Mapping Trends and Hot-spots of Virtual Simulation Research in Nursing: A Bibliometric Analysis

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Abstract

Background: Virtual simulation has been widely used in nursing education and nursing training. This study aims to characterize the publications in terms of countries, institutions, journals, authors, collaboration relationships, and analyze the trends of virtual simulation in nursing research.

Methods: Publications regarding virtual simulation in nursing were retrieved from Web of Science core collection. Microsoft Excel 2010, VOSviewer were used to characterize the contributions of the authors, journals, institutions, and countries. The trends, hot-spots and knowledge network were analyzed by Citespace and VOSviewer.

Results: We identified 611 papers between 1999 and 2021. The number of publications grew slowly until 2019, after that, it got a sharp increase in 2020 and 2021. The USA, Canada and Australia were three key contributors to this field. Centennial College, University of Ottawa, and Ryerson University were three major institutions with a larger number of publications. Verkuyl M was the most productive and highest cited author. Clinical Simulation in Nursing, Nurse Education Today, Journal of Nursing Education were the three productive journals. "virtual patients," "nursing students," "clinical simulation," and "communication skills" were the frontier topics in recent years.

Conclusion: Using the Virtual patients to train nursing students, developing more reliable and objective assessment methods to validate learning outcomes might be the recent and future hot-topics.

1. Introduction

Virtual simulation (VS) or virtual reality simulation is a computer system that creates and experiences the virtual world. Users can directly explore the role and changes of the simulated objects in the virtual environment, experience a sense of immersion[1]. In the last decades, nursing educators have increasingly used VS for nursing education and clinical training. For example, Girao[2] developed a serious virtual reality game for medication preparation and administration training. Weston, Jeannie[3] conducted a virtual simulation with clinical practice for pediatric nursing students during COVID-19 pandemic. Chao, YC [4] applied the immersive three-dimensional interactive video program to help nursing students better acquire nasogastric tube feeding skills. As a fast emerging area, there is an urgent need to investigate the research tendency and hot-spots in virtual simulation research in nursing.

Bibliometric analysis has been widely accepted to map the knowledge network and identify the trends in one certain field[5]. There are several existing bibliometric analysis about topics in nursing[6-8]. However, to the best of our knowledge, no study has focused on research tendency and hot-spots in VS in research nursing. Therefore, in this study, we utilized Citespace and Vosviewer[9, 10] to comprehensively analyze VS in nursing based on the Web of Science Core Collection (WoSCC). We hope this paper will uncover the development of VS in nursing field and predict possible progression in this field in the future.

2. Materials & Methods

2.1 Aims

The aims of this study are as following: (1) to uncover the distributions and academic influence of different countries, institutions, journals, authors in virtual simulation related to nursing research. (2) to analyze the co-operation relationships in this field. (3) to map the knowledge network and identify the frontier topics in this field.

2.2 Design

A descriptive bibliometric analysis of publications in virtual simulation related to nursing research.

2.3 Sample/Participants

The data in this research were retrieved from Web of Science database, so no participants were involved.

2.4 Search Strategy

The advanced search was performed using Web of Science (Thomson Reuters, New York, USA) on August 1st, 2021. Formula: TS= ("virtual simulation" or "virtual reality" or "virtual reality simulation" or "virtual learning") and TS= ("nurs*") was used to screen out publications associated with VS in nursing. Two team members (Qian Zhang and Jing Liu) searched and screened the database independently. Any discrepancies were resolved by discussion with Jia Chen until consensus was reached.

2.5 Inclusion criteria

- (1) Peer-reviewed articles involving VS related to nursing
- (2) Original articles and review articles
- (3) Written in English.
- (4) Web of Science core collection (WoSCC).

2.6 Exclusion Criteria

- (1) Unpublished papers
- (2) Articles required a manual research.

2.7 Data extraction and analysis

The following bibliometric parameters were extracted, such as title, keywords, journal, publication year, citation counts, citations per year, H-index, author, institution, country, and references. And then these data were imported into Microsoft Excel 2010 (Redmond, Washington, USA) to analyze the contributions of different countries, institutions, journals, and authors. VOSviewer (Leiden University, Leiden, the Netherlands) was applied to visualize the maps of coauthor-authorship, coauthor-institution, coauthor-country, and keywords co-occurrence. In the VOSviewer map, node size indicates the number of articles produced. The wider links between nodes means stronger cooperation strength. The color means the

average publication year for the node. Blue represents the early and yellow represents the late. Citespce(Version 5.8. R1) was used to identify the keywords burst and co-cited references burst [10].

3. Results

3.1 General data

An initial research of the WoSCC identified 783 publications. After excluded meeting abstract, early access and limited English language, 611 articles were finally enrolled into analysis. Original article accounts for 86 percent of the total (n=523) (Figure 1). These papers were published from 1999 to 2021. The timing of publication could be divided into three periods (Phase I, 1999-2008; Phase II, 2009-2019; Phase III, 2020-2021). 1999-2008, the number of articles per year was below 10 publications. 2009-2019, the annual output of this field has been increasing steadily to 59 publications. Since 2020, it got a rapidly increased to 126 publications. The peak year was 2020 (n=126). The total number of citations was 8606, with 14 citations per paper and 374 citations per year (Figure 2A). The annual year publications of the top 10 countries were shown in Figure 2B.

3.2 Active authors and co-cited authors

The top 10 prolific authors in this area were all from North America (Table 1). Of them, there were eight from Canada, two from the USA. They published 95 papers and accounted for 15.5% of the total. Verkuyl M. from Centennial College was the most productive author in this scope with 18 publications. Followed by Luctkar-flude M from Queens University with 11 papers, and Tyerman J from University of Ottawa with 10 papers. In terms of co-cited author, Cook Da, Hoffman HG, and Verkuyl M were ranked the first three. Figure S1 showed the author cooperation network and co-cited author network. There were scattered co-operations between them.

Table 1
Top 10 prolific authors and co-cited authors on virtual simulation research in nursing

Rank	Author	Publications	Citations	Country	Co-cited author	Co-citations	Country
1	Verkuyl M	18	173	Canada	Cook, Da	118	USA
2	Luctkar-flude M	11	20	Canada	Hoffman, HG	108	USA
3	Tyerman J	10	20	Canada	Verkuyl, M	103	Canada
4	Hughes M	9	97	Canada	Jeffries, Pr	81	USA
5	Romaniuk D	9	120	Canada	Inacsl Stand, Comm	64	N/A
6	Farra S	8	115	USA	Cant, Rp	62	Australia
7	Lapum JL	8	85	Canada	Foronda, Cl	60	USA
8	Mastrilli P	8	112	Canada	Foronda, C	59	USA
9	Hodgson E	7	89	USA	Liaw, Sy	49	Singapore
10	St-amant O	7	46	Canada	Hayden, Jk	45	USA

3.3 Active journals and co-cited journals

The top 10 active and co-cited journals were identified by VOSviewer. Altogether, 260 journals contributed to VS in nursing. The top 10 productive journals published 247(39.3%) papers. Clinical Simulation in Nursing was the most productive journal (n=92), followed by Nurse Education Today (n=48) and Journal of Nursing Education (n=24). The top three co-cited journals were the same journals as mentioned above, with 820, 667,339 co-citations, respectively (Table2).

Table 2
Top 10 prolific journals and co-cited journals on virtual simulation research in nursing

Rank	Journal	Publications	Citations	IF*	Co-cited journal	Co-citations	IF
1	Clinical Simulation in Nursing	92	735	2.391	Clinical Simulation in Nursing	820	2.391
2	Nurse Education Today	48	509	3.442	Nurse Education Today	667	3.442
3	Journal of Nursing Education	24	206	1.726	Journal of Nursing Education	339	1.726
4	Journal of Medical Internet Research	18	401	5.428	Nursing Education Perspectives	256	N/A
5	Nurse Education in Practice	17	216	2.281	Medical Education	232	6.251
6	Nurse Educator	13	140	2.082	Medical Teacher	212	3.65
7	Cin Computers Informatics Nursing	11	99	1.985	Journal of Medical Internet Research	210	5.428
8	Burns	8	289	2.744	Simulation in Healthcare	206	1.929
9	Journal of Clinical Nursing	8	165	3.036	Nurse Education in Practice	197	2.281
10	Nursing Education Perspectives	8	62	N/A	Academic Medicine	194	6.892
*Abbreviation for impact factor(JCR 2020).							

3.4 Active institutions.

The top 10 most productive institutions were presented in Figure 3A. Among the top 10 institutions, there were five located in Canada, four in the USA, and one in Singapore. Centennial College was the most prolific institution (n= 17 publications), followed by University of Ottawa and Ryerson University. In terms of citations and H-index, University of Toronto (Canada, 576 citations, 9 H-index), University of Ottawa (Canada, 329 citations, 8 H-index), Centennial College (Canada, 173 citations, 7 H-index) ranked in the top three. The co-authorship for organization module in VOSviewer was used to visualize the collaboration

relationship among 39 institutions, which published at least 5 papers. As shown in Figure 3B, There were few and sporadic connecting lines between different institutions.

3.5 Active countries/regions

A total of 58 countries/regions participated in these publications. The top 10 were shown in Figure 4A. Obviously, the USA led in this field with 250 publications (40.9% of the total), 4289 citations, and 34 H-index. The module of co-authorship for country in VOSviewer was used to map the country cooperations network. The smallest number of publications was settled as five. Finally, 26 countries meet our criterion. The USA, Canada, Australia, and England presented as the largest node. The strongest cooperation was between the USA and Canada and between the USA and Australia (Figure 4B).

3.6 Keywords

High-frequency keywords was usually used to describe hot-spots, and construct a knowledge map[11]. Thesaurus was applied to clean out similar keywords. For example, virtual reality simulation and virtual reality were replaced by VS. We identified 1459 keywords in total, 72 keywords occurred more than five times were enrolled into analysis. The top five keywords ranked by number of occurrences were: virtual simulation (n=406), education (n=131), nurse education (n=106), nursing (n=65), skills (n=59). As shown in Figure 5A, the keywords were classified into five clusters. Cluster one (red) referred to pain and anxiety management, the primary keywords were "virtual simulation, anxiety, children." Cluster two (green) referred to virtual patients, the primary keywords were "nurse education, skills, nursing students, virtual patients." Cluster three (blue) referred to clinical simulation training, the primary keywords were "nursing, clinical simulation, simulation training, gaming." Cluster four (yellow) and Cluster five (purple) referred to non-technical-skills, the primary keywords included "performance, communication, impact, surgery, patient, nurses, environments, patient simulation." As shown in Figure 5B, keywords were colored by VOSviewer according to their average publication years. During the early phase, "virtual patients, pain, and distraction" were the primary focus in this field. Recently, the trend has shifted to "nurse education, clinical simulation, and communication skills". Also, Citespace burst module were used to identify the research trends and frontier topics[12]. The burst duration was set to 2 years. The blue and red bar indicated infrequently and frequently cited time. The top 19 keywords with strongest citation bursts were auto-identified and displayed in Figure 5C. Among them, virtual patient has the highest burst strength (n=4.09). During the early stage, "distraction, adolescent, medical education" were the primary topic. More recently, 2015 to 2021, the following topics, such as program, rehabilitation, balance, nursing education, and reality attracted more attention.

3.7 Top cited articles and co-cited references

The top 10 most cited articles were listed in Table 3. To date, the most cited article was by Cook, David A[13] published in Academic Medicine by 2010 with 246 citations, entitled computerized virtual patients

in health professions education: a systematic review and meta-analysis. The co-cited references were the article which cited by the included papers of VS in nursing. The top 17 co-cited references were identified through 18420 references which co-cited more than 20 times by the included 611 papers. As shown in Figure 6A, the article with highest link strength was published by Foronda, Cynthia[14] in Nurse Education Today in 2014, entitled use of virtual clinical simulation to improve communication skills of baccalaureate nursing students: a pilot study. Similarly, CiteSpace citation burst could identify references focused by researchers in a specific period[9, 15]. The burst duration was set to 2 years. At last, 23 references with strongest citation bursts were identified in Figure 6B. Among them, Kidd Li, 2012, J PSYCHOSOC NURS MEN, V50, P28[16] had the highest burst strength($n=7.21$). Articles with citation bursts ending in 2021 were: "Kyaw BM, 2019, J MED INTERNET RES, V21, P0[17]", "Liaw SY, 2014, J MED INTERNET RES, V16, P0[18]," and "Smith PC, 2015, CLIN SIMUL NURS, V11, P52[19]." Kyaw BM performed a meta-analysis study and found virtual reality could improve the knowledge and skills of health professionals compared with traditional education or digital education[17]. Liaw S Y conducted a randomized controlled trial and found that although there were no significant differences in improving nursing students' clinical performance, virtual simulations were more convenient and promising than mannequin-based simulations[18]. Smith PC designed a virtual reality simulation to evaluate Foley catheter skill proficiency in nursing students, and found virtual reality simulation could be a supplemental tool for teaching students critical steps in clinical skills[19].

Table 3
Top10 most cited papers related to virtual simulation research in nursing

Rank	Title	Author	Journal	Year	Total Citations
1	Computerized Virtual Patients in Health Professions Education: A Systematic Review and Meta-Analysis	Cook, David A.	Academic Medicine	2010	246
2	Mastery Learning for Health Professionals Using Technology-Enhanced Simulation: A Systematic Review and Meta-Analysis	Cook, David A.	Academic Medicine	2013	153
3	Evaluation of trauma team performance using an advanced human patient simulator for resuscitation training	Holcomb, JB	Journal of Trauma-Injury Infection And Critical Care	2002	152
4	A pilot and feasibility study of virtual reality as a distraction for children with cancer	Gershon, J	Journal of The American Academy of Child And Adolescent Psychiatry	2004	151
5	Current trends in stroke rehabilitation. A review with focus on brain plasticity	Johansson, B. B.	Acta Neurologica Scandinavica	2011	149
6	Patient Outcomes in Simulation-Based Medical Education: A Systematic Review	Zendejas, B.	Journal of General Internal Medicine	2013	148
7	Effects of distraction on pain, fear, and distress during venous port access and venipuncture in children andAdolescents with cancer	Windich-Biermeier, A.	Journal of Pediatric Oncology Nursing	2007	127
8	Intravenous catheter training system: Computer-based education versus traditional learning methods	Engum, SA.	American Journal of Surgery	2003	123
9	The Insertion and Management of External Ventricular Drains: An Evidence-Based Consensus Statement	Fried, Herbert I.	Neurocritical Care	2016	120
10	A randomized trial of teaching clinical skills using virtual and live standardized patients	Triola, M.	Journal of General Internal Medicine	2006	116

Virtual patient had the strongest burst citations and last from 2012 to 2019. Nursing education colored yellow in VOSviewer keyword network and had a moderate burst strength in 2021. Therefore, we choose virtual patient and nurse education as hot topics in recent years.

4. Discussion

This study, we mapped a knowledge network of VS in nursing research from 1999 to 2021. Meanwhile, we analyzed the contributions of different authors, journals, institutions, and countries. The number of publications in a field reflects the activity and productivity over the years[15]. The overall trend of publication in this field was upward, and could be divided into three phases. Before 2008, the number of articles per year slightly increased. It may be restricted by technology such as internet access or computer popularity. Likewise, previous study found before the year of 2005, the applications of virtual patient in medical education were small[20]. Since 2020, the number of papers got a sharp increase. We speculate several reasons account for this. First, because of social isolation during the COVID-19 pandemic, educators were forced to change the way of program delivery [21]. Numerous online programs have emerged during the COVID-19, such as virtual lab environments[22], three-dimensional virtual world (3DVW)[23], personal protective equipment (PPE) virtual simulation games[24]. Such VS programs effectively enhanced nursing student interest and provided nurse educators with novel and engaging means of content delivery[21]. Second, COVID-19 pandemic accelerated the demand for more nursing staff and higher quality nursing care. Indeed, not all nurses or medical staff have the chance to face such an outbreak. It is difficult to educate and train these back-ups with any physical touch. However, the greatest strength of VS could provide an almost real environment that simulated any emergency in COVID-19. It is perfect to solve this problem.

Without surprising, the USA leads the VS in nursing research, which requires the collaboration of multiple disciplines, such as medical informatics, education, computer science, and software engineering. Other areas displayed the similar leading position of the USA, such as radiation-induced lung injury [25], and human-computer interaction[26], etc. Interestingly, in terms of the number of productive authors and institutions, Canada ranked ahead of the USA. Extensively studies showed that collaborations tend to be stronger between institutions or countries with shorter geographical distances[7]. We speculated the cooperation links between authors and institutions within Canada were stronger than that in the USA. As expected, Figure S1 and Figure 4B further corroborated our hypothesis. There are scattered links between numerous American authors and institutions, but relative close relationships between Canadian authors and institutions. Considering the scattered collaborations in this field, we hope there will be more inter-institutions and international research in the future.

Key journals, institutions, and authors provide the essential information for a given field. Clinical Simulation in Nursing, Nurse Education Today, and Journal of Nursing Education are the top three productive and co-cited journals. Researchers should continue to pay particular attention on them, because some frontier articles may be published in these journals. In addition, researchers could choose these journals for their draft submission. Institutions like Centennial College, University of Toronto, University of Ottawa, and scholars like Verkuyl M, Luctkar-flude M, Tyerman J, Cook Da, and Hoffman, HG should be followed and maybe the potential cooperation partner.

Keyword network and references analysis facilitates researchers to get insight into a certain field quickly[10]. We found the keywords with largest node size were following areas: virtual simulation, nurse education, and skills. Moreover, from the color assigned to keywords by VOSviewer, the trend shifted to nurse education, students, clinical simulation, and communication skills. They all indicated that virtual simulation for nursing teaching is a hot topic in current research. Basically, one of the principles of registered nurses is "do no harm" to patients [27]. However, the traditional apprenticeship learning model does not ensure nurses' acquisition of adequate theory and practical skills before handling the clinical workplace [28]. Therefore, 3D virtual environment such as second Life laboratory to practice the students' experience of learning decision-making skills and communication skills got considerable attention in recent years[29-32]. More importantly, the advanced VS program, virtual patients, was developed to provide numerous realistic standard clinical situations to train the students' skills, like clinical reasoning[33-35], communication skills[36-38], situation awareness, and teamwork capability[39] which paved the way of the medical education into a new era. But we should noticed that while studies have shown the positive feedback of VS in nursing education, previous research has largely overlooked the significance of assessment methods of learning outcomes. Currently, the predominant methods for assessing learning outcomes are combinations of paper-based exams and observations from clinical teachers[40], effective and objective assessment methods related to learning outcomes are still lacking[41-43]. Despite Carina,Georg[44]developed the modified visual patient Lasater Clinical Judgment Rubric (vpLCJR) to evaluate nursing students' clinical reasoning, limited studies investigated the method of assessing outcome of nursing students' non-technical skills.

4.1 Limitations

First, the papers on VS in nursing were searched based on the WoSCC. Although WoSCC is recognized as one of the most authoritative databases, PubMed, Scopus, and Google scholar are also widely accepted by scientists. Second, the number of citations and H-index are influenced by time and remain controversial as a comprehensive indicator of the quality of one paper or the author. Likewise, the larger number of publications was not the only indicator of influence for the journal, as other indicators (e.g., impact factor, SNIP, CiteScore, SJR) are widely accepted[45]. Third, we included only English papers in this study, several papers with non-English languages were excluded, such as Chinese, Japanese, and Russian. Finally, the published articles in 2021 only include the first seven months, and database updates may result in discrepancies. However, we believe that the low citation frequency of new publications has less impact on our conclusions.

5. Conclusions

This bibliometric analysis mapped the knowledge network of virtual simulation in nursing research. Further work should strengthen the co-operation between authors, institutions, and countries. Using the Virtual patients to train nursing students, developing more reliable and objective assessment methods to validate learning outcomes might be the recent and future hot-topics.

Abbreviations

WoSCC: Web of Science Core Collection

VS: virtual simulation

IF: impact factor

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed in this study are available from the corresponding author on reasonable request

Competing interests

The authors declare no competing of interest.

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Authors' contributions

Z.Q. conceived of the study, participated in its design, obtained data and drafted the manuscript. L.J. involved in study design, obtained data and contributed to interpretation, and helped to draft the manuscript. C.J. provided the theoretical frameworks and performed much of the editing of the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1

Flow chart of data screening and bibliometric analysis

Figure 2

The number of publications and total citations related to virtual simulation in nursing studies. (A) The number of papers published and total citations each year. (B) The top 10 countries/regions annual publications.

Figure 3

The top 10 most productive institutions and inter-institution cooperation relationships on virtual simulation research in nursing. (A) The number of publications, citation frequency ($\times 0.05$), and H-index ($\times 5$) in top 10 institutions. (B) The co-authorship network visualization map of institution for virtual simulation in nursing research. Node size indicated the number of articles produced. The distance between any two nodes positively associated with the cooperation strength.

Figure 4

The top 10 prolific countries/regions and international collaborations on virtual simulation research in nursing. (A) The number of publications, citation frequency ($\times 0.05$), and H-index ($\times 5$) in top 10 countries/regions. (B) The co-authorship network visualization map of countries. Node size indicated the number of articles produced. The distance between any two nodes positively associated with the cooperation strength. The color indicated the average publication year for the author, Blue represents for early stage and yellow represents late stage.

Figure 5

Analysis of keywords related to publications of virtual simulation in nursing field. (A) The co-occurrence network visualization map of keywords. The keywords grouped into five clusters according to their color. Large nodes represented keywords with high frequency. (B) Keywords were colored according to the appearance for the average time. Blue represents for early stage and yellow represents more recently. (C) The top 19 keywords with strongest citation burst between 1999 and 2021. The red segment of the blue line denoted the burst duration of a keyword.

A

B

Top 23 References with the Strongest Citation Bursts

Figure 6

Analysis of most cited references and co-cited references of virtual simulation in nursing field. (A) The co-citation network visualization map of references between 1999 and 2021. (B) The top 23 references with the strongest citation burst between 1999 and 2021. The blue line represents the time from its first appearance to 2021, the red line represents the burst time.

Supplementary Files

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- [FigureS1.pdf](#)