Simulation-Based Learning for Computer and Networking Teaching: A Systematic Literature Review and Bibliometric Analysis

Abstract

Simulation-based learning (SBL) offers an extensive variety of chances to practice complex computer and networking skills in higher education and to implement diverse kinds of platforms to facilitate effective learning. Utilizing visualization and computer network simulation tools in teaching computer networking courses has been found to be useful for both teachers and learners. However, little effort has been made to assess the status of this research area and investigate the factors that influence students' perceptions and intentions to use simulation-based learning. Therefore, this study performed a Systemic Literature Review (SLR) to analyze studies of simulation-based learning and utilized a factor derivation method to recognize and categorize the factors derived from students' perceptions of simulation tools in education. Moreover, this study conducted bibliometric techniques to investigate SBL by analyzing scientific publications, the geographical distribution of articles, the co-occurrence of authors' keywords, and the Cite score per year for each article. The study considered Scopus-indexed SBL articles published between 2012 and April 2023. VOSviewer software and PRISMA protocol were employed for bibliometric descriptive analysis and data analysis. The results obtained from the SLR indicate that Cisco Packet Tracer is the most commonly used tool in simulation-based learning for teaching computer networks. Furthermore, the results demonstrate that perceived ease of use, perceived usefulness, and behavioral intention, are among the most indicated factors from the review which influence students' perception of simulation-based learning tools. The bibliometric analysis revealed that the USA is the leading country in SBL. Additionally, simulation-based learning was the most frequently used keyword in the abstract, keywords, and literature. This study provides the theoretical groundwork for forthcoming empirical studies and helps to understand the advantages of using simulation-based learning tools in teaching and learning.

Keywords: Simulation-based learning, SBL, Education, Computer and networking, Bibliometric analysis, PRISMA

1. Introduction

Higher education should design curricula which provides students with excitement and the skills necessary to succeed in the IT industry (Sauls and Gudigantala 2013). One way of doing this by using the pedagogical approach of simulation-based learning (SBL) activities, as they can increase student engagement, motivation, and learning (Shanks and Zhang, 2023). However, even though several articles examine the influence of simulation-based learning tools in higher education institutions (Chernikova, et al., 2020), works dealing with the topic under the view of computer networks and simulation are still scarce, and tend to focus on individualized case studies or experience-based reports. Notably, the Joint Task Force on Computing Curricula: ACM and IEEE Computer Society (2013) highlighted the significance of computer networking as an essential domain within the discipline of computer science, as reflected in the Curriculum Guidelines for Undergraduate Degree Programs in Computer Science. Later reports have also indicated the importance to include networking in courses on cyber security (Jones et al., 2018), and so computer network courses are a major subject for additional study in various advanced networking courses

for instance wireless sensor networks, advanced network security, network design, and telecommunications technology. Indeed, one of the key knowledge domains in cybersecurity according to the Cyber Security Body of Knowledge (CyBOK) is Network Security, which is stated as including 'Security aspects of networking & telecommunication protocols, including the security of routing, network security elements, and specific cryptographic protocols used for network security' (Andrew. et al., 2021). However, training individuals in computer networking can pose a challenge for educators and students alike, especially considering that several of the theoretical concepts can be difficult to articulate and grasp (Tian et al., 2017). Furthermore, some authors have suggested how SBL in the context of computer networking can allow reality to be brought close to the classroom environment (Tian, Liu, & Wang, 2017). Hence, further research is required to ascertain what studies have utilized SBL in the context of computers and networking, and that factors which can lead to greater adoption of SBL in the classroom. By doing so, instructors can gain a greater understanding of good practice they could implement themselves in the context of SBL.

Besides, Kaewwit and Chulajata (2017) agreed that the current educational landscape requires the implementation of information technology to help the learning process. Meanwhile, Scager et al., (2017) outline that within higher education institutions, students should be challenged with situations that stimulate learning and prevent boredom. Thus, to enhance the networking expertise of learners, simulation networking tools are considered vital for students' understanding and visualization of computer network courses. Additionally, Allison (2022) indicate that computer networking courses are generally deemed as a technical topic, and the training and learning procedure is always presented in a mixed form method including lectures and practical sessions. Thus, practical, and hands-on activities are essential to be implemented along with any face-to-face theory session. The mix of the two approaches enables learners to comprehend networking technology and its subject components. Hence, all higher education institutions should prepare themselves to embrace potential simulation tools to remain competitive in the educational sector, particularly as it can promote active learning (Hendrickson, 2021), and enhance student engagement (Haug, et al., 2019). However, SBL is an abstract topic in literature with a theory that can be difficult for learners to understand.

The advancement in technology has revolutionized various parts of modern society including the education sector. It has led to notable enhancements in student involvement, academic achievement, and teacher efficiency through the adoption of innovative techniques in teaching and learning (Obi et al., 2023). Studies have shown that the utilization of technology in education can improve learning results by enabling students to access novel resources, encouraging collaboration and communication, as well as developing skills in critical thinking and problem-solving (Chen et al., 2023). Simulations create a secure and regulated environment where learners can make mistakes without experiencing severe repercussions, with errors serving as opportunities for learning (Levin et al., 2023). SBL has changed the field of education by incorporating cognitive, technical, and interactive abilities into an environment where students suppose the setting is actual, perform as they would reply in the area, and feel safe to create errors for the objective of knowledge from them (Rajaguru and Park, 2021).

Realistic scenarios enable trainees to undergo repeated training and practice until they attain mastery of a given procedure or skill. Additionally, simulations can allow students to improve their

ability to deal with ethical dilemmas (Andersson et al., 2022). Earlier research has affirmed that SBL is a superior and engaging pedagogical approach, allowing students to apply theoretical concepts to practical situations more effectively than traditional methods like lectures and discussions (Maia et al., 2023). Simulations can serve as an effective means to cultivate and evaluate competencies, including knowledge, skills, and attitudes. In fact, SBL can facilitate diverse learning outcomes ranging from acquiring domain-specific knowledge and procedures to honing problem-solving, critical thinking, and self-regulation skills, as well as cultivating positive attitudes, interests, and self-efficacy in the relevant field (Duchatelet et al., 2022). Many of these skills are difficult to accomplish through traditional lecture delivery and course readings (Samaras et al., 2022), thereby highlighting the importance of SBL as a pedagogical approach.

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" (Dai and Ke, 2022). The evolution of technology has made it increasingly feasible to incorporate SBL tools into learning practices, aided by upgrades in computer hardware and software (Campos et al., 2020). As a result, SBL has garnered heightened interest from research and instructional design sectors focused on providing learning opportunities for higher education and vocational training across diverse professional fields (Chernikova et al., 2020). Learning methods by use of SBL tools, games, and software are receiving increased interest from educational and business entities, that utilize SBL to enhance the teaching of their learners and employees. As shown in Figure 1, the prevalence of articles retrieved from Google Scholar using the search term "simulation-based learning" over the past ten years has been plotted. The findings reveal a notable rise in the number of publications, from 9750 in 2012 to 34800 in 2022.

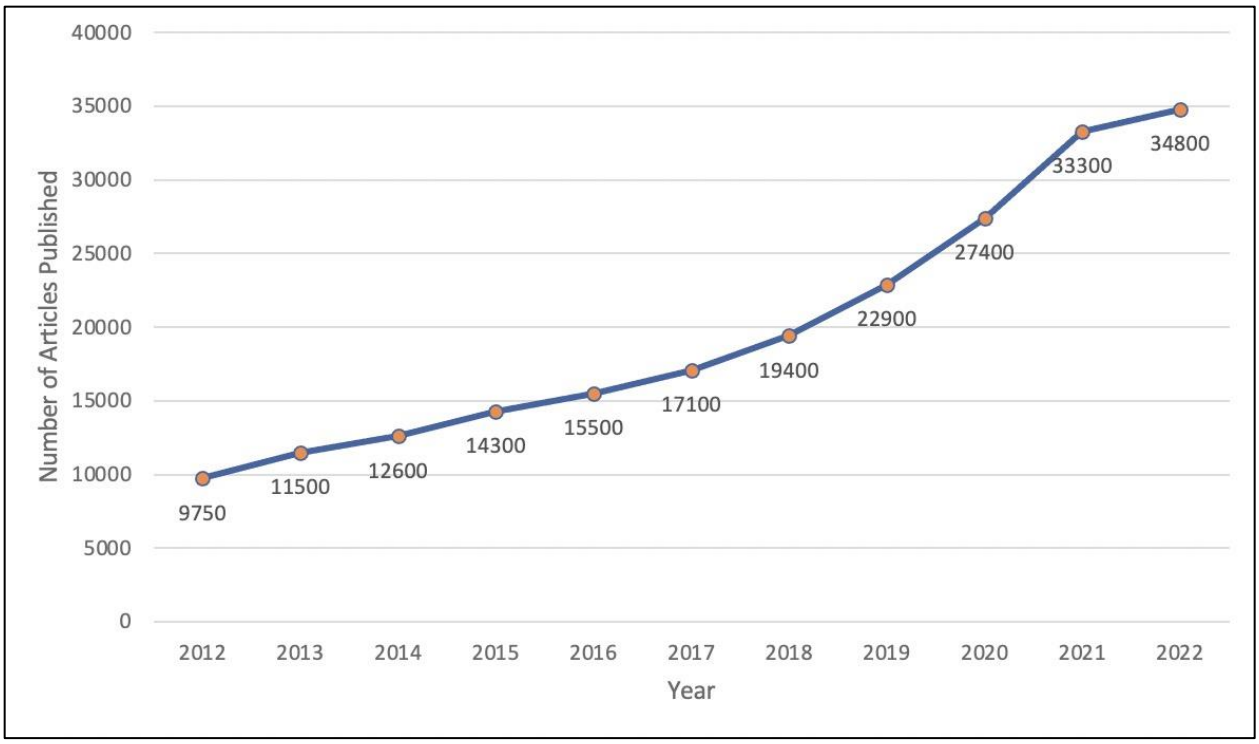

Figure 1. Evolution of the term "simulation-based learning" in Google Scholar (2012-2022).

Nevertheless, despite the extensive variety of studies on SBL, few studies have attempted to review SBL from a computer and networking aspect or to use bibliometric analysis. Hence, there is no review which instructors and researchers can use as a foundation to understand what is shared good practice for the teaching and use of SBL in a computers and networking context, and what factors could lead to greater adoption. Acknowledging the dearth of research in this area, the primary objective of this study is to consolidate and integrate the advancements made in the field of SBL, while also outlining the limitations of prior studies and offering recommendations for future research. To this end, this paper first conducts a systematic literature review and bibliometric analysis to address the following research questions:

- RQ1: What are the primary studies on SBL in computer and networking and which tools are commonly used in teaching computer and networking?
- RQ2: What are the determinants that impact students' views regarding Simulation-Based Learning in computer networking courses?
- RQ3: What is the geographic distribution of articles, document by subject area, and co-occurrence of all keywords on simulation-based learning?

2. Material and Methods

This study applied Dabić et al. (2020) methodological approach for conducting a bibliometric examination and systematic literature review (SLR). Caputo et al. (2018), confirmed that using bibliometric analysis and the SLR method together is considered best use for scientific knowledge. Bibliometric analysis and SLR are two complementary methodological approaches that aid in the development of scientific knowledge within a given field of study. While bibliometric analysis is

a quantitative tool, SLR offers a qualitative approach to the comprehensive examination of subjects and content (Hallinger and Wang, 2020). By concurrently employing these two complementary methodologies, a more comprehensive and detailed depiction can be elucidated pertaining to the advancement of scientific knowledge in a specific domain.

2.1 Adopted methodology for the systematic literature review.

For an in-depth understanding of the research topic, this study investigated prior studies on SBL in computer networking and simulation through the approach of a SLR. According to Suyo-Vega et al. (2022), SLR is a research methodology that employs rigorous criteria to gather studies pertaining to a specific field of knowledge or phenomenon and has become a clearly established form of review-based study in several fields (Asadi and Dahlan, 2017). Therefore, to discover well-utilized SBL tools and identify the most significant factors in using SBL for computers and networking, this study conducted a SLR and focused on the factors derived from previous articles to identify those that are most utilized.

To perform a SLR, this study utilized articles indexed in the Scopus database from 2012 to April 2023 and employed the Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Moher et al., 2009) to organize the search procedure. By utilizing inclusion and exclusion criteria, we can guarantee that the articles chosen are pertinent to our review. This review is dedicated to Simulation-based learning (SBL) factors. Consequently, only empirical articles that investigate the determinants of SBL based on students' perceptions of simulation tools in education are considered. Therefore, the search in Scopus was initiated by using the combined terms "Simulation-Based Learning" OR "SBL" AND "Computer" OR "Networking" to capture articles with SBL in the title, abstract, and keywords.

Initially, we identified 507 articles for screening. In the next stage, we removed duplicate articles and applied inclusion and exclusion criteria based on the abstract and title of each article. Articles outside the publication range of 2012 to April 2023 were deleted, resulting in 359 remaining articles. We only considered articles in the past ten years, as updates in technology and simulation tools mean that anything older than ten years may be greatly outdated. Indeed, Pieper et al (2014) suggest that review papers that are older than five years have a high risk of being not up to date. We also excluded Conference Reviews, Book, Editorial, and Letter articles, leaving 351 remaining articles. Next, we filtered based on the subject area and excluded non-English articles, resulting in a total of 301 records for analysis. Figure 2 illustrates the details of the study selection procedure using the PRISMA approach.

2.2 Adopted methodology for bibliometric analysis.

We adopted a bibliometric statistical analysis approach to examine the systematic review method (Zupic and Čater, 2015), which involves two primary processes: performance analysis and scientific mapping. Performance analysis relies on activity indicators, data, and the number of published articles, including keywords, citation analysis, authorship, and country publications (Mas-Tur et al., 2020). On the other hand, the aim of scientific mapping analysis is to use VOSviewer software to highlight the connections between subjects, disciplines, knowledge, and individual papers or authors by using co-citation, co-occurrence, and keywords, analysis (Bellia et al., 2022). Bibliometric analysis is a quantitative method for studying and evaluating 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 (Cheng et al., 2018). Moreover, Bibliometric analysis is often used by researchers, academic institutions, funding agencies, and other stakeholders to assess the impact and relevance of research outputs, evaluate research productivity, and make informed decisions about research funding and policy (Abumalloh et al., 2022).

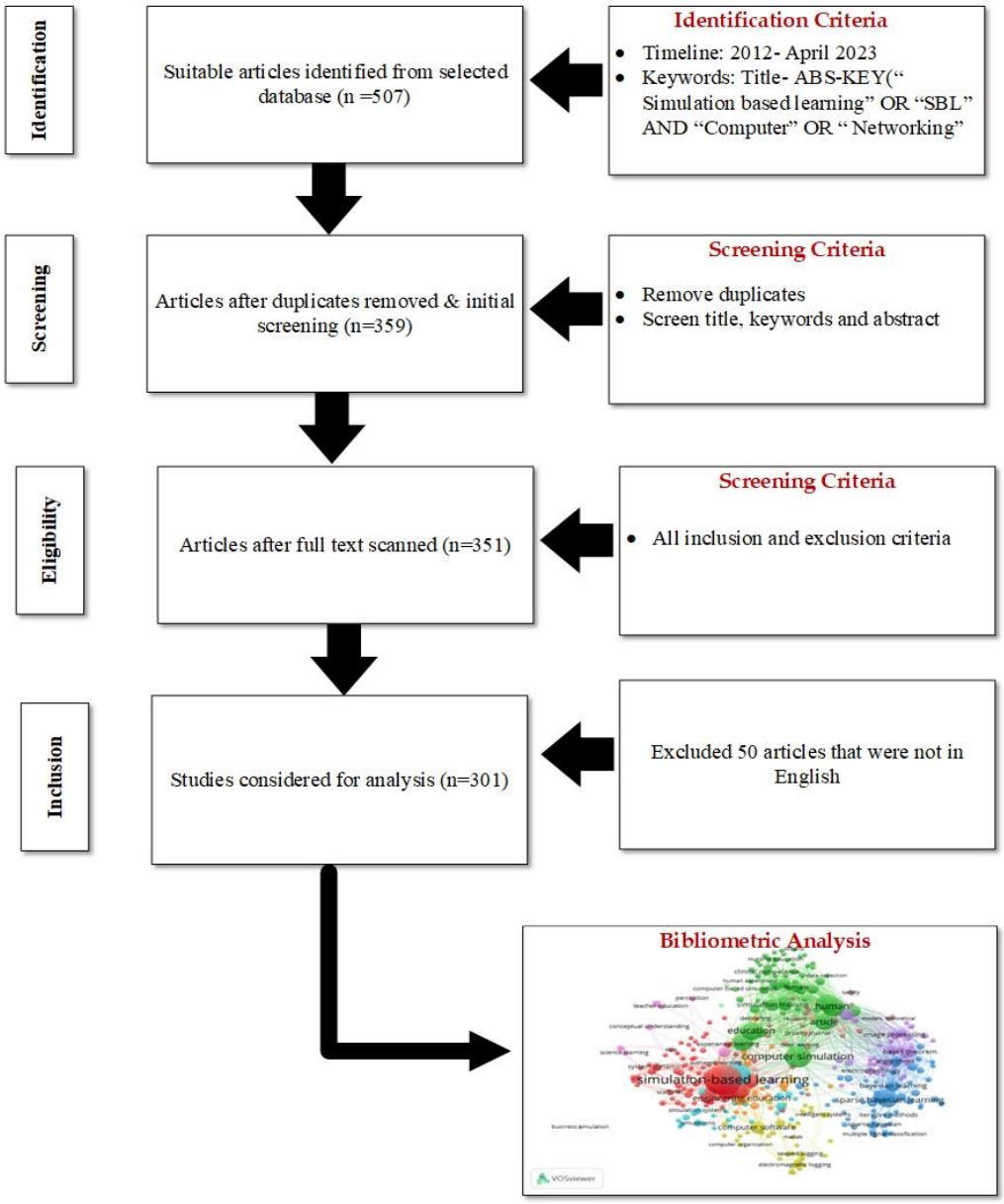

Figure 2. PRISMA Protocol.

3. Results

3.1 Primary Studies on SBL in Computer and Networking

We examined the obtained indexed articles from Scopus based on their relevancy to answer the research question of **"RQ1: What are the primary studies on SBL in the computer and networking field and which tools are commonly used in teaching computer and networking?".**

Appendix A depicts studies that focus on SBL in the computer and networking field. In total, 26 of the 301 articles considered for analysis investigated computer and networking as a primary focus of their study. Here, primary focus means that out of the 301 articles considered for analysis, these studies considered SBL in the context of how it used within computer and networking areas of study only, and therefore does not include those studies where SBL was used in other areas such as healthcare.

As shown in Appendix A, 85.18% of studies used a quantitative approach for their methodological approach. Furthermore, the data was gathered almost all from undergraduate students who were studying computer and networking, or security modules at their university. The obtained results from the Scopus index on SBL on computer and networking consist of 74.04% being published in conference proceedings and 25.96% of them published in academic journals.

There are several simulation tools such as NS2, NS3, OPNET, OMNET++, GNS3, and MATLAB for teaching computer networks to students. However, based on Appendix A, Cisco Packet Tracer was discovered as the most utilized software in computer and network simulation and overall, 93% of studies used Cisco Packet Tracer as a simulation-based learning tool. Čabarkapa (2015) asserted that Cisco Packet Tracer is one of the most utilized SBL software that helps students to test computer network behavior and assists them to enhance their knowledge and skills in decision making, critical thinking, and problem solving. Most notably, Cisco Packet Tracer aids students and teachers to produce their own simulated "network worlds" for investigation, research, and clarification of networking concepts and technologies. Cisco Packet Tracer delivers several opportunities for tutors to determine networking concepts (Allison, 2022), and has been described as user-friendly, suitable for distance learning students, and useful for testing and evaluating student learning (Prvan and Ožegović, 2020).

3.2 Determinants that impact students' views regarding Simulation-Based Learning

To identify relevant research on Simulation-Based Learning in computer networking courses, a comprehensive review was conducted, and 301 studies were included in the analysis. The purpose of this comprehensive investigation was to obtain an extensive number of viewpoints and perspectives on the topic. However, in consideration of the limitations imposed by a targeted research investigation, we methodically reduced our choice to eleven studies that significantly contributed to answering the following inquiry: **"RQ2: What are the determinants that impact students' views regarding Simulation-Based Learning in computer networking courses?"**

The procedure of selecting these eleven studies was not random; instead, it was determined by specific criteria to ensure that the identified factors were comprehensive and relevant. Our study focused on studies that utilized widely recognized theories, including the Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB), and Unified Theory of Acceptance and Use of Technology (UTAUT), in addition to taking into consideration an extensive variety of factors. These theories are substantially acknowledged in scholarly works and offer a strong conceptual structure for comprehending user behavior and acceptability in educational settings that are technology-driven.

As shown from our eleven chosen studies in Table 1, the Theory of Acceptance Model (TAM) was among the most widely individual theories compared to other theories of acceptance. Davis (1989) proposed the Technology Acceptance Model (TAM) to evaluate the adoption of new technologies based on users' attitudes. TAM consists of two primary constructs - Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) - which determine users' acceptance of computer systems. PEOU is characterized as "the extent to which an individual believes that utilizing a particular system would be effortless," while PU is defined as "the extent to which an individual believes that utilizing a particular system would improve their job performance" (Davis, 1989). Moreover, the results revealed that the Theory of Planned Behavior (TPB) was the second most used theory for acceptance of SBL in the previous studies. The TPB was proposed by Ajzen (1991) to predict users’ behavior. The TPB asserted that Attitude (ATT), Subjective norm (SN), and Perceived behavior control (PBC) influence behavior intention of individuals.

Table 1. Previously used theories and factors on SBL.

Title	Authors	Theory	Method	Participants	Factors
"Modeling Students' Perceptions of Simulation-Based Learning Using the Technology Acceptance Model."	(Lemay et al., 2018)	TAM	Mixed methods	120 students studying on a Northeastern North American college nursing program	Attitude toward use; Behavioral intention; Facilitating condition; Fidelity; Perceived ease of use; Perceived Diagonal value
"Effects of Interactivity on Students' Intention to Use Simulation-Based Learning Tool in Computer Networking Education."	(Lu and Lin, 2012)	NA	Quantitative	43 students who attended an "Introductory Course of Information Technology" at a university in northern Taiwan.	Information representation; Responsiveness; Perceived usefulness; Perceived enjoyment; Perceived educational value; Self-evaluation; Behavioral intention
"Simulation-Based Learning in Electronics: Modified TAM and DeLone & McLean IS Success Model."	(Pardiñan and Loremia, 2019)	TAM and DeLone & McLean IS Success Model	Quantitative	858 students and faculty with electronics subjects from nine campuses of Cebu Technological University.	Technical system quality; Information quality; Perceived ease of use; Perceived usefulness; User satisfaction; Intention to use; Net benefits; Actual use
"Effects of simulation-based learning on nursing students' perceived competence, self-efficacy, and learning satisfaction: A repeat measurement method."	(Hung et al., 2021)	NA	Quantitative	79 students from the Department of Nursing at a nonprofit university in southern Taiwan	Students' perceived competence, self-efficacy, and learning satisfaction
"Survey of outcomes in a faculty development program on simulation pedagogy."	(Roh et al., 2016)	TPB	Quantitative	16 Thai participants who completed a two-day faculty development program on simulation pedagogy	Attitude; Subjective norm; Perceived behavior control; Intention to use; Perceived learning
"Effectiveness of online simulation training: Measuring faculty knowledge, perceptions, and intention to adopt."	(Kim et al., 2017)	TPB	Quantitative	52 clinical faculty members of a Midwest college in the U.S	Attitude; Subjective norm; Perceived behavior control; Intention to use
"Developing an Arduino Simulation-based Learning System and Evaluating its Suitability."	(Ah-Fur et al., 2018)	TAM	Quantitative	21 experienced STEAM teachers and e-learning experts	Perceived ease of use; Perceived usefulness, Intention to use; Perceived interest of use
"Using simulation system for collaborative learning to enhance learner's performance."	(Zulfiqar et al., 2018)	TAM	Quantitative	360 multi-national under-graduate, graduate, and post-graduate students of four disciplines (business management, pure sciences, information technology, and engineering) from three Chinese universities.	Perceived usefulness; Perceived ease to use; Perceived enjoyment; Simulation system; Collaborative learning; Learner performance
"Digitalizing skills development using simulation-based mobile (SiM) learning application."	(Juera, 2022)	TAM	Quantitative	345 users who downloaded 'Electrical Wiring Simulator (EWS)' software from Google Play.	Perceived usefulness: Perceived ease to use
"Students' Acceptance of Simulation Games in Management Courses: Evidence from Saudi Arabia."	(Bamufleh et al., 2020)	UTAUT model	Quantitative	115 students at Yanbu University College in Saudi Arabia	Performance expectancy, Effort expectancy, social influence, Facilitating condition, Behavioral intention, Use behavior
"Examining the Effects of and Students' Perception toward the Simulation-based Learning."	(Lin et al., 2012)	NA	Quantitative	37 students from a university in Northern Taiwan studying 'Computer Network Engineering'	Usefulness, Educational value, Intrinsic motivation, Enjoyment, Engagement, Intention, Fragmented, Cohesive

From the eleven studies, thirty-three factors were identified which affect students' perception of SBL. Table 2 illustrates all the relevant extracted factors from the literature. Recognizing well-utilized factors aids in choosing which factors are closer to the focus of the study. Therefore, since it is not appropriate to include all potential factors in one study, we cautiously chose the factors that are close to the focus of the study. As depicted in Table 2, commonly indicated factors include 'Behavioral intention', 'Perceived usefulness', 'Perceived ease of use', 'Perceived enjoyment' and 'Attitude toward use'. These factors are extracted as the most indicated factors which influence the student's perception of using SBL.

Table 2. Identified factors from the SLR.

Category	Factor Name	No.	Citations
User Perception	Attitude toward use	3	(Lemay et al., 2018), (Roh et al., 2016), (Kim et al., 2017)
	Behavioral intention	8	(Pardiñan and Loremia, 2019), (Roh et al., 2016), (Kim et al., 2017), (Ah-Fur et al., 2018), (Lemay et al., 2018), (Lu and Lin, 2012), (Bamufleh et al., 2020), (Lin et al., 2012)
	Perceived enjoyment	3	(Lu and Lin, 2012), (Zulfiqar et al., 2018), (Lin et al., 2012)
	User satisfaction	2	(Pardiñan and Loremia, 2019), (Hung et al., 2021)
	Perceived ease of use	5	(Lemay et al., 2018), (Pardiñan and Loremia, 2019), (Ah-Fur et al., 2018), (Zulfiqar et al., 2018), (Juera, 2022)
	Perceived usefulness	6	(Lu and Lin, 2012), (Pardiñan and Loremia, 2019), (Ah-Fur et al., 2018), (Zulfiqar et al., 2018), (Juera, 2022), (Lin et al., 2012)
	Perceived competence	1	(Hung et al., 2021)
	Self-efficacy	1	(Hung et al., 2021)
	Self-evaluation	1	(Lu and Lin, 2012)
Learning and Education	Perceived educational value	2	(Lu and Lin, 2012), (Lin et al., 2012)
	Facilitating condition	2	(Lemay et al., 2018), (Bamufleh et al., 2020)
	Perceived learning	1	(Roh et al., 2016)
	Perceived interest of use	1	(Ah-Fur et al., 2018)
	Simulation system	1	(Zulfiqar et al., 2018)
	Collaborative learning	1	(Zulfiqar et al., 2018)
	Learner performance	1	(Zulfiqar et al., 2018)
System Quality	Fidelity	1	(Lemay et al., 2018)
	Technical system quality	1	(Pardiñan and Loremia, 2019)
Utility and Benefits	Net benefits	1	(Pardiñan and Loremia, 2019)
	Actual use	1	(Pardiñan and Loremia, 2019)

	Performance expectancy	1	(Bamufleh et al., 2020)
	Effort expectancy	1	(Bamufleh et al., 2020)
Social and Environmental Factors	Perceived diagonal value	1	(Lemay et al., 2018)
	Information quality	1	(Pardiñan and Loremia, 2019)
	Information representation	1	(Lu and Lin, 2012)
	Responsiveness	1	(Lu and Lin, 2012)
	Subjective norm	2	(Roh et al., 2016), (Kim et al., 2017)
	Perceived behavior control	2	(Roh et al., 2016), (Kim et al., 2017)
	Social influence	1	(Bamufleh et al., 2020)
	Engagement	1	(Lin et al., 2012)
	Intrinsic motivation	1	(Lin et al., 2012)
	Fragmented	1	(Lin et al., 2012)
	Cohesive	1	(Lin et al., 2012)

3.3 SBL Article Distribution and Keywords

This section considers the article distribution and metrics of articles included in the SLR, and answers the research question of: **"RQ3: What is the geographic distribution of articles, document by subject area and co-occurrence of all keywords on simulation-based learning?"** The distribution of articles and documents across various subject areas provides valuable insights into the interdisciplinary nature of the Scopus-indexed SBL literature. The Scopus-indexed SBL literature by subject area is shown in Figure 3 which shows the distribution of articles included in the wider review of 301 articles, not just those with a primary focus on computing and networking.

The obtained journal and conference articles spanned the subject areas of Computer science (21 %), Social science (9%), Engineering (14%), Medicine (11%), Mathematics (6%), Physics and astronomy (4%), Earth and planetary (3%), Biochemistry (3%), Nursing (2%), Business, management, and accounting (2%), Materials science (2%), Health profession (2%), Environmental science (2%) and 9% in other subject areas. This finding confirmed the multi-disciplinary nature of this subject. Out of all these subject areas, computer science and engineering are the most likely to focus on the teaching of computers and networking. Together, these subject areas accounted for 35% of all articles in the systematic review. However, those twenty-six articles with a primary focus on computers and networking represent just 8.6% of the overall papers in the review. This therefore also shows the multidisciplinary aspects that are present within subject areas themselves.

The distribution of articles across various subject areas highlights the need for multidisciplinary collaborations to advance the field of SBL research. The interdisciplinary nature of the subject requires researchers from different backgrounds to work together to explore the complex relationships between society, technology, and ethics. This cooperation can result in advanced solutions and perceptions that are not feasible by single disciplinary method. In total, the division of articles according to subject domain in the obtained literature on SBL from the Scopus-indexed highlights the necessity for continuous interdisciplinary studies and collaboration intended at advancing the field as well as tackling the intricate ethical and societal challenges related to SBL.

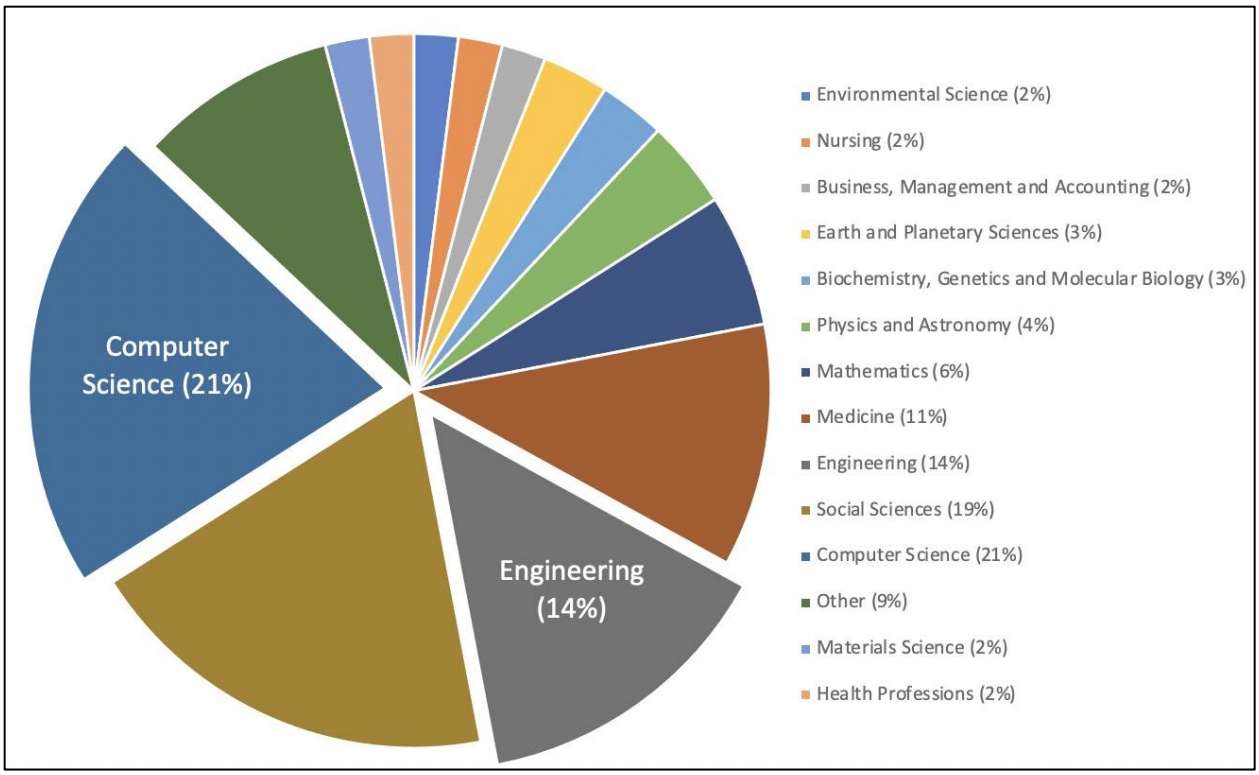

Figure 3. Article breakdown by subject area from the SBL literature review.

Apart from the subject domain covered in SBL literature, this study likewise investigated the total development of study articles on SBL instruments over time. Figure 4 displays the trend of published articles on SBL study from the year 2012 until April 30th, 2023. The analysis indicated a substantial increase in the publication of articles regarding SBL, by an evident surge from 2018 to April 30th, 2023, with 164 published articles. Obtained results also imply that there is a growing interest in simulation-based approaches which identified as an efficient tool for educational sector, and academics are presently investigating innovative techniques to use SBL to advance educational consequences in different fields. The increasing trend of study on SBL also underscores the significance of continued in this field, not only to increase educational practices but also results in educational technology enhancement.

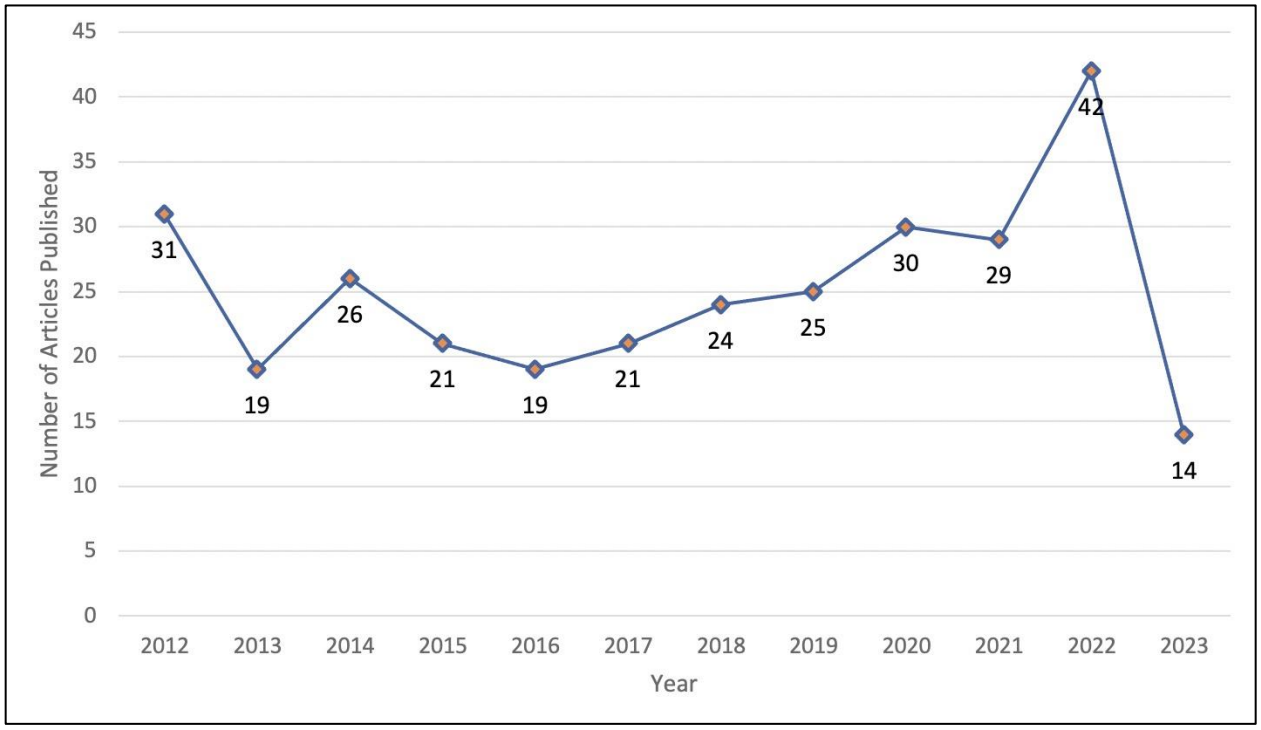

Figure 4. Articles published on simulation-based learning (2012-April 2023).

Figure 5 indicates the geographical distribution of articles pertaining to SBL approaches. It is evident that there is a global attraction in SBL research, as determined by the regular investigations conducted on a global scale. The obtained data from the Scopus-index literature on SBL demonstrates that there are some countries that are most active in research articles on SBL area. Figure 5 displays that United States has the greatest number of publications and was leading country on SBL research with 82 published articles. China was second country interested and contributed on SBL with 34 published articles, followed by Taiwan with 23 articles. There are also several countries including Canada, the United Kingdom, Malaysia, Germany, Australia, India, France, Netherlands, Spain, Thailand, and Italy which had significant contribution on SBL filed at least seven articles have been published by each of these countries in compared to other countries, demonstrating a universal attention in SBL approach. In general, distribution of articles across globe on SBL implies that the subject is keenly studied and examined globally. As well as indicating interest for this subject by academics and experts throughout a wide span of social and linguistic environments.

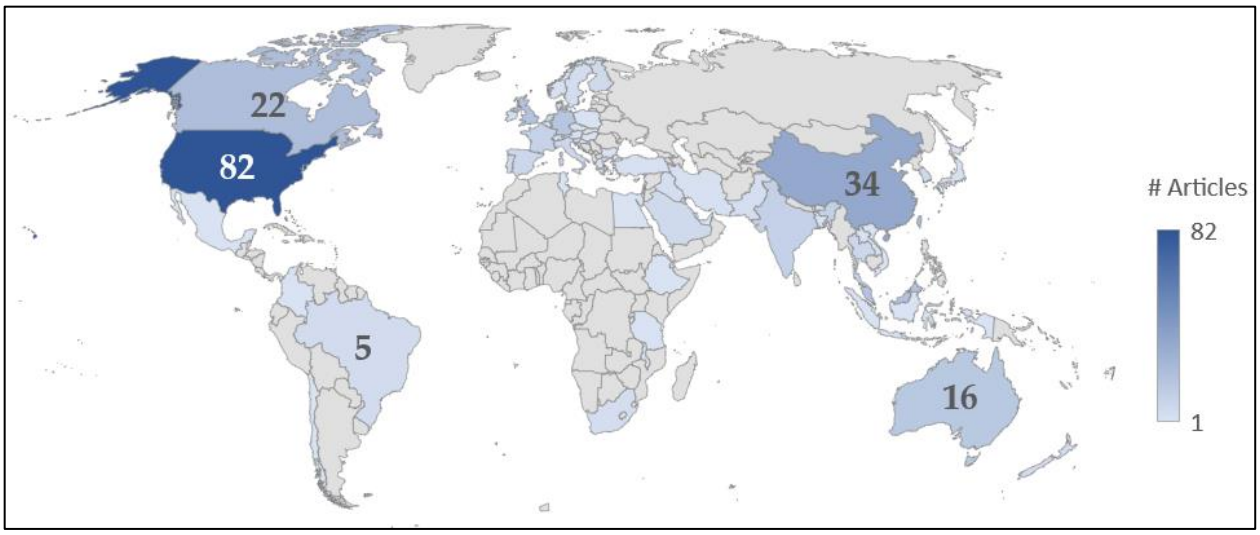

Figure 5. Geographic distribution of articles on SBL.

Apart from the geographical distribution of articles related to SBL approach, bibliographic coupling of countries is illustrated in Figure 6. Bibliographic coupling of countries points toward a bibliometric method that measures the extent of comparison or connection concerning two or multiple countries grounded on an assessment of their scientific journal publications. The number of shared citations between countries is used as a measure of their bibliographic coupling strength. This technique can be used to identify research collaborations and networks between countries and to understand the patterns of knowledge diffusion across different regions (Ma et al., 2022). The distribution of countries is shown in VOSviewer, where the thicker line indicates a stronger relationship among countries. The highest number of published articles is in the American region, followed by China and Europe.

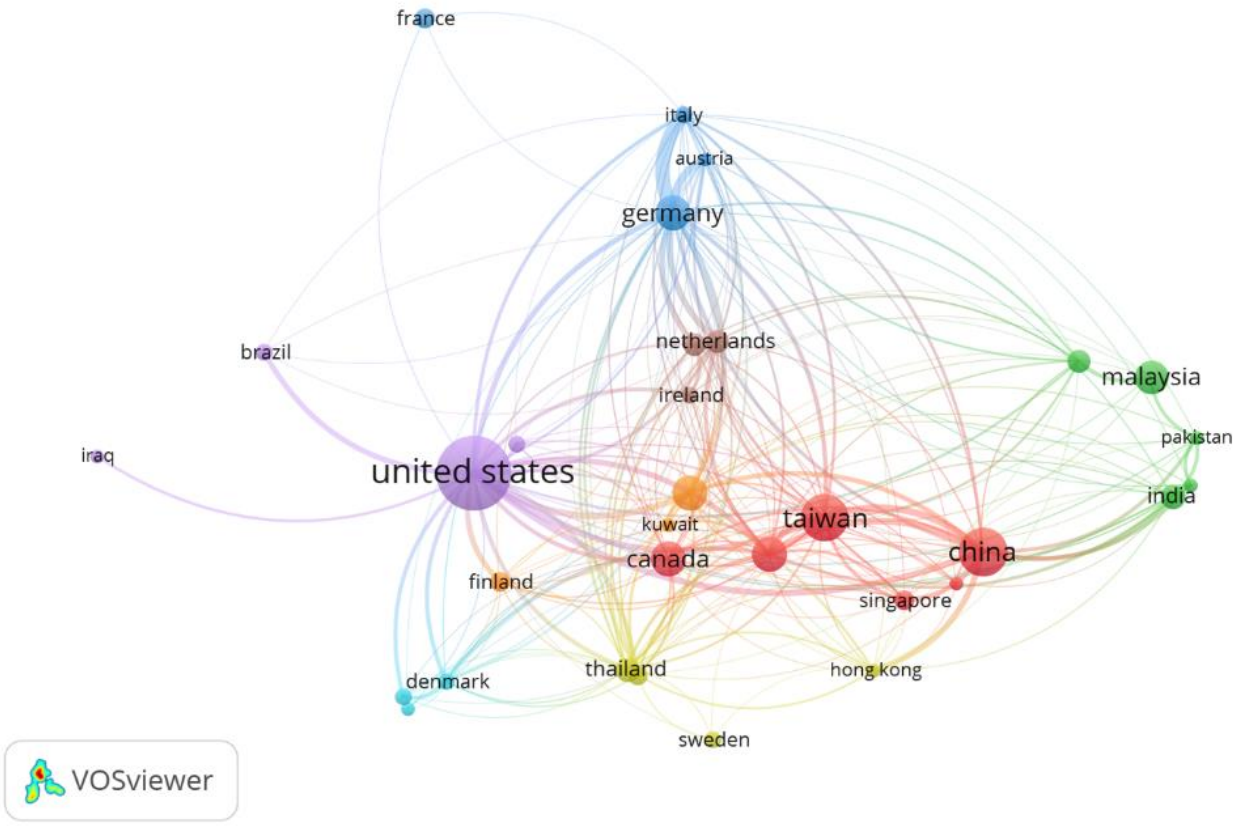

Figure 6. Bibliographic coupling of countries.

In this study, we further utilized a content analysis technique to create semantic visual maps that disclose the intellectual structure of the explored area of study (Abumalloh et al., 2022). To create a bibliometric map (refer to Figure 7), co-word analysis or co-occurring keyword analysis was conducted using VOSviewer software. Co-occurring keywords determine the number of publications in which two keywords appear together (i.e., co-occur) in the titles, abstracts, and author keyword lists of documents included in the review database, as described by Hallinger and Wang (2020). As shown in Figure 7, the terms simulation-based learning (84), students (51), computer-aided instruction (45), computer simulation (42), human (33), education (29), learning systems (27), and teaching (26) were the most frequently used keywords in the abstract, keywords, and literature of those articles included in the SLR.

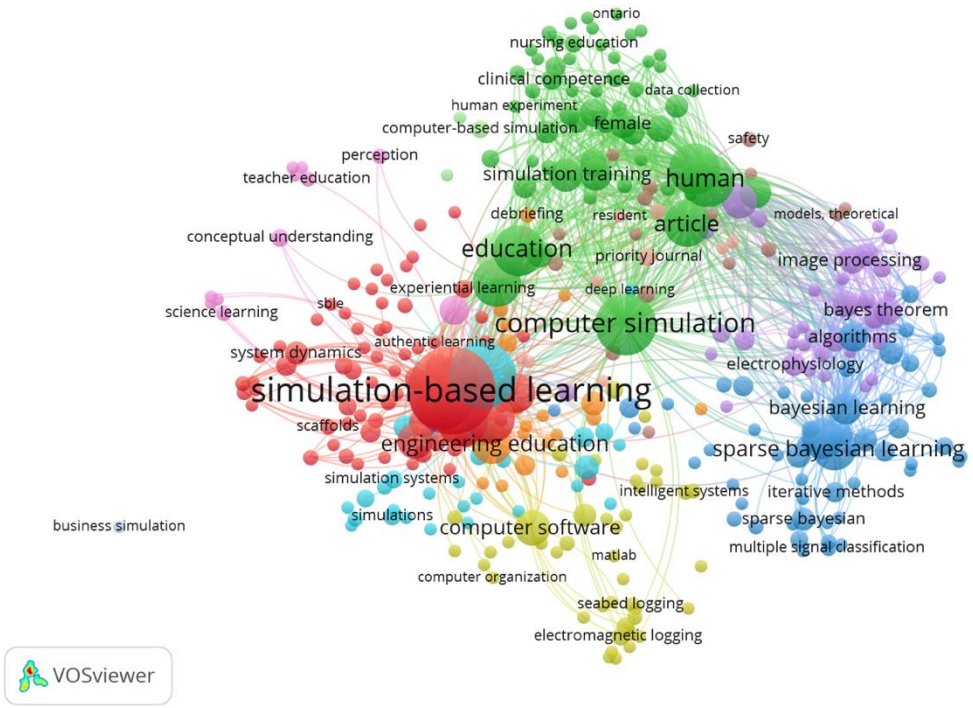

Figure 7. Co-occurrence of authors' keywords: minimum keywords threshold of 3

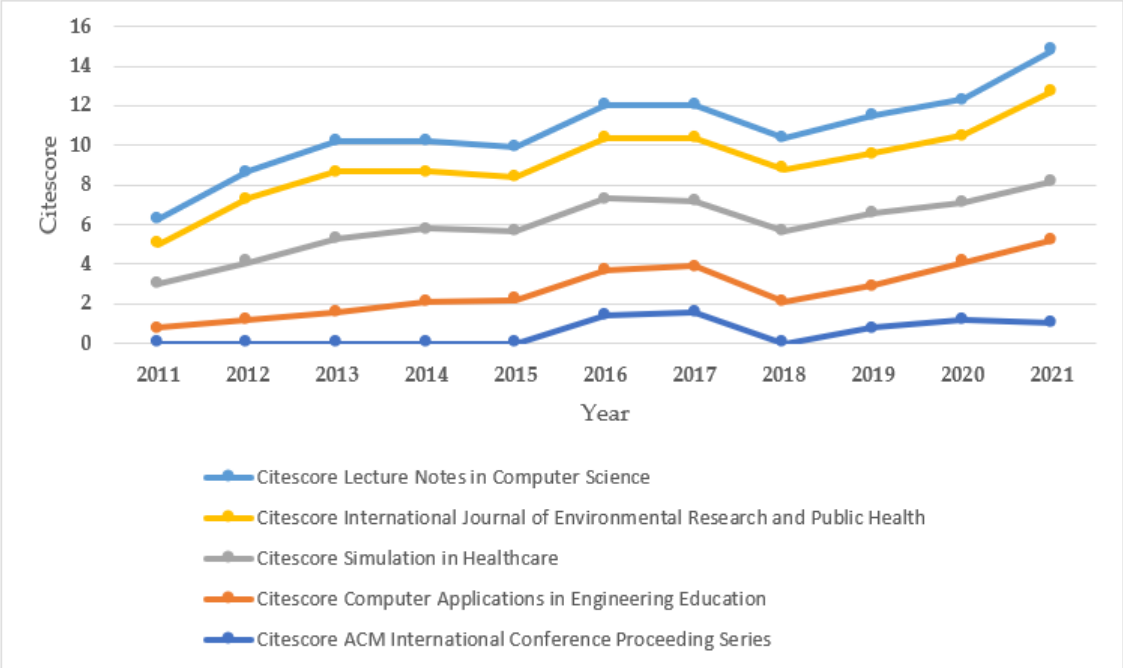

Figure 8. CiteScore publication by year.

As shown in Figure 8, the CiteScore publication per year varies based on the information source. This indicates the impact of a journal can be influenced by the number of citations it receives, and therefore, its CiteScore. In the field of computers and networks, the top chosen outlets for publication on SBL are "Computer Applications In Engineering Education", "Lecture Notes In

Computer Science", and "ACM International Conference Proceeding Series". Table 3 provides further details on the number of publications per year in these sources, which can be used to track the progress of research in these areas. Overall, these metrics are useful for assessing the impact of research publications in a given field and can help guide future research efforts.

Table 3. Publications per year per journal.

Source	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Computers and Education	6.7	7.8	8.3	8.2	9.3	10.1	10.4	11	12.7	14.4	19.8
Interactive Learning Environments	2	2.8	3	2.5	2.7	2.6	3.1	3.8	4.9	5.1	7.2
Simulation and Gaming	2.2	3.1	2.3	1.5	2.4	2.4	2.8	3.1	3.5	4.2	4.7
Computer Applications in Engineering Education	0.8	1.2	1.6	2.1	2.2	2.3	2.3	2.1	2.1	2.9	4.2
Lecture Notes in Computer Science	1.3	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.9	1.8	2.1
ACM International Conference Proceeding Series	-	-	-	-	-	1.4	1.6	-	0.8	1.2	1

Figure 9 demonstrates a significant concept of the distribution of articles published through institutional affiliation by publishing three or more articles that were published on SBL. The obtained results from the SLR revealed that 17 institutions contributed to SBL area with total publishing 65 articles in scientific journals. Between these institutions, the Universiti Teknologi Petronas, and the National Taiwan Normal University become the leading in publishing articles and have more attraction to the SBL field with seven published articles each of this institution. This demonstrates the high contribution and active involvement of these institutions in simulation-based approaches.

Following closely were the Chinese Culture University Taiwan, the University of Toronto, the Technical University of Munich, the National Taiwan University of Science and Technology, McMaster University, and Universidade Europeia, with four publications each. These institutions have also made notable contributions to the SLR, indicating they have a strong research focus on SBL. Moreover, the data reveals the next nine institutions published three articles each. This suggests there is a considerable level of research interest in SBL among these institutions, and they have also contributed to the SLR to a considerable extent.

Overall, the findings presented in Figure 9 provide a comprehensive overview of the distribution of published articles by affiliation for institutions with three or more publications on SBL within the SLR. This information can be useful for researchers and institutions who are interested in understanding the current state of research in this field and identifying potential collaborators for future research projects.

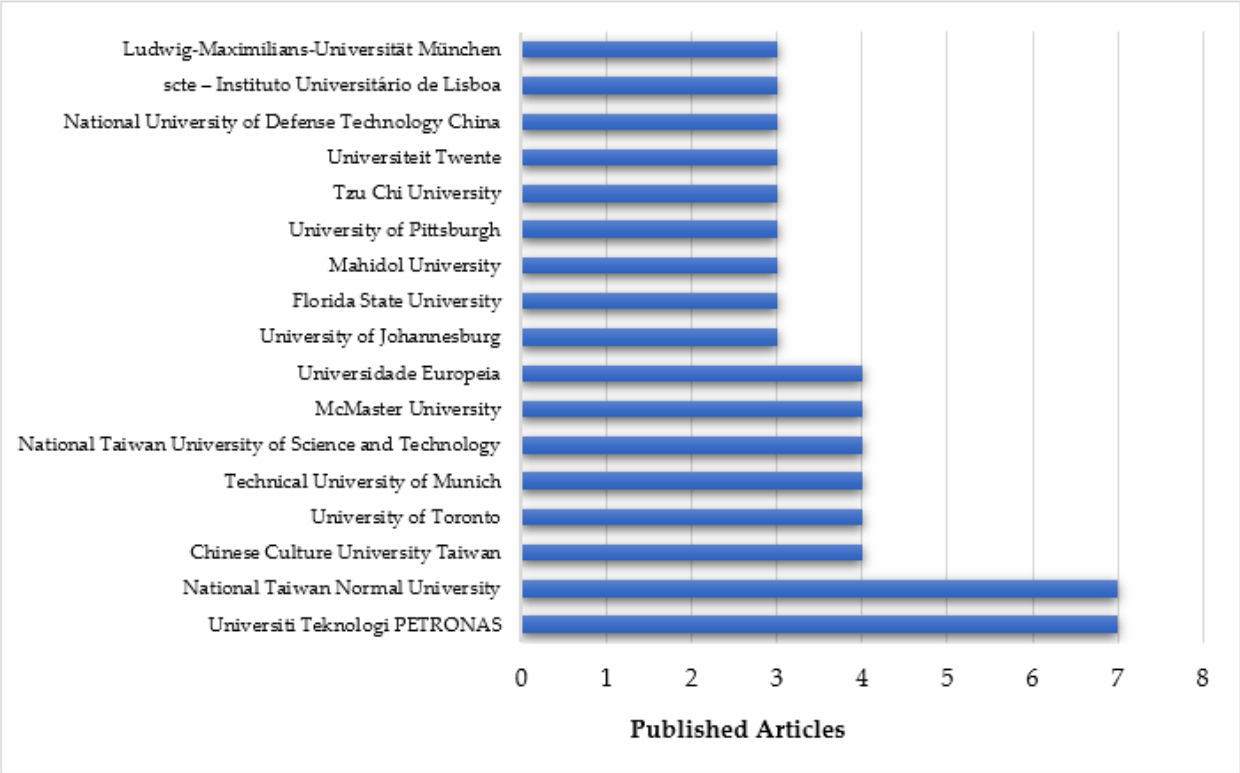

Figure 9. Published articles per affiliation.

4. Discussion

This study conducted the SLR along with bibliometric analysis. We identified 301 articles indexed in Scopus. Although many studies have explored SBL in the computer and networking field, no comprehensive review of the state-of-the-art on the subject had been conducted until this study. The findings of this research indicate scholars are increasingly focusing on SBL. Therefore, this study aimed to investigate and provide an overview and calculation of such studies. More precisely, we wanted to address three principal research questions:

4.1 RQ1: What are the primary studies on SBL in computer and networking and which tools are commonly used in teaching computer and networking?

After applying the exclusion criteria, a total of 301 documents were considered for the review process. The results of the research question (RQ1) pertaining to primary studies on SBL in computers and networks revealed that 26 out of the 301 articles concentrated on the subject of SBL in computer and networking studies. Furthermore, the findings revealed that previous researchers have utilized several simulation tools to study SBL in computers and networks. These simulation tools include Cisco Packet Tracer, NS2, NS3, OPNET, OMNET++, GNS3, and MATLAB. The use of these simulation tools has allowed researchers to simulate various scenarios and test the effectiveness of different SBL techniques and algorithms under different conditions. According to the results presented in Appendix 1, it is worth noting that Cisco Packet Tracer was predominantly used in previous studies as a tool to aid students in learning the principles of computers and

networks with hands-on experience and advanced skills in Cisco technology (H. K. Lu & Lin, 2012; Rashid et al., 2019). This finding highlights the effectiveness of SBL as a pedagogical approach in computer and networking education. In this context, SBL has been found to help with rapid prototyping (Demeter et al., 2019; Gumina & Tang, 2021), increased confidence for students working on real networking devices (Zhang et al., 2012), helps students understand the communication protocols and concepts of computer networks (Zhang et al., 2012; Tian et al., 2017; Noor et al., 2018), and provide a safer environment for learning security concepts (Trabelsi & Saleous, 2019).

Reddy et al. (2020) also stated that Cisco Packet Tracer is among the most extensively used simulation tool for learning by educators and teaching by tutors in the computer and networking field because this tool is inexpensive and user friendly. The findings of our study are consistent with their report, as we also found that Cisco Packet Tracer was predominantly used by previous researchers in the field of SBL in computers and networking. The consistency in the findings emphasizes the significance and efficacy of utilizing Cisco Packet Tracer in computer and networking education. This simulation tool is cost-effective and user-friendly, making it easily accessible to both students and educators. For instance, Muniasamy et al., (2019) outline how a key benefit of Cisco Packet Tracer is that labs can be conducted more readily as there is no need for real and expensive devices and software. Hence, with its application, learners can acquire practical experience and foster advanced skills in computer technology and networking.

In addition to its affordability and user-friendliness, Cisco Packet Tracer software enables students to simulate and model complex systems without requiring specialized equipment (Prvan and Ožegović, 2020, Allison, 2022) and is commonly employed in Cisco Academy training courses to develop and evaluate the skill sets necessary for successful course completion. Hence, Cisco Packet Tracer proves to be an invaluable resource for improving the learning outcomes of computer and networking education. It provides learners with hands-on experience, fosters the development of advanced skills, and allows them to apply theoretical knowledge in practical settings. Moreover, Vijayalakshmi et al. (2016) revealed that Cisco Packet Tracer is a long-lasting simulation tool that provides a visualization and animation environment with an extensive diversity of features that facilitate students to design a wide range of networking scenarios. Furthermore, the authors found that the average marks obtained in quizzes by students before using Packet Tracer was 65% and after using the tool it was 85% (Vijayalakshmi et al., 2016). Hence, showing how using simulation tools can aid with student learning.

Additionally, Petcu et al. (2013) also agreed with the advantages of using the SBL tool in teaching and learning. They described that Cisco Packet Tracer is a powerful simulation and visualization tool which enables students to conduct troubleshooting exercises in a safe environment. Both learners and instructors can use Cisco Packet Tracer to create virtual network environments and to create complex networking system designs and technical ideas. Furthermore, due to being an accessible simulation tool, it is also suitable for distance learning, homework, and for an easy evaluation of student work (Uramova et al., 2019).

Although the benefits of Cisco Packet Tracer are well researched, our findings reveal the relative scarcity of research on other SBL tools used for computers and networking such as OPNET and GNS3. Only one the twenty-six reviewed papers considered GNS3 (Cuzme-Rodríguez et al., 2020),

and this study did not have GNS3 at the focus, as the authors considered several simulation tools Furthermore, only three of the twenty-six reviewed papers considered OPNET, and of those, just one had OPNET as the focus of the study. This paper showed that those students who used OPNET Networking simulator had significantly higher grades and greater motivation than those of their control group (Abdel-Maksoud, 2018). Hence, some individualized case-studies have shown promise with other simulation tools for networking other than Cisco Packet Tracer, but further studies would need to be conducted to further support these findings. Hence, studies exploring the use of other SBL tools are a possible direction for future research. As technology is constantly evolving, it is crucial to explore and evaluate the effectiveness of other SBL tools that can enhance the learning outcomes of computer and networking education.

4.2 RQ2: What are the determinants that impact students' views regarding Simulation-Based Learning in computer networking courses?

Although thirty-three factors were identified from the literature (Table 2), many of these were only mentioned in one study. There are some, which are much more common from our review. The three most common factors identified in order were ‘Behavioral intention’ (8), ‘Perceived usefulness’ (6), and then ‘Perceived ease of use’ (5). As the main factors identified, these will be considered in greater depth.

4.2.1 ‘Behavioral intention’

‘Behavioral intention’ can be described as the amount of willingness an individual has regarding adopting and using some technology or innovation (Taiwo, Mahmood, and Downe, 2012). It has been shown to play a significant relationship in several fields for the adoption of technology such as artificial intelligence (Wang et al., 2023) or mobile technologies (Vărzaru et al., 2021). Hence, behavioral intention is a key aspect for students to use simulations tools for computers and networking, and our review has indicated studies where this has been shown to be the case. Bamufleh et al., (2020) found that there is a positive effect between behavioral intention and user behavior in the context of simulation tools. In addition, Pardiñan and Loremia (2019) conducted a study combining TAM and DeLone & McLean IS Success Model to investigate the impact of SBL in the learning environment. Their findings indicated attitude towards using technology and behavioral intention has a significant influence on learners' perception towards using simulation software for learning electronic concepts. The authors recommend that there needs to be further evaluation of technology used for simulation purposes (Pardiñan and Loremia, 2019).

Several authors have highlighted how learning about computer networks is complex, and so students need to put in a lot of time and energy to succeed (Janitor, Jakab, and Kniewald, 2010; Allison, 2022). Therefore, if instructors try to obtain a better understanding of student perspectives of simulation tools (i.e. their behavioral intention), initiatives to use simulation tools in a classroom environment are more likely to be successful. For example, studies have shown how engagement can be enhanced if students feel more connected to course content (Haug, et al., 2019), and therefore, if it is shown to students how simulations are linked to course content, behavioral intention may increase, but further studies would be required to validate this.

4.2.2 ‘Perceived usefulness’

As previously mentioned, perceived usefulness refers to “the extent to which an individual believes that utilizing a particular system would improve their job performance" (Davis, 1989). Previous studies have strongly indicated the positive effect of perceived usefulness on a students’ perception to use simulation tools (Lemay et al., 2018). Given the effect that students perception of usefulness has on their intention to use different technologies, it has been suggested that the interactivity of simulation-based learning tools is a key feature that should be considered in developing simulation tools (Lu & Lin, 2012). Indeed, more recent studies have also confirmed that perceived usefulness significantly influences the development of user’s skills (Juera, 2022). Therefore, as an implication for practitioners, instructors need to consider how they can convince students how simulation-based learning tools for computers and networking are useful for them in developing their skills for the real world, and the tangible benefits that can be achieved from using simulation tools. By doing so, students are more likely to use simulation tools more readily, and adoption of tool usage will increase.

4.2.3 ‘Perceived ease of use’

As previously mentioned, perceived ease of use is characterized as "the extent to which an individual believes that utilizing a particular system would be effortless," (Davis, 1989). It is a significant factor which leads to adoption of new technologies. This relationship has been confirmed in simulation-based learning studies (Lefrid, et al., 2023). Venkatesh et al. (2003) previously found that customers' perception of factors such as ease of use, usefulness, and enjoyment influence their intention to use a system. In the SBL context, Lu and Lin (2012) investigated the impact of interactivity on students' perception of using SBL tools in computers and networking and reported that perceived usefulness, perceived enjoyment, and educational value had a significant and positive effect on student’s intention to use Cisco Packet Tracer.

Similarly, Zulfiqar et al. (2018) studied how SBL can improve collaborative learning and the performance of students using TAM. The authors found that perceived enjoyment, perceived ease of use, and perceived usefulness significantly and positively impact learners' perception of using SBL. Additionally, they observed that SBL can act as a dynamic tool to enhance and accelerate student learning by increasing cooperation and interaction between learners, thereby improving their learning capabilities and performance (Zulfiqar et al., 2018). Therefore, we assume that if students perceive SBL tools, such as Cisco Packet Tracer, GNS3, or OPNET, as easy to use, they will be more inclined to embrace SBL tools in their learning. Hence, as an implication for practice, instructors should consider how they can create guided tutorials and activities that can easily acclimatize students to simulation-based learning tools, while minimizing any opportunities for confusion. By doing so, students should consider the SBL tools as easier to use, and hence, more inclined to use.

Overall, this SLR builds upon and expands existing literature by providing a comprehensive overview of the factors influencing students' perception of SBL in computers and networking across multiple studies. Although thirty-three distinct factors were identified, there are three main factors that are more commonly discussed; ‘Behavioral intention’, ‘Perceived usefulness’, and ‘Perceived ease of use’.

4.3 RQ3: What is the geographic distribution of articles, document by subject area and co-occurrence of all keywords on simulation-based learning?

The last research question (RQ3) examined the geographic distribution of articles, documents by subject area, and co-occurrence of all keywords on SBL. The analysis of SBL literature based on the geographical distribution showed that several countries and regions were interested in SBL, with the countries most engaged in SBL and having published articles being of the USA (82 articles), China (34 articles), and Taiwan (23 articles), as presented in Figure 5. It is unknown why the distribution of articles is this way, and why certain countries are more prominent in the SBL literature. Therefore, future studies could consider the variables that may influence the use and adoption of SBL for teaching in different countries, such as education policy, or teacher training initiatives. Moreover, this study conducted a Bibliographic coupling of countries and the results demonstrated communications between countries and the most influential countries in the SBL concept. United States collaborated with several countries in the SBL field extremely, such as Canada, Taiwan, and China.

Furthermore, the Co-occurrence network of keywords analysis was conducted by using VOSviewer software. The results demonstrated that simulation-based learning, students, computer-aided instruction, and computer simulation were the most frequently used keywords in the abstract, keywords, and literature. Therefore, this should aid in scholars looking to identify different works on SBL, and what keywords are suitable to use for publication. This keywords analysis is also beneficial for those looking to consider further systematic reviews on SBL, as there are similar but different words utilized in the literature such as ‘computer simulation’.

Moreover, we discovered that the Computers and Education journal by Elsevier was the target of several authors, and they are highly motivated to publish in this journal compared to others. Finally, this study found that the Universiti Teknologi Petronas and the National Taiwan Normal University were the leading institutions in the published articles on SBL with seven publications from each university. This analysis of SBL in the field of computer and networking has not been conducted before and so these results are significant as providing insight into the distribution of existing literature on the topic.

5. Conclusion

This study conducted the SLR with bibliometric analysis by using VOSviewer software. The results obtained were from indexed journals and conferences in Scopus. This study includes articles from 2012 to April 2023. This study showed the annual publication, distribution of countries, affiliated universities, and most leading journals or conferences in the SBL field. The findings of this study may be useful for future researchers in selecting an appropriate conference or journal for their publication. Furthermore, the obtained keywords will be helpful for researchers to investigate new topics and help in forecasting directions for their research.

To summarize, simulation-based learning is a powerful tool for educating students about computer and networking concepts. Through engaging learners in a simulated environment, they can practice in a real environment to understand and uncover complicated systems with practical approach. Furthermore, simulations offer a secure and controlled environment for investigation, that

encourages students to develop problem-resolution skills and understanding from errors and prepare learners for the workforce. Eventually, SBL is considered as an effective teaching and learning approach that educators from networking and computer field ought to think about integrating into their course.

5.1 Limitations and future research

One of the limitations of this study is that its scope is restricted to SBL tools in networking and computer field, thus ignoring the possibility of employing another learning tools or technologies. Therefore, future scholars can include other learning tools to focus on wider surroundings of SBL in education. The second limitation of this study is related to selection bias, since the criteria for exclusion and inclusion of articles was merely based on the authors' biased judgment. Moreover, the quality of the obtained articles was not systematically evaluated, may possibly have impacted the result of the investigation. Thus, it is necessary to consider the outcomes of this research with caution, and upcoming scholars would study employing extra accurate techniques to choose and evaluate the articles' quality. The third limitation of this study is the database is limited to Scopus indexed for extracting published articles on SBL to performing SLR, there is possibility of missing some articles. Therefore, it is essential for future researchers to use other databases such as Web of Science, or Google Scholars to uncover an extensive range of articles on SBL in higher learning institutions.

Moreover, this study merely conducted bibliometric techniques to investigate SBL in educational settings. Future studies could focus on the empirical approach by using quantitative or qualitative approaches to investigate learners and tutors' perceptions of using SBL in cybersecurity, networking, and computer concepts. lastly, this study found a dearth of studies on the examining of SBL in the field of computer and networking. Hence, forthcoming studies will pay attention to examine the suitable methods and tools for evaluating learning consequences in SBL settings, accordingly future researchers are suggested to examine the effectiveness of SBL in cybersecurity and networking field.

5.2 Managerial implications

A fundamental knowledge of computer networking has become crucial within many fields such as cyber security (Jones, et al., 2018), computer science and engineering (Prvan and Ožegović, 2020; Vijayalakshmi et al., 2016). Therefore, effective education is crucial for a pipeline of future professionals. This study offers some implications for educational management for providing strategic plans in institutions by engaging educators to using SBL to improve outcomes of teaching and learning, as simulations have been found to be effective ways to design learning environments in higher education (Chamberlin, et al., 2017). Therefore, instructors can provide simulated classroom environments and prepare the necessary tools for simulation in educational settings, which can result in improving better outcomes and understandings of students in the subjects of cyber security, networking, and computer science.

Learning computer networking is a complex task which can be difficult for students (Janitor, et al., 2010), and given the benefits that simulation tools can provide, it is therefore important to identify what factors contribute to influencing students' perceptions of these tools. Hence, as a key implication for the practice, the obtained results from SLR demonstrate that the factors perceived

ease of use, perceived usefulness, and behavioral intention were the most indicated factors from our review which influence students' perception towards using SBL tools. Therefore, this information can be utilized by institutional managers to focus the development of SBL interfaces towards addressing these factors. By doing so, this should consequently increase the engagement of learners and increase their performance in learning. Additionally, the results of SLR exhibits that Cisco Packet Tracer was the most widely used tool for simulation-based learning and teaching of networking and computer science. Thus, educational managers can utilize this information when planning to purchase simulation devices for learning and teaching, and benefit from multiple studies indicating how Cisco Packet Tracer has been utilized. However, Cisco Packet Tracer does not contain every feature and function that may occur in the real world (Uramova et al., 2019). Therefore, to keep pace with technological developments, future studies should consider how other simulation tools are being used for computers and networking such as GNS3, OPNET, or any new simulation tools as they are brought to market.

Additionally, this study reveals that the USA is the leading country in SBL. Hence, managers can consider this information to explore collaborations with US-based educational institutions to enhance their SBL initiatives. Finally, this study provides a theoretical foundation for future empirical research in SBL. Consequently, managers can use this information to prioritize research on SBL and promote its adoption in their educational institutions. To conclude, educational managers can use simulation-based learning to create a strategic plan to enhance teaching and learning outcomes. They can prioritize the adoption of SBL in their educational institutions to improve students' understanding of computer and networking-based subjects.

Data availability statements: Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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Appendix A: Primary studies on SBL in computer and networking.

Title	Study & Origin	Simulation Tools	Method	Sample Size	Details of Study	Regional context
"Simulation Tools for Solving Engineering Problems."	(Cuzme-Rodríguez et al., 2020)	NS2, NS3, OPNET, OMNET++, GNS3 and MATLAB	Quantitative	16	Descriptive analysis and the opinion of 16 experts	Ecuador/ South America
"Simulation-based education involving online and on-campus models in different European universities."	(Campos et al., 2020)	Cisco WebEx	Various case studies	NA	Case study Spain-Portugal and Ireland	Europe
"Simulation-Based Learning via Cisco Packet Tracer to Enhance the Teaching of Computer Networks."	(Allison, 2022)	Cisco Packet Tracer	Nine Practical Lab	NA	First-year undergraduate students in Computer and Security module	UK/Europe
"Teaching Computer Networks to Electrical Engineering Students by a Lecture-based Course and a Lab Course: A Quantitative Analysis of Students' Perceptions."	(Abdrabou and Shakhatreh, 2021)	Cisco Packet Tracer	Quantitative	125	Data Communications and Networking courses are detailed and evaluated by the students.	UAE/Asia
"The Impact of Virtualized Technology on Undergraduate Computer Networking Education."	(Chamberlin et al., 2017)	Cisco Packet Tracer	Quantitative	43	Network Design and Engineering course between two groups of	United States

					students: one using physical lab equipment and the other using virtual lab software.	
"A quantitative study of using Cisco Packet Tracer simulation software to improve IT students' creativity and outcomes."	(Demeter et al., 2019)	Cisco Packet Tracer	Quantitative	530	Students' views on access, to laboratory hardware in comparison to activities performed using the simulation	Transylvania/ Europe
"Inspiring Student Creativity: Collaboration on a Network Design Using IoT Project."	(Gumina and Tang, 2021)	Cisco Packet Tracer	Quantitative	NA	Students implement their network designs with the Packet Tracer simulation tool	Columbia/ South America
"Adoption of a Hybrid Model to Investigate User Retention for the Cisco Packet Tracer Tool for Computer Networks."	(Kaewwit and Chulajata, 2017)	Cisco Packet Tracer	Quantitative	37	37 Information Communication Technology (ICT) students enrolled in the Computer Networks and Security course	Thailand/ Asia

"Innovative methodology and implementation of simulation exercises to the Computer networks courses."	(Kainz et al., 2015)	Cisco Packet Tracer	Practical Lab	50	Two methodologies Alpha and Beta implemented throughout the the course of two years on a set of fifty students	Slovakia/ Europe
"Effects of Interactivity on Students' Intention to Use Simulation-Based Learning Tool in Computer Networking Education."	(Lu and Lin, 2012)	Cisco Packet Tracer	Quantitative	43	43 students who attend the course - "Introductory Course of Information Technology"	Taiwan/ Asia
"Simulation-based learning in management education: A longitudinal quasi-experimental evaluation of instructional effectiveness."	(Lu et al., 2014)	NA	Quantitative	28,100	Course Evaluation Questionnaire for all courses taught between the first term (June) of the 2001 academic year and the second term of the 2007 academic year.	Thailand/ Asia

“A Study of the Impact of Collaborative Problem-Solving Strategies on Students' Performance of Simulation-Based Learning--A Case of Network Basic Concepts Course.”	(Lu and Lin, 2017)	Cisco Packet Tracer	Quantitative	72	72 undergraduate students who were enrolled in the course "An Introduction to Networks" offered by a university in northern Taiwan.	Taiwan/Asia
“Examining the Effects of and Students’ Perception toward the Simulation-Based Learning”.	(Lin et al., 2012)	Cisco Packet Tracer	Quantitative	37	Data were gathered through a survey conducted in two classes of a university in Northern Taiwan	Taiwan/ Asia
“Application of Cisco Packet Tracer 6.2 in teaching of advanced computer networks.”	(Čabarkapa, 2015)	Cisco Packet Tracer	NA	NA	NA	Serbia/ Europe
“Teaching innovation in computer network course for undergraduate students with packet tracer.”	(Zhang et al., 2012)	Cisco Packet Tracer	Quantitative / Case study	NA	Data were collected from computer major students	China/ Asia
“Effect of feedback mechanisms on students’ learning in the use of	(Ghani, 2014)	Cisco Packet Tracer	Quantitative	80	All 80 participants were randomly	USA

simulation-based training in a computer engineering program."					but equally assigned to four groups: (1. Hands-On group, 2. No-Feedback group, 3. Knowledge-of-Correct-Response Feedback group, 4. Answer-Until-Correct Feedback group)	
"Best practice for creating Packet Tracer activities for distance learning and assessment of practical skills."	(Uramová et al., 2019)	Cisco Packet Tracer	Quantitative	58	58 secondary school teachers who came from 19 different cities in Slovakia.	Slovakia/ Europe
"Streamline Architecture of Network Simulator to Facilitate Teaching of Computer Networking."	(Tian et al., 2017)	NS2	Quantitative	208	Student responses to questions from year 2012 to 2015. The total number of students is more	China/ Asia

					than 40 in each year.	
"Using Simulation and Modeling Tools in Teaching Computer Network Courses."	(Sllame and Jafaray, 2013)	Packet tracer, GNS2, OPNET, and fat-tree simulator	NA	NA	NA	Libya/ North Africa
"Exploring the Opportunities of Cisco Packet Tracer For Hands-on Security Courses on Firewalls."	(Trabelsi and Saleous, 2019)	Cisco Packet Tracer	Quantitative	52	An anonymous questionnaire was given to 52 students that participated in the Cisco Packet Tracer lab exercises in order to collect their feedback.	UAE/Asia
"Integrating Cisco Packet Tracer with Moodle platform: support for teaching and automatic evaluation."	(Petcu et al., 2013)	Cisco Packet Tracer	NA	NA	Instructor and students can practice, test and validate their skills	Romania/ Europe
"Effectiveness of Using Cisco Packet Tracer as a Learning Tool: A Case Study of Routing Protocol."	(Hsu, 2017)	Cisco Packet Tracer	Quantitative	132	132 second year students from the Bachelor of Computer Science (Software	Malaysia/ Asia

					Engineering) and Bachelor of Computer Science (Informatics Maritime)	
"Packet Tracer Simulation Tool as Pedagogy to Enhance Learning of Computer Network Concepts."	(Vijayalakshmi et al., 2016)	Cisco Packet Tracer	Quantitative	NA	The effectiveness of the simulation activity is measured by conducting Quiz from students before and after the activity.	India/Asia
"Student's Performance Assessment and Learning Skill towards Wireless Network Simulation Tool – Cisco Packet Tracer."	(Muniasamy et al., 2019)	Cisco Packet Tracer	Quantitative	41	41 students of level 5 Diploma Community College under King Khalid University enrolled in a course entitled" Computer Wireless Networking" in the Fall Semester 2015.	Saudi Arabia/ Asia

"When virtual becomes better than real: Investigating the impact of a networking simulation on learning and motivation."	(Abdel-Maksoud, 2018)	OPNET Network Simulator	Quantitative	116	116 undergraduate students who were then randomly assigned to an experimental group (N= 59), which used the OPNET Network simulator, and a control group (N= 57) which studied the same content via the traditional physical lab.	Egypt/Asia
"Cisco Packet Tracer Simulation as Effective Pedagogy in Computer Networking Course."	(Rashid et al., 2019)	Cisco Packet Tracer	Quantitative	55	Students' overall feedback on the utilization of Cisco packet Tracer as simulating tool in teaching and learning of MTN3023 course is examined	Malaysia/ Asia