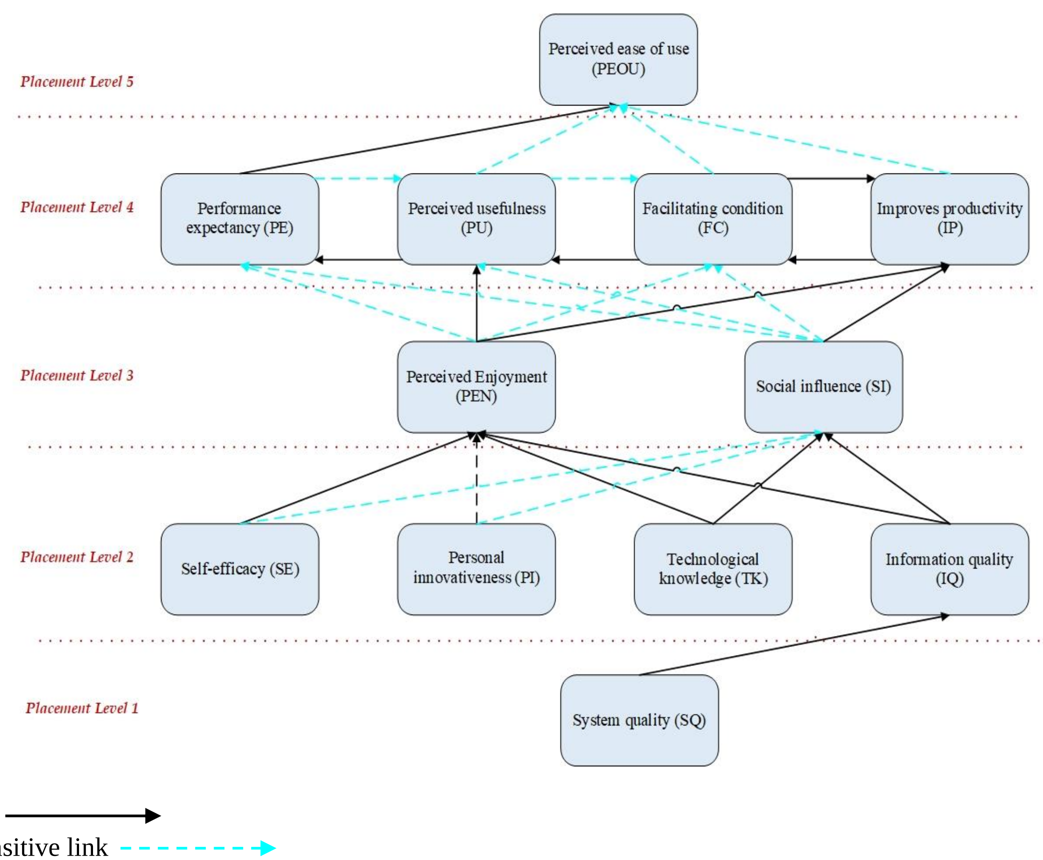

Fig. 5. The interpretive hierarchical structural model

The MICMAC analysis is the final aspect of implementing the ISM approach. The principle of the MICMAC analysis in this study is to explore and classify the driving power and dependence of the determinants of using SBL tools, as

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illustrated in Fig. 6. Using the driving power and dependence values obtained from the FRM, the recognized factors have been assigned to their particular quadrants. As shown in Fig. 6, the factors SE, PI, TK, SQ, and IQ exhibit higher driving power. However, these respective factors demonstrate lower dependent power. The factors PEN and SI display partial driving and dependent power with a value of 6. The factor PEOU is positioned in the dependent quadrant with high dependent power and lower driving power. Lastly, the factors PU, PE, FC, and IP are clustered in the dependent quadrant with high dependent power and low driving power. Notably, as depicted in Fig. 6, no factors are clustered in the linkage and autonomous quadrants.

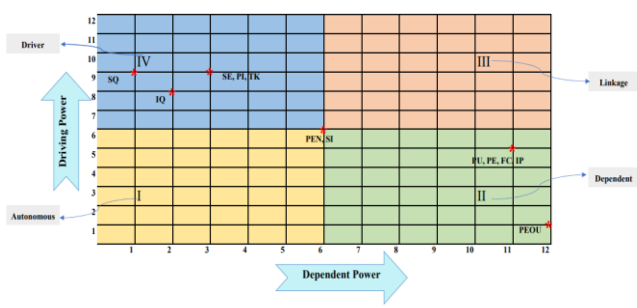

Fig. 6. MICMAC analysis

V. DISCUSSION AND CONCLUSION

The integration of SBL tools in higher education represents a sizable shift in instructional methods, facilitating instructors to design active and effective learning environments. In this context, this study identified the factors that influence users' intention towards using SBL tools for their teaching approach for computer and networking courses. This study explored twelve factors from the literature review and identified the relationships between these factors, by employing the ISM technique, which is one of the most widely utilized interactive learning methods for analyzing data. The process of MICMAC analysis, along with the driving and dependence power assessments, provided valuable knowledge into the significance and relationship among the factors influencing the intention to use SBL tools.

The obtained results from MICMAC analysis revealed that system quality (SQ) is the key fundamental factor that impacts users' intention towards using SBL tools. Therefore, enhancing the quality of the system, and improving its effectiveness and reliability will consequently lead to a significant positive impact on users' intention towards using SBL tools. It is evident that employing SBL tools in higher education relies predominantly on the SQ. The accuracy of the simulations largely depends on the vigorous infrastructure, regular support, and system updates which are crucial in SQ and enhancing practical learning experiences in networking and cybersecurity tools such as Cisco Packet Tracer and GNS3. The findings of this study support Hassanzadeh et al [73], who revealed SQ is a significant predictor of students' intention to use the e-learning system.

The factors SE, TK, PI, and IQ are situated at the second level of the hierarchical structural model and demonstrate higher driving power, as indicated by the MICMAC analysis. Instructors with a high level of SE and TK can overcome challenges encountered while working with SBL tools through their skills and knowledge. Instructors with higher confidence, TK, and advanced abilities are more likely to use SBL tools effectively. When facing difficulties during the utilization of SBL tools, instructors can utilize known solutions and effective strategies, thereby enhancing their success in achieving student learning outcomes. This statement aligns with similar research by Bartimote-Aufflick et al [25], which demonstrated the significant impact of SE on learners' achievement and understanding in the context of higher education. This finding further supports the work of Liu [85], which highlighted the essential role of TK in effectively utilizing GNS3 tools to enhance performance. In turn, PI and IQ are crucial for employing SBL tools for computer networking teaching. Providing necessary and precise information is crucial to instructors and students in using complex networking tools such as Cisco Packet Tracer, OPNET, and OMNET++, or other simulation tools. Thus, providing precise and appropriate tools enhances practical knowledge and learning experience.

The factors PEN and SI are positioned at the third level of the hierarchical structural model and demonstrate average values of driving and dependent power, as indicated by the MICMAC analysis. When instructors perceive the learning procedure as an enjoyable and pleasurable experience, they are more likely to be interested in using simulation-based tools for their students. The findings align with Hunde, Demsash [60], who revealed that students are more eager to utilize e-learning systems if they perceive the system as enjoyable and pleasant. Alternatively, SI was found to be another significant factor that influences the intention of instructors to use SBL tools in their teaching. If it is perceived that students and instructors can utilize SBL tools effectively and accomplish positive results in their teaching and learning, instructors are more likely to implement these tools in their computers and networking teaching. This finding aligns with Alshurideh et al [95] as well as Leow et al [96], who confirmed the significant role of SI in the adoption of technology and its influence on intention towards using technology.

The factors PE, PU, FC, and IP are positioned at the fourth level of the hierarchical structural model. These factors were identified as dependent factors based on the MICMAC analysis. Regarding PE and PU, when instructors perceive that SBL tools like Cisco Packet Tracer and GNS3 are valuable, relevant, and useful to achieving learning objectives, they are more inclined to adopt and engage SBL tools in their teaching practice to enhance learning outcomes and performance. This finding aligns with Papakostas, Troussas [119] and [77], who emphasized the substantial impact of PU and PE on students' intention towards using innovative technologies. Factors FC and IP are also crucial in influencing instructors' intention to use SBL tools. Hence,

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instructors may be more likely to intend to use SBL tools in the process of teaching if facilitating features are developed. Accessible SBL tools enhance facilitating conditions and therefore, the intention to use them for computers and networking. Therefore, students are more likely to intend to use SBL tools during the learning process when facilitating features are developed. These findings are consistent with the results of Al-Mamary [44] and Su and Chao [50], confirming the significant positive influence of FC on both students' intention and the actual use of innovative technologies. In terms of IP, the integration of SBL into higher education through dynamic, practical learning, actual application, and simulation leads to improved productivity and creativity in understanding computers and networking subjects. This results in enhanced learning effectiveness and advanced problem-solving.

Accordingly, PEOU is the final factor that is located at the fifth level of the hierarchical structural model. This factor was attained as the most dependent factor based on the MICMAC analysis. These findings imply that although instructors are likely to use SBL tools if they perceive them as easy to use, the extent of PEOU is influenced by other factors. A user-friendly interface enables instructors to concentrate on the existent content significantly instead of struggling with the tool itself. Al-Maroof et al [57] highlighted that when individuals recognize a technology as easy to use, they tend to have more positive opinions towards using that technology.

VI. Implications for Managers and Educational Institutions

The outcome of this study has considerable impact and implications for both institutional managers and educational institutions aiming to adopt SBL tools in higher education for complex computer and networking subjects. The study found that SQ is the most significant and driving factor for adopting SBL tools by instructors. Therefore, it is crucial for institutional managers and educational institutions to identify and provide SBL tools with high quality, reliability, and effectiveness. Providing robust infrastructure and constant support by the provider will lead to the successful implementation of SBL tools. Since SE and TK are identified as crucial determinants of intention to use SBL tools and have higher driving power, it is recommended for institutions to focus more on advancing SE and TK of instructors to enable them to utilize SBL tools effectively for their teaching. The enhancement of SE and TK will help them to overcome challenges they face while using the tools in the classroom environment. Thus, providing appropriate training will enhance instructors' SE and TK which will have a significant impact in fostering the development of a successful learning environment. In terms of IQ, managers and educational institutions can provide accurate information for students while using complex networking tools. For instance, quality assurance for testing the functionality of the tools and if updates are required for effective usage.

The results confirmed that PEN and SI have an influential role in shaping instructors' intention to use SBL tools. Therefore, institutional managers and educational institutions should create communities for students or instructors to share their ideas regarding the use of SBL tools. Regarding PEN, instructors and institutions should focus on integrating components that affect learning positively, for instance interactive activities, to improve the efficacy of SBL tools.

The findings of this study revealed that FC, PU, PE, IP are dependent functions based on the MICMAC analysis. Thus, educational institutions can improve FC, PU, PE, IP by providing accessibility and full support that can motivate instructors to employ SBL tools. Managers and education institutions should recognize the significance of these crucial factors which impact the utilization of SBL tools by instructors and therefore students. When students perceive SBL tools like Cisco Packet Tracer and GNS3 as useful and appropriate to their learning, their engagement increases. Furthermore, available SBL tools and improved FC contribute to the intention to use these tools in teaching computers and networking. Therefore, providing simple instructions and support through technical assistance to use SBL tools would be beneficial in computers and networking subjects. Finally, regarding the importance of PEOU, it is crucial to make the SBL tools as easy to use as possible. Developers can work on developing a user-friendly device. This can include a simple design, and straightforward features that aid in improving instructors and students' interaction with the system.

VII. Limitations and future research

This study identified twelve factors that impact instructors' intention towards using SBL tools. However, similar to any research endeavor, this study has certain limitations that can offer insights for guiding future research. First, this study did not utilize any information system (IS) theories as a foundation. Consequently, future researchers could use well know IS theories such as TAM, UTAUT, and TPB to examine the relationship between these constructs. Secondly, previous studies have agreed that ISM is a well-established and strong decision-support analytic tool for uncovering contextual relationships among specific elements. However, it has certain limitations to validating theoretical frameworks. Therefore, future researchers could consider using structural equation modeling such as (PLS-SEM) to reveal the relationship among the determinants of SBL tools. Moreover, we recommend that future investigations explore various approaches such as DEMATEL or other Multiple Criteria Decision Making (MCDM) methods, including fuzzy DEMATEL or SVNS-DEMATEL, in addition to the existing methodology. Conducting comparisons with the current methods could yield valuable insights, enhancing our overall understanding of the subject matter and highlighting possibilities for future research.

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