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Ikpe Justice Akpan * and Asuams A. Akpan

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Review

Evolutionary Trends in Decision Sciences Education Research from Simulation and Games to Data Analytics and Generative Artificial Intelligence

Ikpe Justice Akpan [1,*] and Asuama Akpan [2]

[1] Professor, Department of Information Systems and Business Analytics, Kent State University, OH, USA
[2] Research and Development Department, Ibom International Center for Research and Scholarship, Windsor, ON, Canada
* Correspondence: iakpan@kent.edu; Tel.: +1-330-308-7572; Fax: +1-330 339-3321

Abstract: Decision sciences (DSC) involve studying complex dynamic systems and processes to aid informed choices subject to constraints in uncertain conditions. It integrates multidisciplinary methods, techniques, and strategies to evaluate decision engineering processes, identifying alternatives and providing insights towards enhancing prudent decision-making. This study analyzes the evolutionary trends and innovation in DSC education and research to uncover the transformations over the years. We employ the science mapping method, text analytics, and metadata from bibliographic databases to evaluate thematic and social structures. The results highlight data science methods, including data mining and business/learning analytics as essential components. The evolutionary trends in DSC education and research mirror the development in practice, including technological transformation, computer science advances, and engineering processes. Sustainable education through virtual/online learning also constitutes a significant component of scientific production. The evolutionary trends in DSC education and research highlight innovative pedagogical approaches and strategies, including computer simulation and games ('play and learn'). The current era witnessed generative artificial intelligence (GenAI) adoption (e.g., ChatGPT) in teaching, learning, and scholarly activities amidst challenges (academic integrity, plagiarism, intellectual property violations, and other ethical and legal issues). Future research will implement and integrate AI automatic detection systems to address some GenAI adoption challenges.

Keywords: decision sciences; complex dynamic systems; simulation; GenAI; engineering process innovations; learning analytics; technological transformation; generative artificial intelligence; ChatGPT

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1. Introduction

Decision sciences (DSC) focus on studying complex dynamic systems and processes to aid informed choices subject to constraints in uncertain conditions. The DSC field integrates problem-solving methods, techniques, and strategies from several disciplines, including engineering, business and economics, psychology, and mathematics/statistics, to evaluate operations, production, and processes, assess alternatives, and provide understanding and insights into complex systems to enhance prudent decision-making [1–3]. The DSC field straddles many traditional departmental boundaries, cutting across business, engineering, psychology, and mathematical sciences [1,4,5]. Other pioneering and allied disciplines that contribute significantly to the advancement of the DSC field include operational/operations research (OR), management sciences (MS), and computational and statistical sciences [1,5,6]. The OR/MS also offers potent decision support systems and methods, such as computer simulation, decision theory, and combinatorial and optimization techniques. These constitute effective and practical additions to the DSC methods and further expand the application areas [5,6].

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As DSC education and practice continued to evolve, simulation and games became some of the most long-standing and transformational pedagogical strategies and effective learning techniques [7], starting with the Monopoly board games in the early 20th century [8]. The advent and continuous advancement of computer technology from the mid-20th century led to the development of computer simulation applications for role-playing, which were introduced into DSC academic programs as a teaching strategy and for industry training and practice [7,8]. This development later culminated in creating and adopting visual interactive simulation and the first sets of commercial simulation software, e.g., "SEE-WHY, FORESIGHT, WITNESS" [9]. The subsequent transformation led to visual interactive modeling and simulation as a decision support system [10]. Over the years, computer simulation has progressed significantly, evolving into advanced 3D visualizations [10,11]. The Decision Sciences Institute (DSI) was also formed in 1969 to enhance the continuous expansion and concretization of the DSC field as many Universities soon began offering DSC curricula [5,6]. Also, as part of DSI's contributions to promoting the discipline through education, research, and practice, the organization floated two specialized journals to disseminate knowledge in the field, the first source which published the first issue in 1970 focusing on the DSC research and practice [8]. In 2003, DSI launched another journal dedicated to publishing and advancing DSC education towards advancing the discipline [12]. This development demonstrated the commitment of DSI to providing avenues for researchers and teachers to share innovative teaching approaches and pedagogical strategies to train learners in creative techniques to meet industry requirements in the field, including supply chain management, operations management, and the management sciences [5,6,12].

As DSC education continues evolving with technological advances and accelerated development in computing capabilities and the Internet of Things (IoT), DSC has adopted sophisticated analytic methods emphasizing data-driven decision-making, including business intelligence, big data, business analytics, and artificial intelligence (AI) supported learning [13–15]. This study analyzes the evolutionary trends and innovation in DSC education and research to uncover the transformations over the period 2000-2024. Specifically, this study seeks to achieve the following five objectives:

a. RO1: evaluates the growth trends in DSC education research and citation impacts from 2000 to present.
b. RO2: examine the thematic structure, themes dynamics, and text analytics of DSC education research and identify the transformation over the period.
c. RO3: identify potential future research directions.

2. Materials and Methods

2.1. Bibliometrics Analysis

This study employs quantitative or evaluative bibliometric analysis/science mapping techniques and visual analytics to evaluate the evolution and trends of DSC education research covering 2000-2024. The quantitative bibliometric analysis helps uncover the research trends, themes' dynamics, performance, and citation impact analyses [16]. Evaluating the thematic structure and trends highlights the theme's evolution of the research over the period. Visual analytics helps map the topics and themes and produce visualization [16,17].

The study utilizes two complementary bibliographic applications in the above analyses: an R-based Bibliometrix [16,18] and the VOSviewer [19]. Both applications are open-source and freely available. While the Bibliometrix application package is embedded in the R-Studio environment [18], the VOSviewer is a stand-alone solution and easily usable to produce bibliometric network analysis and visualization capabilities [19]. The two bibliometric evaluation applications can handle "big data" and produce quantitative results.

2.2. Database Survey and Data collection

The stages involved in conducting the database survey and data collection process in this study include

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- identifying the search keywords,
- developing search criteria,
- identifying the bibliographic database(s), and
- conducting the survey.

After retrieving the metadata, the subsequent steps included filtering and screening the bibliographic data based on set criteria (Table 1). However, these processes are the norm when undertaking research involving data collection from scientific publications [20,21]. The publications on DSC education and AI supported learning in this study are available in several proprietary bibliographic databases, including SCOPUS and Web of Science (WoS), the two most popular in quality and coverage [22]. Initially, this study surveyed both data storage platforms. The SCOPUS tends to index more documents on DSC topics than the WoS, a situation that holds sway and is already established in previous and related bibliographic database surveys [22–24].

Table 1. Database survey and data collection processes: search and retrieval, filtering, screening, and selection criteria of publications.

Activities/Focus	Criteria
Data Source(s)	SCOPUS Bibliographic Database search.
Search Criteria	TOPIC: (((“decision science” OR “decision engineering” OR “management science” OR “managerial science” OR “operation* research”) AND (“education” OR “learning”))) OR SOURCETITLE: (((“decision science”) AND (“education” OR “learning”))); Years covered: 2001-2024; Language = English or formerly translated into English; Total =5,570
	Documents Filtering, Screening, and Selection
Filtering	Removed 250 documents: [5513-250 = 5,263]; Book (240); Report (4); Undefined (6).
Screening	Screened out 8 irrelevant documents and reviews 5,263-3,907-=1,413 (documents not addressing decision sciences in education genre).
Final Documents Selection	A total of 1413 publications from SCOPUS between 2001 and May 27, 2024 (when the final literature survey was conducted). Documents retrieved in text formats (.txt and .csv files) for the analysis.

The SCOPUS bibliographic database interface allows users to search and retrieve the data in different formats (e.g., Excel, Text, and more). This study collected the data as a text file and exported it to the BIBLIOMETRIX and VOSVIEWER applications (explained in Section 2.1 above) for processing and analysis. Table 1 shows the search terms used for the database survey and the document selection criteria. The documents retrieved from SCOPUS were subjected to screening and selection processes, during which over 3,907 publications that did not address the topic on DSC education and AI supported learning were discarded. Table 1 presents the search terms/keywords for data collection and the filtering and screening criteria.

3. Results and Discussion

This section presents the results of the quantitative bibliometrics analysis and visual representation of the outputs and discusses the implications.

3.1. Sample Description and Data Summary

This section presents preliminary results and data summary. The dataset used for the analyses came from the final screened and selected publications on DSC education in the past twenty-five years (2000 and 2024). After the final screening to remove the scientific publications (SCP) that did not address the topic of interest, the 1413 documents were extracted as metadata in text format and exported onto ‘Bibliometrix,’ an R-based software application and VOSviewer for analysis and visualization. The 1413 documents appeared in 500 sources (journals: 55%; conference proceedings: 42%; book chapters: 3%). Table 2 shows the full data summary.

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Table 2. Summary metadata on decision sciences education and artificial intelligence supported learning research.

Description	Results	Description	Results
Years of Publications	2000-2024	***Other Documents Info:***	
Sources	500	Document Average Age (Years)*	9.44
Documents Information:		* Publications in 2023: As of July 31.	
Total Publications: Journal article: 777 (55%); Conference papers: 590 (42%); Book chapters: 46 (3%).			
Annual Publications growth rate %	2.74	***Authors and Collaboration:***	
Average citations per document	12.12	Authors	3,324
Total references	40,397	Authors of single-authored document	283
Documents Contents:		Single-authored documents	303
Keywords Plus (ID)	5,669	Co-Authors per document	2.64
Author's Keywords (DE)	3,739	International co-authorships percentage	11.25%

3.2. Performance Bibliometrics Analysis

This Section presents the performance bibliometric evaluation relating to the SCP trend and the citation impact analysis, which addresses the first research objective (RO1).

3.2.1. Scientific Publication Trend

The publication trend for the past 25 years (2000-2024) shows an average of 57 SCPs yearly. The highest single-year research output occurred in 2011, with 178 publications (more than three times the annual average). The ten year-period covering (2000-2009) shows low research productivity (257 or 18%) compared to the next ten year-period (2010-2019), which recorded more than twice the value (778 or 55%), and 2020-2024 May, (378 or 25%), despite 2024 being less than half-year. Further investigation reveals that a spike in the publication of conference proceedings in 2011 contributed to the sharp increase in the SCP for the year. The proceedings papers constituted 70% of the year's SCP and 21% of the 590 total proceedings papers for the entire period. Table 2 presents the complete summary of the sample data. Subsequent years (2012-2024) witnessed an above-average SCP, except for 2013, which had 51 published documents. Figure 1 presents the complete trend for the publications on DSC education research from simulation and games, and AI.

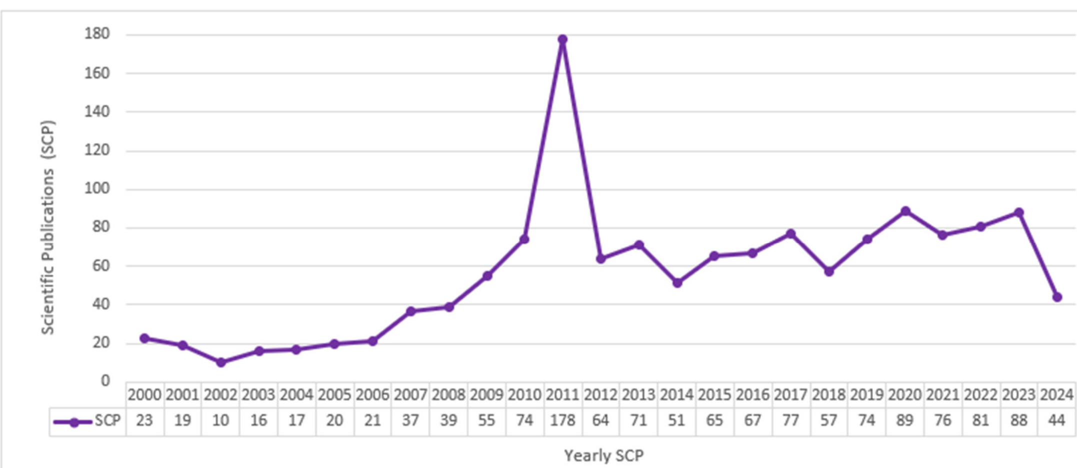

Figure 1. Scientific publications on decision sciences education and artificial intelligence supported learning (2001-2024*) *Publication count for 2024 as of May.

3.2.2. Citations Trend and Impact Analysis

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The second aspect of the first research objective (RO1) analyzes the SCP's citation impacts on DSC education research, including simulation, games, and AI in teaching and learning. The results show that 953 of the publications earned a total of 17,125 citations, with an average of 12.12 per document. Also, 460, or 33%, of publications did not earn any citations, while 67% earned at least one (Table 3).

Table 3. The citation impacts of publications per year (2000-2024).

Year	SCP	TC	Mean TC/SCP	Mean TC/CY	CY	NC	NC%
2000	23	261	11.35	0.47	24	3	13.0
2001	19	599	31.53	1.37	23	3	15.8
2002	10	1190	119	5.41	22	2	20.0
2003	16	348	21.75	1.04	21	9	56.3
2004	17	339	19.94	1	20	4	23.5
2005	20	792	39.6	2.08	19	7	35.0
2006	21	832	39.62	2.2	18	4	19.0
2007	37	570	15.41	0.91	17	16	43.2
2008	39	286	7.33	0.46	16	17	43.6
2009	55	697	12.67	0.84	15	20	36.4
2010	74	1640	22.16	1.58	14	36	48.6
2011	178	1075	6.04	0.46	13	91	51.1
2012	64	1270	19.84	1.65	12	6	9.4
2013	71	920	12.96	1.18	11	12	16.9
2014	51	876	17.18	1.72	10	7	13.7
2015	65	715	11	1.22	9	9	13.8
2016	67	1077	16.07	2.01	8	12	17.9
2017	77	676	8.78	1.25	7	13	16.9
2018	57	926	16.25	2.71	6	9	15.8
2019	74	479	6.47	1.29	5	13	17.6
2020	89	605	6.8	1.7	4	15	16.9
2021	76	492	6.47	2.16	3	23	30.3
2022	81	340	4.2	2.1	2	38	46.9
2023	88	101	1.15	1.15	1	56	63.6
2024	44	19	0.43	-	0	37	79.5
	1413	17125	-	-	-	460	

TC (total citation); CY (citable years); Mean TC/SCP (mean TC per scientific publication); Mean TC/CY (mean TC discounted by citable years); NC (SCPs with no citations).

The citation structure of the publications showed that 665 documents (47.1%) earned between 1 and 10 citations, 223 (16%) earned 11 to 50, and 40 (3%) earned 51 to 100 citations. The two other strata included twenty-two articles that earned 101 to 500 citations and two documents earning 1001+ citations.

The results imply that only a few publications (65 or 5%) earned the most citations (9719 or 57%). As expected, recent publications with fewer citable years earned few citations and vice versa. The SCPs published in 2023 and 2024 earned fewer citations because of the fewer citable years. For example, 63.6% and 79.5% of the SCPs produced in 2023 and 2024 did not earn any citations. Table 3 shows the citation trend from 2000 to 2024, highlighting the yearly count and average per document and annual earned citations discounted by the citable years (CY). Further, the highest single year earned citation occurred in 2010 (1640 or 9.6%), followed by 1270 or 7.4% in 2012 and 1120 or 6.5% in 2002.

The citation count reported above is as recorded on the SCOPUS bibliographic database. The data on Google Scholar (scholar.google.com) can be higher. The citation count on SCOPUS is from sources indexed by it, while Google Scholar records from several other sources. For example, a study entitled "Data envelopment analysis and its application to the measurement of efficiency in higher education" earned 398 citations on SCOPUS as of June 2024 [25]. In contrast, the citation count on Google Scholar (996) was much higher during the same period.

3.2.3. Sources Citation Impact Analysis and SCP Productivity

Another aspect of the citation structure examines the sources' SCPs and impact. The results in Tab1e 2 identify 500 sources that published the 1413 documents (journals: 777 or 55%; proceedings: 590 or 42%; book chapters: 46 or 3%) assessed in the study. The results of the Bibliometrix application highlight the eminent sources that published the most documents and earned the most citations.

Table 4 shows the 16 most eminent sources (fifteen journals and one conference proceeding), most of which are multidisciplinary, including one dedicated DSC education journal (Decision Sciences Journal of Innovative Education - DSJIE). The DSJIE contributed 298 or 21.1% of the SCPs and earned significant citations compared to all other journals (3354 or 19.5% citations). One of these articles examines the title "Teaching Artificial Intelligence through Gamified Social Entrepreneurship in an Introductory MIS Course," which has received 42 citations on SCOPUS [26]. Other eminent sources that produced high SCPs and earned significant citations are "Journal of the Operational Research Society," "Journal of Decision Support Systems," and "Journal of Decision Systems." Table 4 shows the complete results.

Table 4. Eminent sources by SCP and citation impact.

Element	SCP	TC	PY_Start
Decision Sciences Journal of Innovative Education	298	3354	2011
Journal of the Operational Research Society	30	561	2000
Decision Support Systems	18	862	2007
Journal of Decision Systems	17	104	2007
IOP Conference Series: Materials Science and Engineering	16	56	2017
IEEE Access	14	132	2014
Interfaces	13	80	2003
European Journal of Operational Research	12	1603	2001
Journal of Cleaner Production	8	549	2003
Journal of Professional Issues in Engineering Education and Practice	7	67	2001
International Journal of Educational Management	6	140	2004
Management Science	5	1399	2001
Technological Forecasting and Social Change	5	198	2007
Operations Research	5	116	2001
Applied Sciences (Switzerland)	5	49	2017
Socio-Economic Planning Sciences	5	43	2010

TC (total citations); PY_Start (publication year start), that is, when the journal started publishing articles or proceedings.

The sources listed in Table 4 highlight the interests of top-ranking journals in DSC and OR/MS. These journals also produce SCPs that address the methods, techniques, and strategies that enhance the analysis of complex systems and producing outputs to aid decision-making. Although conference proceedings formed 42% of the total SCP in this study, only one paper is listed among the most impactful publishing sources.

3.3. Thematic Structure of DSC Education Research

This Section evaluates the thematic structure and themes dynamics of DSC education research to uncover the evolution, trends, and transformation in the research themes over the period. The results of science mapping of the DSC education research and the thematic structure of SCPs address the second research objective (RO2).

One of the most popular uses of bibliometric mapping is identifying the research areas, topics, and themes [18–20,27,28]. The evaluation uses author keywords as the unit of analysis. Previous science mapping studies show that authors' keywords point to a research focus and can help to map the research streams for any scientific study [28,29]. The analysis involves identifying the most prominent, emerging, and least popular research themes and evaluating themes' dynamics to uncover any potential transition or transformation in research over the period covered in this study.

The dataset in this study contains 3,739 unique authors' keywords extracted from the 1413 published documents (Table 2), with a total unstemmed cumulative word frequency (f) of 5,734. Some of the terms appeared more than once in the dataset. The sample is stratified into categories based on keyword popularity for in-depth analysis as follows:

- The prominent author keywords; word frequency (f >= 10): 42
- Emerging research themes; word frequency (10 > f >= 5): 78
- The least used keywords; word frequency (f < 5): 3619

As explained earlier, there are 3,739 unique authors' keywords, which is the sum of the prominent, emerging, and least frequently used themes (42, 78, 3,619). Figure 2 shows that there are 3,129 unstemmed keywords appearing once. This means that 3,129 unique terms had word frequency of one, while keywords appearing twice occurred 338 times. In total, the 3,739 unique words had total frequency (f) of 5,734 in the sample. Classifying author keywords into the three (3) categories (prominent, emerging, and least frequent ones) intends to provide an in-depth and exhaustive analysis of the thematic structure of the SCP on DSC education research, including simulation and games, and AI.

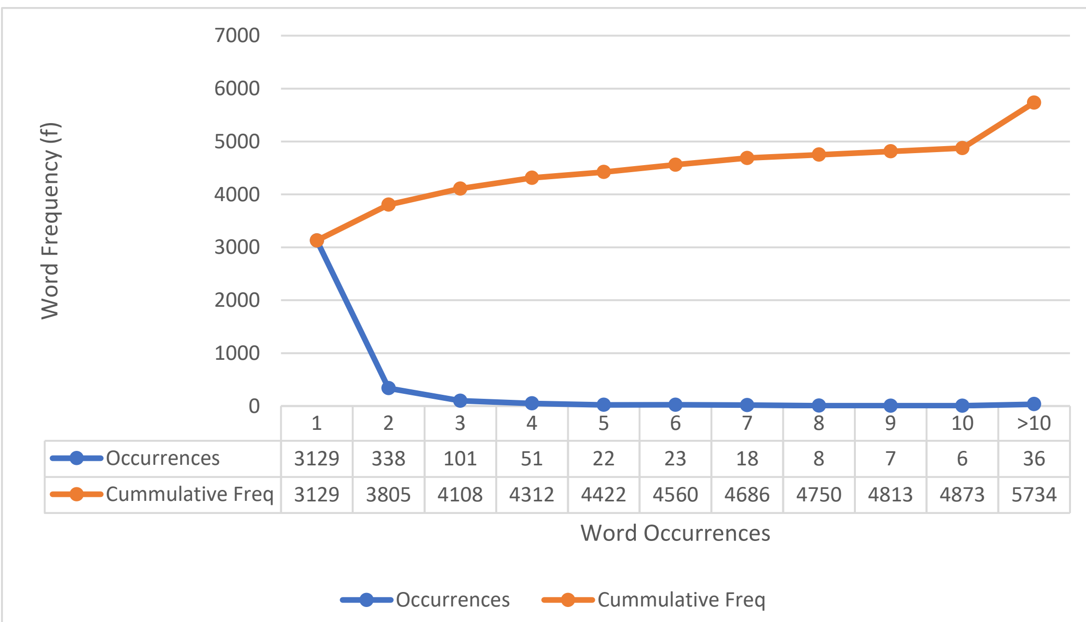

Figure 2. Text analytics results of unstemmed word occurrences and cumulative frequency.

3.3.1. The Prominent Themes and Trends

As listed above, the most prominent keywords are classified as the ones with the frequency (f) of occurrences greater than or equal to 10 (f >= 10). The results produced by using the Bibliometrix application in the R-studio environment identifiedforty-two (42 or 1%) unique keywords (unstemmed) occurring ten times or more (Table 2), having a total word frequency of 921 times (16.6%) of the total 5,734 occurrences. The 42 most prominent unique terminologies went through a manual stemming process, producing 27 keywords and themes. The keyword stemming combines terms with the same meaning even though spelled differently. For example, the theme "decision

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support system" was combined with "decision support systems" or "decision-support systems" as these terms point to the same theme "decision support system" (f1 = 84) as the most frequently researched theme. The next popular theme is "pedagogical approaches" (f2 = 64), the next most used term. Figure 3 presents the results of all the prominent terms (stemmed).

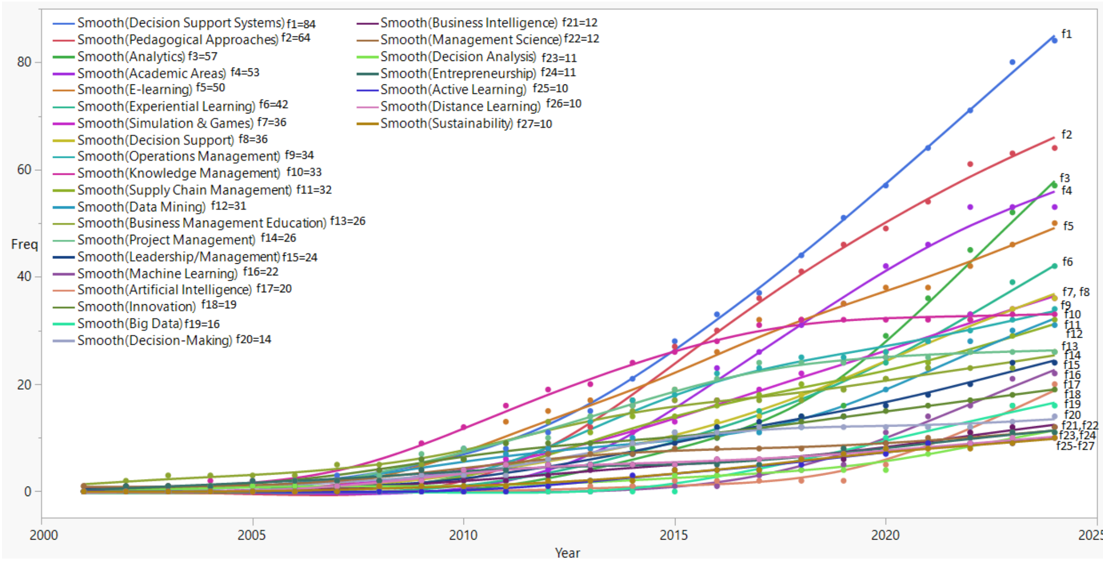

Figure 3. The trend analysis of prominent themes on DSC education research (2000-2024).

Also, the dynamics of the themes are presented from 2000 to 2024, highlighting the most frequently top-researched themes, and mapping the trends. For example, the third popular theme is "Analytics" (f3 = 57), while "experiential learning" came as the 6th (f6 = 42), while "simulation and games" also made the list as the 7th (f7 = 36). The trend shows that "knowledge management" (f10= 33) was one of the popular themes in the early 2000s but now receiving less attention in recent years (Figure 3). On the other hand, themes such as "machine learning" (f16 = 22) and "artificial intelligence" (f17= 20) emerged more recently and remain relevant.

Another essential aspect of DSC education research and trends is that the frequent themes also include the core DSC and OR/MS subject areas, including "operations management" (f9 = 34), "supply chain management" (f11 = 32), and business management education" (f13= 26). Figure 3 shows the complete thematic trends.

3.3.2. Evolutionary Trends in Decision Sciences Education Research

The evolution of themes presented in this Section reinforces the trends of prominent terms on DSC education discussed in the previous Section. The analysis focuses on the dominant research topics split into three-period strata. The first two strata cover ten years each (2000-2009, 2010-2019), while the third segment covers the remaining 5 out of the 25 years (2020-2024).

Using the Bibliometrix application in the R-studio environment [18] and the text analytics capability enables a comprehensive evaluation of eminent themes in the three-period segments. The purpose is to uncover the evolution of research themes during the 25 years (2000-2024). The results highlight the origin and evolution of these dominant research topics in DSC education in each period. Table 5 presents 15 frequent themes in each period segment generated.

- The First Segment (2000-2009)

In the first segment (2000-2009), the three most popular themes studied include "knowledge management" (KM), "data envelopment analysis" (DEA), and "decision support systems" (DSS). Some of the studies addressed 'KM education and curriculum development' [30], "Critical skills and knowledge requirements of IS professionals" [31], and 'Knowledge-based improvement, simulation, and artificial intelligence' [32]. The DEA theme examined its application to measure the efficiency in

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higher education [24]. The DSS study analyzed the use of a "decision support tool to identify AACSB peer schools" [33]. However, evidence shows that these themes existed in the broader OR/MS research landscape before the year 2000, e.g., the following studies occurred in the 1990s before the period covered in this study, including 'knowledge management perspectives' [34], "survey of knowledge-based systems research in decision sciences" [4]; 'dynamic DEA' [35]; 'improving decision making using marketing DSS' [36], a survey of DSS and roles [31,37]. These studies appeared in high-ranking OR/MS and DSC sources.

Table 5. Evolution of dominant research themes on decision sciences education research including simulation games and artificial intelligence.

	2000-2009			2010-2019			2020-2024		
No.	**Themes: n=785 [21%]**	f	LS	**Themes: n=1907 [51%]**	f	LS	**Themes:n=1047 [28%]**	f	LS
1	Knowledge management	9	32	Pedagogical/teaching approaches	45	157	Decision support systems	50	188
2	Data envelopment analysis	8	33	Online education/e-learning	32	93	Experiential learning	23	89
3	Decision support systems	8	31	Decision support systems	26	124	Artificial intelligence	20	77
4	Technology/policy/ management	8	30	Operations management	24	97	Machine learning	17	91
5	Engineering/systems	8	29	Knowledge management	23	55	Data mining	17	79
6	Project management	7	27	Supply chain management	20	68	Data analytics	18	57
7	Innovation	6	20	Experiential learning	19	73	Pedagogical approaches	15	61
8	Decision analysis	6	12	Project management	17	56	Online education/e-learning	22	93
9	Entrepreneurship/ orientation	6	21	Teaching using games and simulation	17	45	Supply chain management	11	34
10	Change management	5	17	Academic areas	16	75	Business analytics	10	32
11	Data mining	5	16	Simulation	12	38	Big data	9	61
12	Efficiency	5	22	Data mining	9	25	Leadership	9	39
13	Organizational learning	5	15	Decision-making	9	34	Games/simulation	9	35
14	Decision-making	5	16	Innovation	8	43	Operations managt	9	32
15	Economic growth	5	17	Data envelopment analysis	8	33	Decision analysis	7	31

f: keyword frequency; LS: Link Strength of the themes in the network.

- The Second Segment (2010-2019)

Some prominent themes from the previous period continued to increase while other terms faded. For example, studies on KM, DEA, and DSS continued to attract the interest of DSC educators and researchers during the second segment, with studies such as "university knowledge management tool for the evaluation of the efficiency and quality of learning" [38], "knowledge management for learning software project management" [39], and "benchmarking using data DEA" [40].

Several new themes also emerged and advanced into prominence during the (2010-2019) period. The newly evolved themes include 'pedagogical and innovative teaching approaches' such as "consulting practicum as a strategy to enhance students' readiness for a professional career" [41], 'simulation and serious games as a pedagogical tool for managerial decision-making,' and 'teaching using games and simulation' through role-playing [42–44], and 'online education/e-learning in DSC' [45]. However, "simulation and games," as a DSC method or technique, had been a tool for learning and decision-making in industry practice well before this period (e.g., a study on computer simulation conducted by Kaczka in 1970 [46]). The service production and manufacturing sectors also experienced games and simulation applications for learning and practice over the years [7,8,47] and continue to the current era [23,48].

Another interesting occurrence in the thematic evolution in the period (2010-2019) is the emergence into prominence of data science/analytics techniques and methods as essential parts of DSC and DSS industry practice is "data mining" [49] alongside related terms, including "big data" [50,51], "business analytics" [51–54], and "learning analytics" [52]. However, the literature provides evidence that these data science concepts emerged well before this period (e.g., [55,56]), but evolved into a sustained research topic in 2010 and beyond. Even in this study, the data mining theme first appeared in the previous decade segment (2000-2009) but became more prominent in the second segment (2010-2019) [49-54; Table 5]. In the second period, data science and related themes in DSC education research became prominent. Some of the topics include 'preparing or training data scientists and designing a big data analytics course' [50], identifying the "knowledge, skills, and abilities for entry-level business analytics positions" in the industry [53], and "turning data into better decision-making" [54].

- The Third Segment (2020-2024)

The third segment coincides with the waves of digitization and digitalization, such as an accelerated use of technological equipment, devices, and digital platforms for daily operations, including remote services and educational activities [57,58]. Some of the reasons that influence rapid digitization include the fourth industrial revolution (i4.0), which ushered in well-developed interconnected technologies through the Internet of Things (IoT) [23,59,60], and the fallouts from the SARS-CoV-2 outbreak, which mandated the use of digital technologies and platforms [58,61,62].

With the above hindsight, the research landscape in DSC education and industry applications has also evolved to match the practice in the broader society. Studies on "data mining" [49,55,56] and related themes, including "business/data analytics" [50–53,63], continued to evolve into prominence and remained a sustained research topic. In this period (2020-2024), data analytics has become a significant bidirectional pedagogical approach. On the one hand, capstones as learning strategies have been developed to enable learners to gain practical and suitable business/data analytics skills for the industry. On the other hand, data science methods such as learning analytics and deep learning are also becoming pedagogical strategies in DSC education and 'management learning' [51,52,64,65].

In addition to DSS and 'experiential learning' being the top two themes in this segment, AI and machine learning have been prominent topics in DSC education and practice research in recent years (Table 5). However, its use to generate insight and aid managerial decisions started in the 1990s (e.g., Pomerol [66] investigated AI and human decision-making as an OR technique in 1997). Similarly, Robinson et al. [32] investigated using 'simulation and artificial intelligence to identify and improve human decision-making' in 2004, a period that falls within the first segment of this analysis (2000-2009). Generally, some researchers consider AI just as another educational technology that enhances teaching and learning [67]. However, generative AI (GenAI), such as a "chat generative pre-trained transformer" (ChatGPT), plays a more significant role in DSC education and practice by helping teachers to generate curriculum and learning materials quickly [68,69]. Students also use ChatGPT to study, create essays, and complete assignments and homework [70,71]. Academic researchers have also used the GenAI platforms to research and produce scholarly papers [71]. However, these new dimensions created by GPT tend to generate significant controversies due to ethical, legal, and social implications, such that some scientists and researchers have suggested a ban on GenAI [69–71]. At the same time, policymakers race to control and check any misuse [72,73].

3.3.3. Visualization of Prominent and Emerging Themes in DSC Education Research

This Section employs the science mapping technique and text analytics to visualize the thematic structure of DSC education research in a network map. We used data on the prominent and emerging themes generated through text analytics from the Bibliometrix application embedded in the R-Studio, as defined in the previous Section [16,17]. The prominent and emerging themes (42, 78, respectively) comprise 120 unstemmed unique keywords or 3.2% of the 3,739, described as the terms with a frequency or occurrence of 5 and above (f>=5), which includes the prominent and emerging themes (as defined in Section 3.3.1).

The network map visualizes the DSC education research themes using the co-occurrence of author keywords and the interconnectedness [15–18]. Using the VOSviewer application (explained in Section 2), the algorithm stratifies the themes into color-coded clusters, with the same color nodes indicating the same Cluster. The network map comprises nodes (circles), edges (lines), and node labels. At the same time, the edges (lines) connect one node to another throughout the network. The nodes' sizes and labels depend on the number of occurrences of specific keywords that point to research topics or subjects. The bigger the node, the more frequently the word occurs [15,16,18,19]. The network map sets the keyword frequency at 5 (f>=5), which generates 120 unstemmed keywords as a pointer to the research themes [16–19]. The VOSviewer software used to create the visualization

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allows the analyst to remove nugatory terms or words that do not convey contextual meanings [18]. The bibliometric algorithm in VOSviewer stratifies the keywords into color-coded clusters. Also, the themes in the same Cluster are mapped to the colored trend line to correspond with the cluster colors marked by the year of publication. The VOSviewer application does not automatically stem the keywords but considers terms with different spellings as unique despite being similar in meanings (e.g., "decision support system" and "decision support systems" are considered unique terms). Figure 4 presents the network visualization of the prominent and emerging themes in DSC education research and practice.

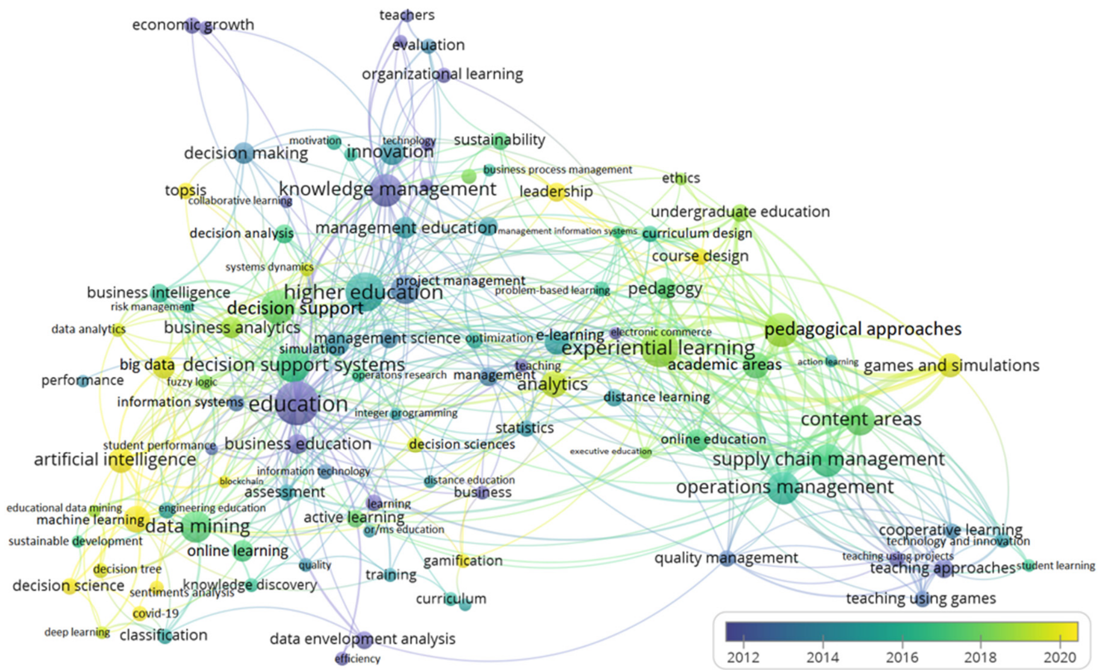

Figure 4. Network visualization of themes in DSC education research and practice.

The result (Figure 4) shows the themes classified into five color-coded clusters produced using the VOSViewer application as follows:

a. purple: covers themes published between 2000 and 2012, some of the themes in this Cluster ("education," "data envelopment analysis," "organizational learning," "knowledge management," "teaching using games," and more).
b. ocean-blue: The themes in this Cluster were published between 2012 and 2014. (Some of the items are: "business intelligence," "innovation," "e-learning," "operations management," "OR/MS education," and more).
c. green: published between 2014 and 2016 ("decision support systems," "data mining," "ethics," "pedagogy," and more).
d. lemon-green: occurred between 2016 and 2018 ("pedagogical approaches," experiential learning," and more).
e. yellow: This Cluster contains themes published between 2018 and 2024 ("artificial intelligence," "business analytics," "big data," "machine learning," "games and simulations," and more).

The themes dynamics (a-e) identify the trends and evolution in DSC education research, games and simulation, and artificial intelligence and correlate with the analysis of the periodic evolution presented in Sections 3.3.1 and 3.3.2.

The above results show that DSC pedagogical approaches in education and research closely mirror industry practice development. While the early years of research focused on core DSC and OR/MS methods techniques (e.g., purple Cluster), the recent ones also highlighted the technological trends such as data science and AI.

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3.3.4. The Least Frequent Themes

This section analyzes the research themes that occur the least times. The results in this section help address the third research objective (RO3). These are themes with frequency (f) occurring four times or less (f < 5). The least occurring themes form the majority (3619 or 97%) of the 3739 author keywords. This category also denotes the least researched topics, usually new or abandoned researched fields. The network map is also represented by nodes (circles) and edges (lines). However, there are quite a few or no interconnecting links (edges) between the nodes due to little research work associated with those themes.

Figure 5 shows the results produced on a network map using the VOSViewer platform, showing a less connected network of topics covering the period. The period shows the themes classified into five color-coded clusters. For example, the purple Cluster shows the themes published on or before 2010. These themes can be termed abandoned due to the absence of further research on those topics in the DSC education genre. Some of the themes in this Cluster are ("edukiwi," "globalization," "collaboration," and more). Interestingly, the period corresponds with the period that these topics emerged in the early 2000s but waned with time. However, it is not unusual that the topic can still receive attention in different fields, such as "globalization."

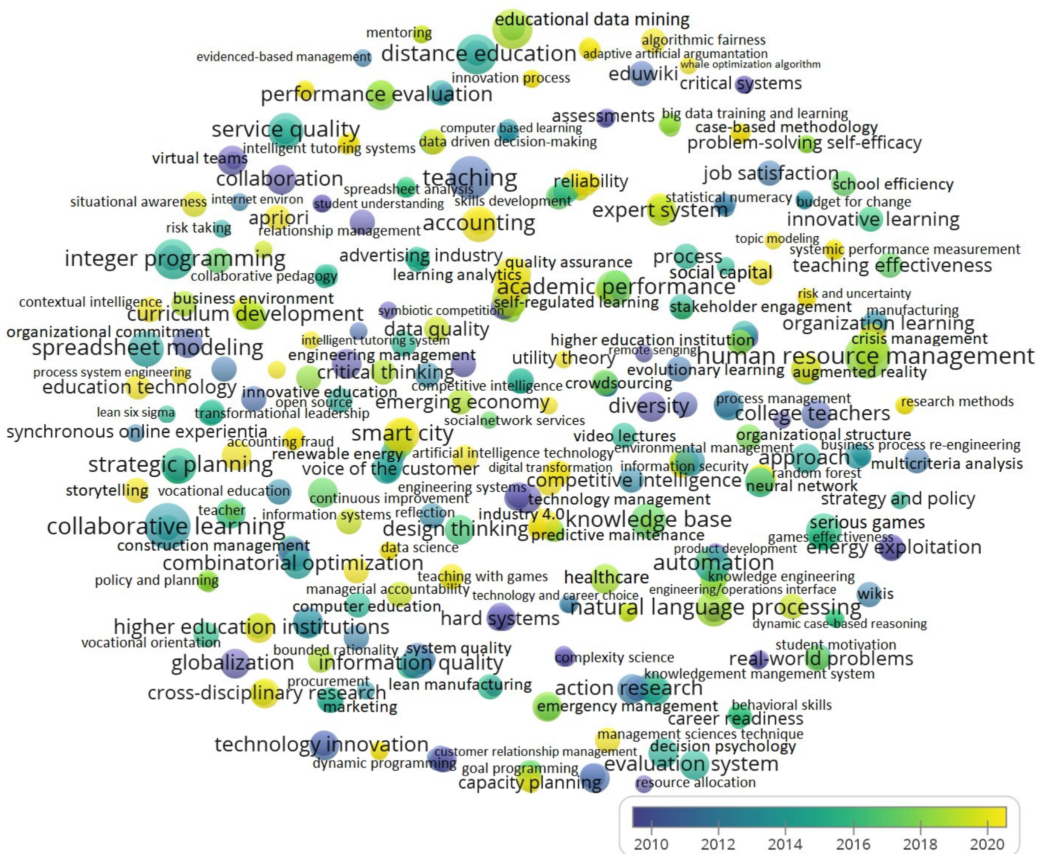

Figure 5. The least frequent themes (f < 5).

In recent periods (2018-2020: the lemon-green coded Cluster), and (2021-2024: the bright-yellow-colored nodes). Some of the least researched topics include "competitive intelligence," "educational data mining," "learning analytics," "industry 4.0," and more) as shown in Figure 5. Again, these are currently trending topics. The results indicate the transformative nature of DSC education, which closely mimics trends in industry practice and research.

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3.4. Simulation and Games, Data Analytics, and GenAI in DSC Education

The adoption of simulation and games, data analytics, and GenAI were introduced in DSC education at different times. However, the three pedagogical strategies have recently become complementary as integrated learning techniques and in industry practice. Adopting these approaches enhances learners' academic experience and industry training. Games such as Monopoly Board have a long history of application in DSC for teaching decision-making since the mid-20th century [7,8,42,43]. Similarly, simulation games offer an experiential and applied learning opportunity by transforming abstract concepts into tangible ones by replicating real-world environments and scenarios in the classroom. The practical scenarios allow students to apply theoretical knowledge in practical situations, thus offering more profound insight into complex real-world scenarios and improving decision-making [46,47]. Simulation and games also provide an immersive learning experience and a virtual environment for active involvement, making the learning process more engaging and enjoyable [11,23,74,75]. The virtual environment created by simulation helps students develop critical thinking skills and decision-making in a risk-free but realistic setting [11,74,75].

Furthermore, the millennium witnessed significant advances in computer technology that came with increased personal computer storage capacity and processing speed. The introduction of Internet-based cloud computing and user-generated content brought about the data analytics era [13,50,51]. This evolution ushered in the introduction of data science methods, including learning analytics, brought more opportunities for learners, and enabled real-time data generation and processing to generate insights for informed decision-making. By adopting these technologies, educators can provide students with the skills and knowledge to solve complex DSC problems [53,54].

The DSC discipline and OR/MS are prominent areas adopting artificial intelligence [6,32]. More recently, the introduction of GenAI in education has been considered a disruptive technology that can revolutionize traditional education as we know it. The introduction of GenAI in DSC education offers significant benefits. For example, enhancing decision-making, which is the goal of DSC, involves modeling and simulating complex systems that can help generate insight for decision-making. GenAI can be helpful in problem-solving as students can create a scenario and feed a description onto GenAI (e.g., ChatGPT) to develop the model of complex systems [67–69,71,73]. Also, ChapGPT can be trained to generate extensive synthetic data for analysis. However, the limitations associated with such synthetic data do not always mimic real-world scenarios [76,77].

An integration of simulation and games, data analytics, and GenAI offers the opportunity to create interactive, immersive, and engaging learning experiences and improve students' learning outcomes.

3.5. Countries' Productivity and Impact

The country productivity and impact analysis using R-Bibliometrix produces the results of scientific literature productivity and citation impact on DSC education SCP during the period covered in this study (2000-2024). The top four productive countries include the USA, China, Indonesia, and the UK. The USA stands out as the dominant country in SCP and citation impact, where most literature (over 31%) originates. Table 5 lists the top 16 countries contributing at least 1% of the total literature publications.

Table 5. Eminent Countries in decision sciences education research productivity and impact.

Countries	SCP	SCP%	TC	Average Citations	TC%
USA	1086	31.3	7014	19.9	41.0
China	658	19.0	833	4.1	4.9
Indonesia	179	5.2	57	3.6	0.3
UK	122	3.5	1176	29.4	6.9
India	85	2.4	288	16.0	1.7

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Australia	81	2.3	715	32.5	4.2
Canada	72	2.1	549	21.1	3.2
Germany	70	2.0	183	13.1	1.1
Spain	67	1.9	204	12.0	1.2
Brazil	66	1.9	29	2.9	0.2
Portugal	57	1.6	224	20.4	1.3
South Africa	56	1.6	36	1.9	0.2
Malaysia	54	1.6	22	3.7	0.1
France	34	1.0	97	9.7	0.6
Italy	34	1.0	174	19.3	1.0
Greece	33	1.0	28	4.7	0.2

Table 5 also highlights the impacts of the publications from the 16 countries that contributed at least one percent of the publications. The citation impact follows a similar trend to the literature publication, with the USA being the most cited country with a majority (41%) and an average of 20 citations per document. The other countries were the UK (7%) and China (4.9%). However, the UK recorded a higher average citation per published document (29.4), compared to 4.1 for China. Table 5 presents the complete results. Table 5 presents the complete results.

4. Conclusion

This study analyzed DSC education research advances and evolutionary trends in the past two and a half decades (2000-2024). The authors designed several research objectives to examine the topic exhaustively. We analyzed the growth and citation impacts, evaluated the thematic structure, themes dynamics, and text analytics, and identified the transformation over the period.

In the text analytics using the R-Bibliometrix application employed word frequency (f) or co-occurrence of themes and categorized the research keywords into three groups, namely, the most prominent topics (f >= 10), emerging research themes (10 > f >= 5), and the least researched topics (f < 5). About 97% of the keywords fell in the least frequent co-occurrence of words, indicating the research themes that attracted the lowest research interest as pointers to areas for future studies (Figure 5). The emerging research themes made up 2.1%. Among these research fields include “online education,” “business analytics,” and “online learning resources). Figure 4 shows a full list. The most prominent category made up 1.1% (Figure 2) and includes “decision support systems,” “pedagogical approaches,” “e-learning,” and “artificial intelligence.” Others include teaching methods and practices involving decision sciences subjects (operations management and supply chain management). The themes dynamics show the consistency of publications involving these research fields across the years covered in this study (2000 to 2024).

The study highlights the symbiotic relationship among DSC education, ‘simulation and games,’ data analytics, and AI and identifies potential future research directions. Computer simulation plays an essential role in DSC and OR/MS as a decision support system, while simulation games can be a potent pedagogical technique in several disciplines. This study has demonstrated the effectiveness of simulation, serious games, experiential learning techniques, and AI as strategies in aiding teaching and learning, industry training for solving complex problems and developing decision-making skills, and practical applications in making informed decisions [11,47,75]. Also, simulation and games help to bridge the gap between DSC theory and practice [76].

The latest trend witnesses the integration of GenAI. Also, the fusion of simulation and games, big data analytics, and GenAI in DSC education indicate the potential to positively transform teaching, learning, and research and improve decision-making [10]. However, to ensure the successful application of GenAI as a disruptive technology in DSC education, research, and practice, educators must develop appropriate policy guidelines on ethical issues, data privacy, and security to check against any potential abuse. Future research will implement and integrate AI automatic detection systems to address some GenAI adoption challenges.

Despite the strong and valid evidence that GenAI offers DSC education, serious concerns about its potential negative impacts on academic integrity violation, unethical use, and data privacy and security, amongst others [67,68,71]. There are urgent calls for educational institutions to develop policy guidelines on using GenAI for academic teaching, learning, research, and creative activities. However, policy enactment might only be a necessary but not sufficient solution to checkmate the potential abuse. We propose implementing and integrating AI automatic detection systems to address some GenAI adoption challenges.

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