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REVIEW ARTICLE

Assessing the Intellectual Structure of the Evolving Knowledge Base on ChatGPT in the Field of Education and Health

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Background/purpose –The unprecedented developments in AI-based technologies and large language models such as ChatGPT have exhibited a brand-new territory to be explored. Since its first release in November 2022, the potential utility of ChatGPT has garnered incremental attention in the scientific world, and has already accumulated a great number of studies from diverse fields. The current study was conducted with the purpose of exploring the scientific landscape of the evolving knowledge base related to the use of ChatGPT in the field of education and health through science mapping analysis of published research.

Materials/methods – Data were retrieved from Web of Science and Scopus, and a comparative, period-based science mapping analysis was conducted using the SciMAT software.

Results – The results showed that the studies published during the first period mostly focused on machine learning, reproductive medicine, education and first-year undergraduate themes. During the second period, though, the studies featured themes that are closely related to the design and performance of ChatGPT such as large language models (LLMs), natural language processing (NLP) and chatbot while abandoning a focus on artificial intelligence. These results imply that discussions and investigations over ChatGPT were being departed from those in the field of artificial intelligence, and the focus was becoming more central to the features of ChatGPT as a language model that can process huge amounts of information to generate human-like texts. Plagiarism and research ethics were also emerging themes during the last period.

Conclusion – The results of the science mapping showed a growing interest into the opportunities and risks of ChatGPT, particularly for fields of education and medicine, and indicated that much research is warranted to discover the potential of GPT technology as an uncharted territory.

Keywords – ChatGPT, education, artificial intelligence (AI); large language models (LLMs); natural language processing (NLP); chatbot; SciMAT

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1. INTRODUCTION

Artificial intelligence (AI) technologies are being widely used in many parts of human life. These technologies, which are designed as systems equipped with capabilities to perform tasks that can naturally be performed by intelligent beings such as learning, judgment and decision-making (Karakose & Tülübaş, 2023; Polat et al., 2023; Sadiku, Musa, & Chukwu, 2021; Xu, Li, & Li, 2023) have currently proved their ability to successfully solve a variety of complex problems (Ouyang, Zheng, & Jiao, 2022). OpenAI, which was established as a research laboratory in 2015 (Brockman et al., 2016), has made a significant contribution to the advancement of AI technologies by developing DALL-E and ChatGPT models in a short time (Devlin et al., 2018). Computer programs that were previously designed to simulate talking to people over the Internet have made significant contributions to the development of GPT technology, which can generate texts that are almost indistinguishable from natural human language (Dale, 2021; Pavlik, 2023).

ChatGPT is a machine learning model that uses supervised and unsupervised learning techniques to understand and respond in many modern languages (Radford et al., 2018). As an AI-based chatbot developed with a GPT language model technology (Kirmani, 2022), ChatGPT is built on the algorithm of summarizing large language models (LLMs), answering questions posed to it, translating the given text into different languages, understanding and generating responses in a variety of modern languages (Min et al., 2021; Shen et al., 2023). Large language models (LLM), a type of generative AI models, have the ability to process and use a vast amount of data to create new content (Gozalo-Brizuela & Garrido-Merchan, 2023). Prior to its release in November 2022, ChatGPT was trained on a massive dataset of approximately 570 GB (Brown, 2023; Susnjak, 2022). Having reached more than 100 million users short after its release (The Guardian, 2023), ChatGPT has managed to attract the attention of people with diverse interests and expertise. ChatGPT, which is still in its infancy and being tested on various tasks (Su & Yang, 2023), is also capable of developing itself by constantly learning from previous interactions thanks to its intelligent communication ability (Kohnke, 2022; Shen et al., 2023).

1.1. The promises of ChatGPT

Soon after its release, ChatGPT has proven that it might assist or guide many tasks that previously required human intelligence and effort. To list a few of these benefits, ChatGPT, with its ability to engage in human-like communication, has the potential to contribute to the development of the users' fluent and correct sentence formation skills as well as promoting critical thinking skills (Anders, 2022; Cotton, Cotton, & Shipway, 2023). Similarly, it can help users attain digital skills (Carlisle, Ivanoz, & Dijkmans, 2021; Tülübaş, Karakose, & Papadakis, 2023) via providing them with instant feedback (Gilson et al., 2023; Kuhail et al., 2023), improves their writing skills (Zhai, 2023), and computer programming skills (Biswas, 2023). Moreover, ChatGPT facilitates access to information (Cascella et al., 2023; Zhai, 2023) and thus supports individualized learning (Latifi et al., 2021). In broader terms, ChatGPT facilitates the learning of complex subjects by providing an opportunity and guidance to learn (Farrokhnia et al., 2022). ChatGPT could also support teachers through providing feedback for students' written assignments, and thus reduce their workload (Mizumoto & Eguchi, 2023).

Further trials and investigations into the capabilities of ChatGPT have revealed its strong potential in several other fields. As cited in İpek et al.'s (2023) recent review, ChatGPT showed great performance in abstracting, paraphrasing, and translating texts, generating answers to high-level questions in several exams, and solving complex mathematical problems. In their recent study, Karakose et al. (2023a, 2023b) also evidenced that ChatGPT was able to support scientific work process through providing accurate, clear, and concise information in a matter of time. Their comparative analysis with ChatGPT-3.5 and ChatGPT-4 also demonstrated that much progress was made with its latest version (e. i. GPT-4). In a different context, Huang et al. (2023) revealed that ChatGPT-4 had a stronger potential to support clinical decision making and to provide medical education for general public and cancer patients. In the field of manufacturing industry, Badini et al. (2023) found that ChatGPT was successfully trained to improve the efficiency and accuracy of Gcode generation process (e type of 3D printing technology). They asserted that through saving time and materials, ChatGPT could improve the quality of the final product and offer cost-effective solutions for the manufacturing industry. Such recent findings continue to inspire and excite people from various backgrounds and working in diverse fields.

1.2. The concerns over ChatGPT

Despite its ability to provide a wide scope of benefits and convenience, ChatGPT also bears some pitfalls and raises concerns in many ways (Borji, 2023). For one thing, although ChatGPT demonstrates an outstanding performance in producing logical, relevant, consistent and grammatically correct text (OpenAI, 2023), it does not fully understand the logic in generating its answers (Bogost, 2022). Perhaps due to this fact, there is often no depth in its responses (Borji, 2023; Tülübaş et al., 2023). ChatGPT could also generate responses that fall out of the scope of the query (Lecher, Duron, & Soyer, 2023). This supports the view that ChatGPT' tends to generate superficial responses to complex problems. What's more, ChatGPT's lack of human skills to evaluate the reliability of the data it is trained on (Barocas & Selbst, 2016) could make it generate biased responses, particularly when the training data includes biased information (Bakpayev et al., 2022). Another major criticism of ChatGPT is that it lacks higher-order thinking as well as lacking contextual awareness, and common sense (Bakpayev et al., 2022; Baymurzina et al., 2023). ChatGPT also poses a significant threat to academic integrity since it can generate fluent, grammatically accurate, and relevant texts in response to queries as well as inciting students to cheat especially in unsupervised online exams (Garg & Goel, 2022; Gašević, Siemens, & Sadiq, 2023). Its tendency to focus on plausibility than accuracy (Delouya, 2023), limited ability to solve mathematical problems (Frieder et al., 2023), likelihood to cause problems regarding intellectual property rights (Chui, Roberts, & Yee, 2022) are also raised as significant concerns.

1.3. The purpose of the current study

Although ChatGPT has just recently become public, it has already attracted the attention of researchers from diverse fields, and a significant number of studies have been published, accumulating a sufficient knowledge base to be explored. However, to the researchers' knowledge, the conceptual architecture and the thematic evolution of ChatGPT research field have not been exhibited yet. Considering such work is significant to delineate the state-of-

the-art knowledge in the field and to guide future studies, the current study aims to explore the scientific landscape of the evolving knowledge base related to ChatGPT through science mapping analysis of published research and to facilitate insights into the conceptual structure and thematic evolution of this emerging knowledge base. The study particularly addresses the following research questions:

RQ1: What is the extent and growth rate of 'ChatGPT' literature?

RQ2: What are the evolving research themes in 'ChatGPT' literature?

RQ3: What research themes have attracted the greatest and the weakest attention of scholars in ChatGPT literature?

RQ4: What are the emerging research themes in ChatGPT literature?

2. METHODOLOGY

The current research was designed as a science mapping study with the purpose of delineating the prominent, evolving, and emerging themes in the ChatGPT literature, and map the scientific landscape of this research domain.

Science mapping methodology is a type of bibliometric review. However, unlike traditional review studies, it does not address the findings of the published research but aims to identify thematic linkages in a field of study (Cooper, 2016). Therefore, 'the unit of analysis in science mapping is a domain of scientific knowledge that is reflected through an aggregated collection of intellectual contributions from members of a scientific community or more precisely defined specialties' (Chen, 2017, p. 3). Science mapping analysis allows for revealing the relationships between the disciplines, fields, and specialties, as well as identifying the cognitive structure and thematic evolution of a knowledge domain (Cobo et al., 2012). Thus, it enables to illustrate the development and evolution of the scientific knowledge in a particular domain, and provides new perspectives into the opportunities, gaps, and future directions of research (Furstenau et al., 2021; López-Robles et al. 2021).

Different software tools exist to conduct science mapping analysis such as VOSviewer, Bibexcel or CiteSpace. However, in the present analysis, we preferred to use SciMAT, which is capable of combining several stronger aspects of the previously developed software tools (Cobo et al., 2012). In addition, SciMAT is particularly powerful as it analyzes the themes in four categories based on the strength of their relationship to the development of the field, and allows for period-based analysis. It also demonstrates the central themes with relevant subthemes, which enables to make better interpretations and offer deeper insights. More significantly, SciMAT can yield the thematic evolution of the field through illustrating the evolution trends and linkages of the themes across periods, which is an analysis not performed by other tools.

2.1. Data search and extraction

Data for the current study were collected via simultaneous searches conducted on two reputable databases: Clarivate's Web of Science (WoSCC) and Elsevier's Scopus. These databases are renown for indexing a wide array of high-quality studies from diverse research fields. Given that both Scopus and WoS are regarded as optimal databases to retrieve data for

science mapping and bibliometric studies (Cañadas et al., 2021; Martínez et al., 2015), data search for the current study was conducted on both databases. While selecting data, the inclusion/exclusion criteria listed in Table 1 was used. The rationale behind the listed criteria is also included in the table.

Table 1. Inclusion/exclusion criteria

Criteria	Inclusion	Exclusion	Rationale
Language	English	Other languages	English is international science language Single language helps yield comprehensive science mapping analysis.
Document Type	Articles	Books, book chapters, conference proceedings	Targeting Scopus-WoS indexed research with rigorous preview/keywords are significant
Context	All	No exclusion	Wide coverage of results
Database	Scopus / WoS	Other databases (e. g., Google Scholar, PubMed, ERIC)	Broad coverage of high-quality research

While conducting data search, no time specification was made considering the recent nature of ChatGPT publications, and to keep the scope of the analysis as broad as possible. The following keyword string was used to perform a keyword search against the Scopus and WoSCC bibliographic database on May 12, 2023:

> *for WoSCC bibliographic database:* TI=("ChatGPT" OR "Chat generative pre-trained transformer")
>
> *for Scopus database:* TITLE ("ChatGPT" OR "Chat generative pre-trained transformer")

The selection of the publications included in the analysis is reported according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidance (Moher at al., 2019), and presented in Figure 1.

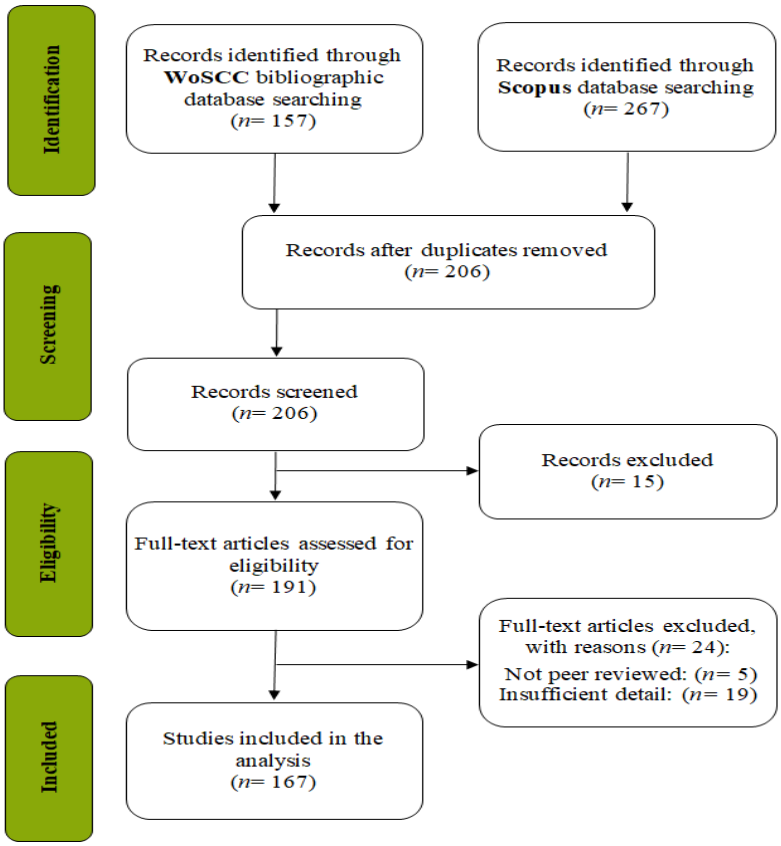


Figure 1. PRISMA flow diagram

As reported in the PRISMA diagram in Figure 1, our search on WoSCC first yielded 157 publications while the Scopus search yielded 267 publications. First, the two lists were examined using the R computer programming to detect the duplicates, and at this stage 206 publications remained after excluding 218 publications from the list for being duplicates. Next, the titles and abstracts of these 206 publications were screened by the authors, and a total of 39 publications were excluded due to not being peer-reviewed or providing insufficient details. At the end of this data curation procedure, a total of 167 publications were included in the final analysis, which were published between December, 2022 and May, 2023.

2.2. Data extraction and analysis

With the purpose of exhibiting the conceptual structure and thematic evolution of ChatGPT research field, data retrieved from Scopus and WoS were submitted to science mapping analysis (Cobo et al., 2011; Martínez et al., 2015). In the current study, SciMAT software (version 1.1.04) was used because it allows for comparative, period-based analysis as well as determining and visualizing thematic trends and evolution in a particular field of study across periods (Cobo et al., 2011; Chen, 2017). The analysis started with data curation and extraction. First, the bibliometric data for each article in the selected dataset were transferred to the SciMAT program, and prepared for the analysis. First, the keywords that are very similar or slightly different versions of each other such as 'chatbot / chatbots', 'large language models / LLMs' were grouped manually, which is a necessary step to reach rigorous results (Cobo et al., 2011; López-Robles et al., 2021).

Next, science mapping analysis was conducted based on the frequency of cooccurrence of each keyword restored in the SciMAT program. The analysis was performed using the 'equivalence index' and the 'clustering algorithm'. The former is used for calculating similarities and identifying the strength of the association between clusters representing the themes while the latter allows for identifying the strength of the relationship between different clusters. The results of the science mapping analysis are presented in a strategic diagram with four quadrants and two dimensions as shown in Figure 2 (Sott et al., 2020). The dimensions represent the centrality (x-axis) and the density (y-axis) values, where centrality refers to the external relationships between the themes and density refers to the internal relationships within a theme. In other words, centrality shows the extent of the interaction between clusters and the strength of their relationship while density shows the capacity of themes to persist and develop over time in that particular research field and indicates the strength of the relationship between the keywords within each theme. Centrality values are calculated using the mathematical formula 'c=10*Σekh', where 'k' represents a keyword belonging to one theme and 'h' represents a keyword belonging to another theme. Centrality is significant in determining the relationship between themes, and shows whether a cluster or network is an important crossing point during the specified period. As the relationship between themes become stronger, the themes move to the right in the strategic diagram. The density values are calculated using the mathematical formula 'd =100 (Σeij/w)' where 'i' and 'j' represent the keywords of the theme, and 'w' represents the number of keywords in the theme. As the internal relationship between keywords within a theme increases, the themes move upwards in the strategic diagram (Cobo et al., 2011).

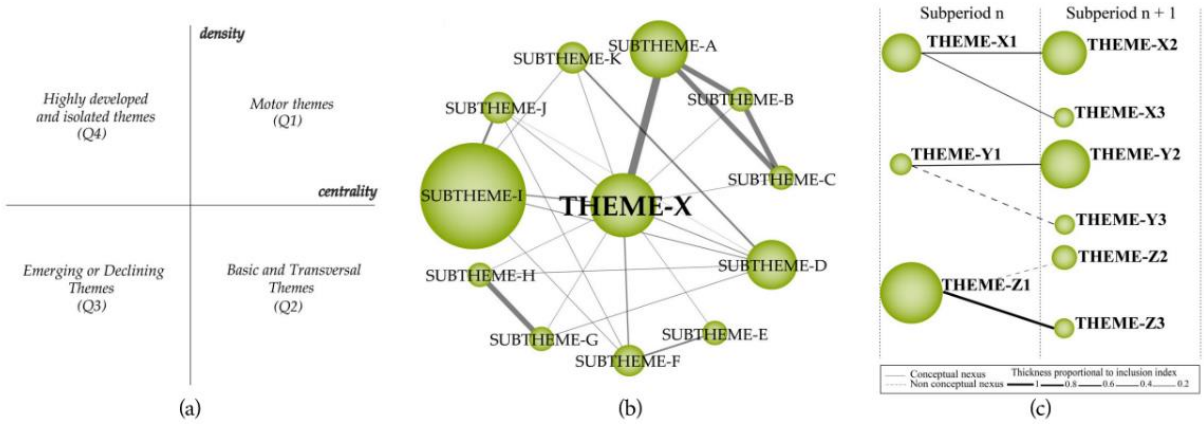


Figure 2. (a) Strategic Diagram, (b) Thematic Network Structure, (c)Thematic Evolution Structure (Sott et al., 2020)

As for the four quadrants in the strategic diagram (Figure 2a), each represent the type of themes yielded by the science mapping analysis for the relevant period. Themes with high centrality and density appear in quadrant 1 (Q1). These themes are called 'Motor Themes', and are the most important themes because they enable the development and structuring of the research field. Themes with high centrality and low density appear in quadrant 2 (Q2). These themes are called 'Basic and Transversal Themes'. Although they significantly relate to the research field, they are not developed enough to become a motor theme. However, they are the strongest candidates to become motor themes in the future as their high centrality values imply. Themes with low centrality and density appear in quadrant 3 (Q3). These

themes are called 'Emerging or Declining Themes'. Whether these themes are newly emerging or disappearing during the period of analysis could be determined through qualitative analysis or a systematic review of the literature. Themes with low centrality and high density appear in quadrant 4 (Q4). These themes are called 'Highly Developed and Isolated Themes'. These themes are peripheral for the research field under analysis, or they are highly specialized on their own. These themes might have been replaced by newly-emerged concepts or terms or may have lacked the appropriate background to support the research field.

Figure 2b shows the *Thematic Network Structure* in a cluster of a theme. The *Thematic Network Structure* illustrates the subthemes of a strategic theme as wells as the relationships between these subthemes. Each network structure is labelled using the most central (thus the most important) keyword in the cluster, and the subthemes related to this central theme are scattered around it. The volume of the spheres gets larger as the number of corresponding articles increases while the lines become thicker as the relationship between the subthemes becomes stronger (Cobo et al., 2011, 2012).

Figure 2c illustrates the *Thematic Evolution Map*. As its name suggests, this illustration shows the evolution of strategic themes across periods of analysis as well as their origins, time periods, and their interrelationships over subsequent periods. The *Thematic Evolution Map* includes a set of themes which may or may not be a continuation of any one theme. The relationship between the themes across periods is shown using solid or dashed lines. When two themes share the same keywords as the theme label, these lines are solid, and they get thicker as the degree of their relationship increases. When two themes share common keywords different from the theme label, these lines are dashed. The size of the circles that represent a theme reflects the number of corresponding articles to that theme (Cobo et al., 2011, 2012; Martínez et al., 2015).

To conduct a comparative, period-based science mapping analysis, the total number of publications was divided into two periods. As suggested by Cobo et al. (2011), including almost even number of articles in each period of analysis is significant to obtain rigorous results. Therefore, the articles selected for analysis were divided into two categories which were later called Stage 1 and Stage 2, representing the two subsequent stages of development in the ChatGPT research field. Stage 1 comprises 84 articles published between December 2022 and March 2023 while Stage 2 comprises 83 articles published between April 2023 and May 2023.

3. RESULTS

3.1. Publication and citation trends

In order to analyze the publication and citation trends in the ChatGPT research field, a bibliometric performance analysis was first performed and the distribution of articles by months, the number of accumulated publications, and the average citations per article were determined (Zupic & Čater, 2015). The results are illustrated in Figure 3.

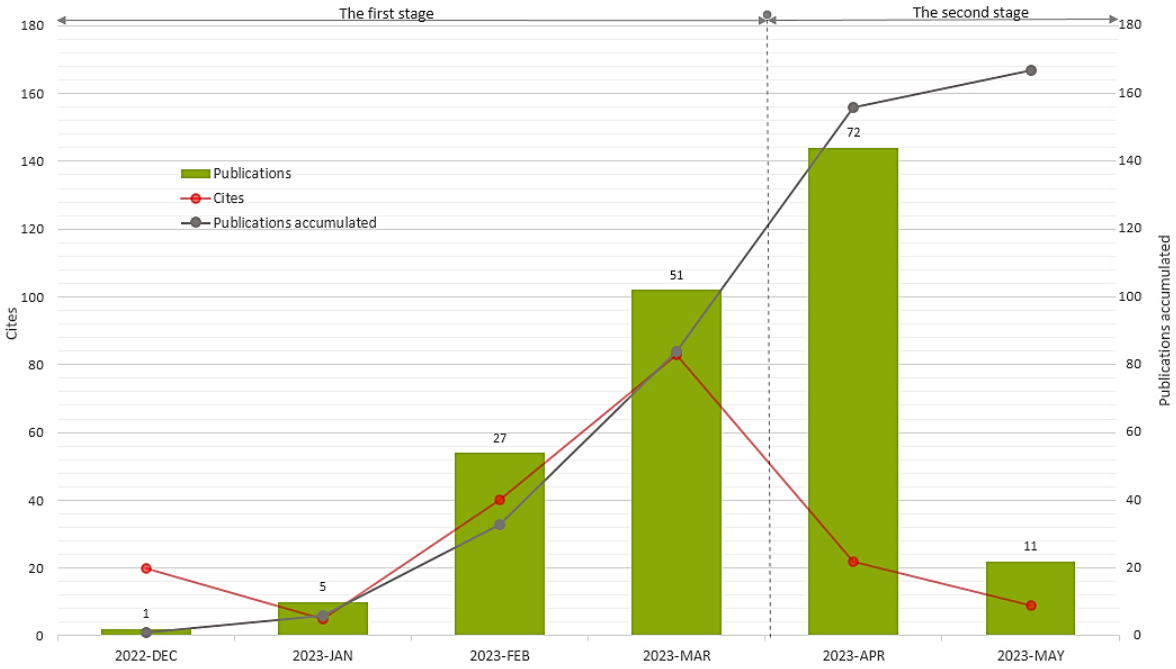


Figure 3. Distribution of articles and citations by month (Data: WoSCC/ Scopus, 12 May 2023)

As shown in Figure 3, studies on ChatGPT began to be published right after ChatGPT-3.5 was made public in November 2022, and a total of 6 articles were published by the end of January 2023. Since then, the number of publications increased, and made a huge leap in April with 72 new publications. 11 articles were published in the first quarter of May 2023, until the time the data search was conducted. This is quite a good number of publications in such a short time span. As for the citation trends, it is evident that articles published in February and March received the highest citation rates. As the number of publications increase in the coming months of 2023, the citation rates for articles published in April and May could also be expected to increase.

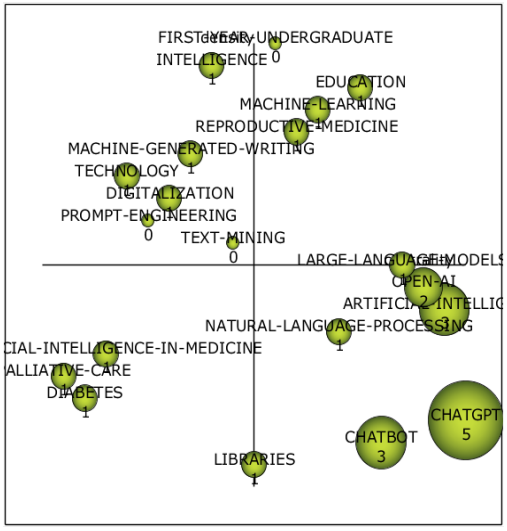
3.2. Science mapping analysis

This section presents the results of the science mapping analysis conducted using SciMAT software regarding the dataset retrieved from WoSCC and Scopus databases. The results are presented in three categories: (1) thematic analysis for Stage 1 and Stage 2; (2) overlapping map; (3) thematic network analysis. The performance values of themes, i. e. document counts, h-index values, citation rates, centrality and density values are presented next to each strategic diagram.

Scientific evolution structure

Stage 1 (2022/Dec–2023/Mar): For the science mapping of Stage 1, a total of 84 articles were included in the analysis, which yielded 20 themes. The strategic diagram and the performance values for these themes are presented in Figure 4.

a. Stage 1 (2022/Dec–2023/Mar)



b. Themes' Performance

Theme	Document Count	h-index	Cites	Centrality Range	Density Range
CHATGPT	17	5	70	1	0.15
ARTIFICIAL-INTELLIGENCE	19	3	39	0.95	0.4
OPEN-AI	8	2	13	0.9	0.45
LARGE-LANGUAGE-MODELS	7	1	1	0.85	0.5
CHATBOT	9	3	17	0.8	0.1
EDUCATION	2	1	1	0.75	0.9
NATURAL-LANGUAGE-PROCESSING	6	1	21	0.7	0.35
MACHINE-LEARNING	3	1	2	0.65	0.85
REPRODUCTIVE-MEDICINE	1	1	2	0.6	0.8
FIRST-YEAR-UNDERGRADUATE	1	0	0	0.55	1
LIBRARIES	2	1	5	0.5	0.05
TEXT-MINING	1	0	0	0.45	0.55
INTELLIGENCE	1	1	2	0.4	0.95
MACHINE-GENERATED-WRITING	2	1	5	0.35	0.75
DIGITALIZATION	1	1	1	0.3	0.65
PROMPT-ENGINEERING	1	0	0	0.25	0.6
TECHNOLOGY	2	1	16	0.2	0.7
ARTIFICIAL-INTELLIGENCE-IN-MEDICINE	1	1	2	0.15	0.3
DIABETES	2	1	1	0.1	0.2
PALLIATIVE-CARE	1	1	1	0.05	0.25

Figure 4. (a) Strategic diagram for Stage 1; (b) Performance analysis for Stage 1; Source: SciMAT

20 themes that emerged from the analysis of articles published during Stage 1 were distributed to all four quadrants of the strategic diagram. *Large-Language-Models, Education, Machine-Learning, Reproductive-Medicine*, and *First-Year-Undergraduate* themes emerged as motor themes. Namely, these themes contributed to the development of the ChatGPT research field during the first stage. *Intelligence, Machine-Generated-Writing, Technology, Digitalization, Prompt-Engineering*, and *Text-Mining* themes were found to be highly developed and isolated themes. Although they were strongly related to each other, they did not have the appropriate background or significance for the research field. On the other hand, *Artificial-Intelligence-in-Medicine, Palliative-Care,* and *Diabetes* themes appeared in quadrant three as emerging or declining themes. *Libraries, Natural-Language-Processing, Open-AI, Artificial-Intelligence, Chatbot,* and *ChatGPT* themes were found to be basic and transversal themes. Although these themes were related to the field, they were not developed enough during the first period of analysis.

Cluster networks (see Figure 5) were analyzed to determine the subthemes related to the motor themes. The analysis showed that the central theme of *Large-Language-Models* (0.85, 0.5) had relationships with the *Student-Character, Political-Bias, Health, Gpt-3.5, Generative-Artificial-Intelligence-And-Science-Education, Digital-Technologies, Algorithmic-Bias* and *Stress* subthemes. In addition, the cluster network showed that *Stress, Health,* and *Student-Character* themes were investigated in relation, and *Digital-Technologies and Generative-Artificial-Intelligence-and-Science-Education* themes were strongly related. These studies on Student-Character (Crawford et al., 2023), Political-Bias (Rozado, 2023), Health (Sallam, 2023), Generative-Artificial-Intelligence-and-Science-Education (Cooper, 2023), and Algorithmic-Bias (Rozado, 2023) support our findings with regard to the Large-Language-Models cluster network.

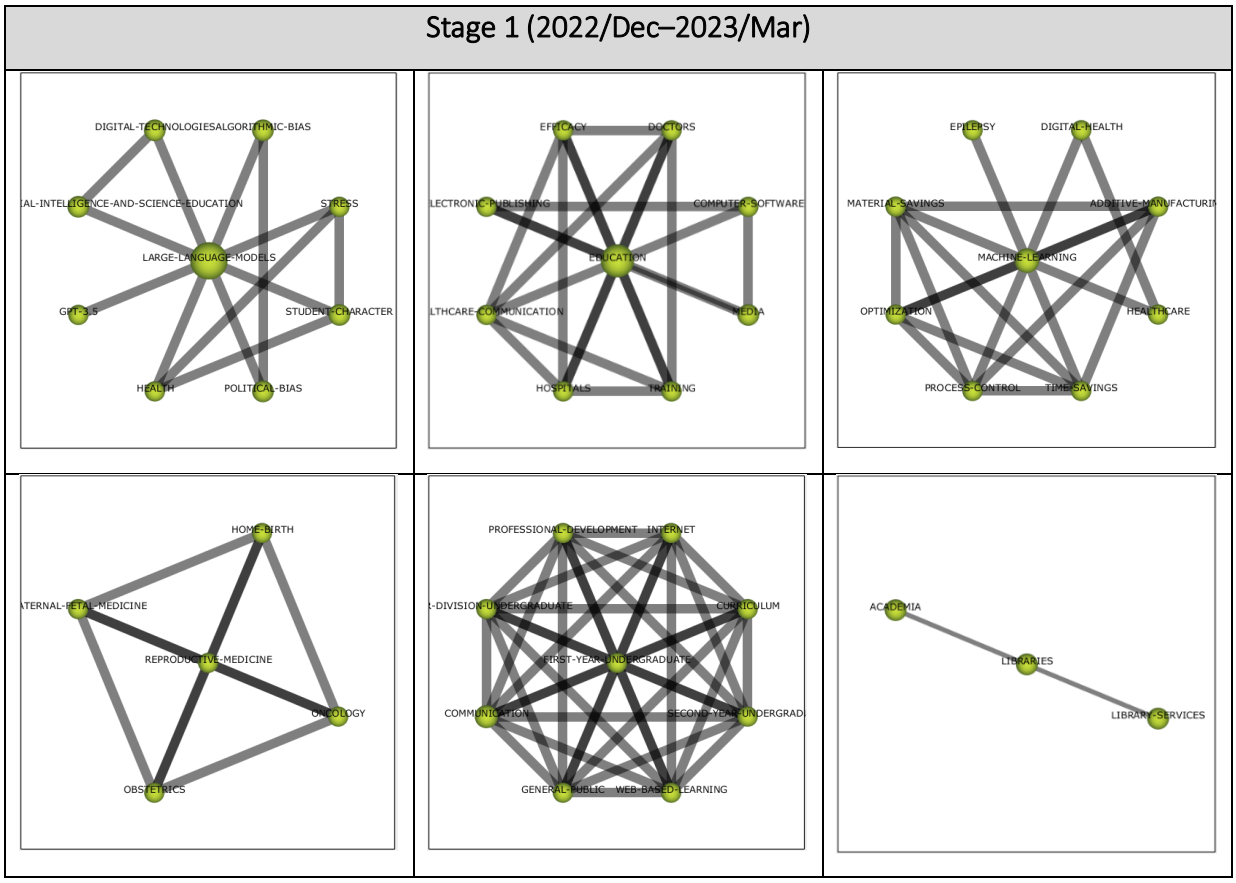


Figure 5. Thematic network structures (stage 1)

The central theme of Education (0.75, 0.9) was determined to have relationships with the *Media, Training, Hospitals, Healthcare-Communication, Electronic-Publishing, Efficacy, Doctors,* and *Computer-Software* subthemes. There were strong relationships among the *Computer-Software, Media* and *Electronic-Publishing* subthemes and among *the Training, Hospitals* and *Healthcare-Communication* subthemes. These studies on Media (Pavlik, 2023), Training, Healthcare-Communication, Efficacy, Doctors (Santandreu-Calonge, et al., 2023) and Computer-Software (Fernandez, 2023) support our findings with regard to the Education cluster network.

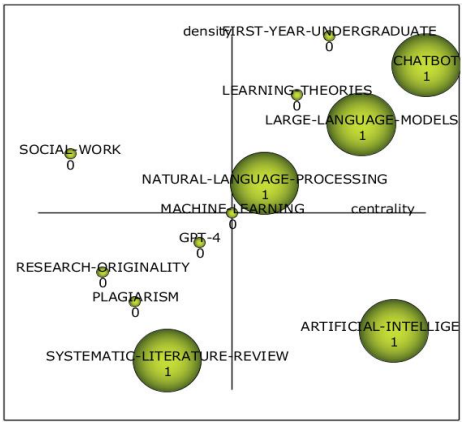
The central theme of Machine-Learning (0.65, 0.85) was related to the subthemes of *Healthcare, Time-Savings, Process-Control, Optimization, Material-Savings, Epilepsy, Digital-Health*, and *Additive-Manufacturing*. Strong relationships were also observed among these subthemes, as reflected by the thick lines connecting them. These studies on Healthcare (Vaishya et al., 2023), Time-Savings (Badini et al., 2023), Epilepsy (Boßelmann, Leu, & Lal, 2023), and Digital-Health (Sallam, 2023) illustrate our findings with regard to the Machine-Learning cluster network.

The central theme of Reproductive-Medicine (0.6, 0.8) was found to have relationships with *Oncology, Obstetrics, Maternal-Fetal-Medicine* and *Home-Birth* subthemes. These studies on Oncology (Ebrahimi et al., 2023), Maternal-Fetal-Medicine, and Home-Birth (Grünebaum et al., 2023) support these findings with regard to the Reproductive-Medicine cluster network.

The central theme of First-Year-Undergraduate (0.55, 1) was related to *Second-Year-Undergraduate, Web-Based-Learning, General-Public, Communication, Upper-Division-Undergraduate, Professional-Development, Internet* and *Curriculum* subthemes and the thick lines connecting the themes indicate that these themes were strongly related to each other. These studies on Second-Year-Undergraduate (Humphry & Fuller, 2023), Web-Based-Learning (Fergus, Botha, & Ostovar, 2023), Communication, Upper-Division-Undergraduate & Professional-Development (Ağaoğlu et al., 2012; Emenike & Emenike, 2023), Internet (Khan et al., 2023), and Curriculum (Das et al., 2023) support these findings with regard to the First-Year-Undergraduate cluster network.

Stage 2 (2023/Apr–2023/May): For the science mapping of Stage 2, a total of 83 articles were included in the analysis, which yielded 12 themes. The strategic diagram and the performance values for these themes are presented in Figure 6.

b. Stage 2 (2023/Apr–2023/May)



b. Themes Performance

Theme	Document Count	h-index	Cites	Centrality Range	Density Range
CHATBOT	12	1	1	1	0.92
ARTIFICIAL-INTELLIGENCE	10	1	5	0.92	0.17
LARGE-LANGUAGE-MODELS	8	1	2	0.83	0.75
FIRST-YEAR-UNDERGRADUATE	3	0	0	0.75	1
LEARNING-THEORIES	1	0	0	0.67	0.83
NATURAL-LANGUAGE-PROCESSING	4	1	1	0.58	0.58
MACHINE-LEARNING	3	0	0	0.5	0.5
GPT-4	2	0	0	0.42	0.42
SYSTEMATIC-LITERATURE-REVIEW	2	1	1	0.33	0.08
PLAGIARISM	1	0	0	0.25	0.25
RESEARCH-ORIGINALITY	1	0	0	0.17	0.33
SOCIAL-WORK	1	0	0	0.08	0.67

Figure 6. (a) Strategic diagram for Stage 2; (b) Performance analysis for Stage 2; Source: SciMAT

The 12 themes determined from the analysis of articles published during Stage 2 appeared in all four quadrants of the strategic diagram. The first quadrant included the Chatbot*, Large-Language-Models, Natural-Language-Processing, First-Year-Undergraduate, Learning-Theories* and *Machine-Learning* themes. These themes were the motor themes that had driven the development of the research field during the second stage. The *Social-Work* theme was found to be a highly developed and isolated theme while *GPT-4, Research-Originality, Plagiarism*, and *Systematic-Literature-Review* themes appeared in Q2, representing the emerging/declining themes. Finally, the *Artificial-Intelligence* theme was found to be a basic and transversal theme, which had a strong potential to become a motor theme in the subsequent period.

Cluster networks (see Figure 7) were analyzed to determine the subthemes related to the motor themes emerged during Stage 2. The analysis showed that the central theme of Chatbot was related to the *Generative-Language-Models, English-Language-Learning, ChatGPT, Intelligence, Tourism, AI-In-Tourism, Teaching* and *Socratic-Dialogue* subthemes. ChatGPT was found to have relationships with all the subthemes in this cluster. These studies on Generative-Language-Models (Carvalho & Ivanov, 2023), English-Language-Learning

(Kohnke et al., 2023), ChatGPT (Tekinay, 2023), Teaching (Kohnke et al., 2023), Intelligence (Guo et al., 2023), AI-In-Tourism (Skavronskaya, Hadinejad, & Cotterell, 2023), and Socratic-Dialogue (Gregoric & Pendrill, 2023) support these findings with regard to the Chatbot cluster network.

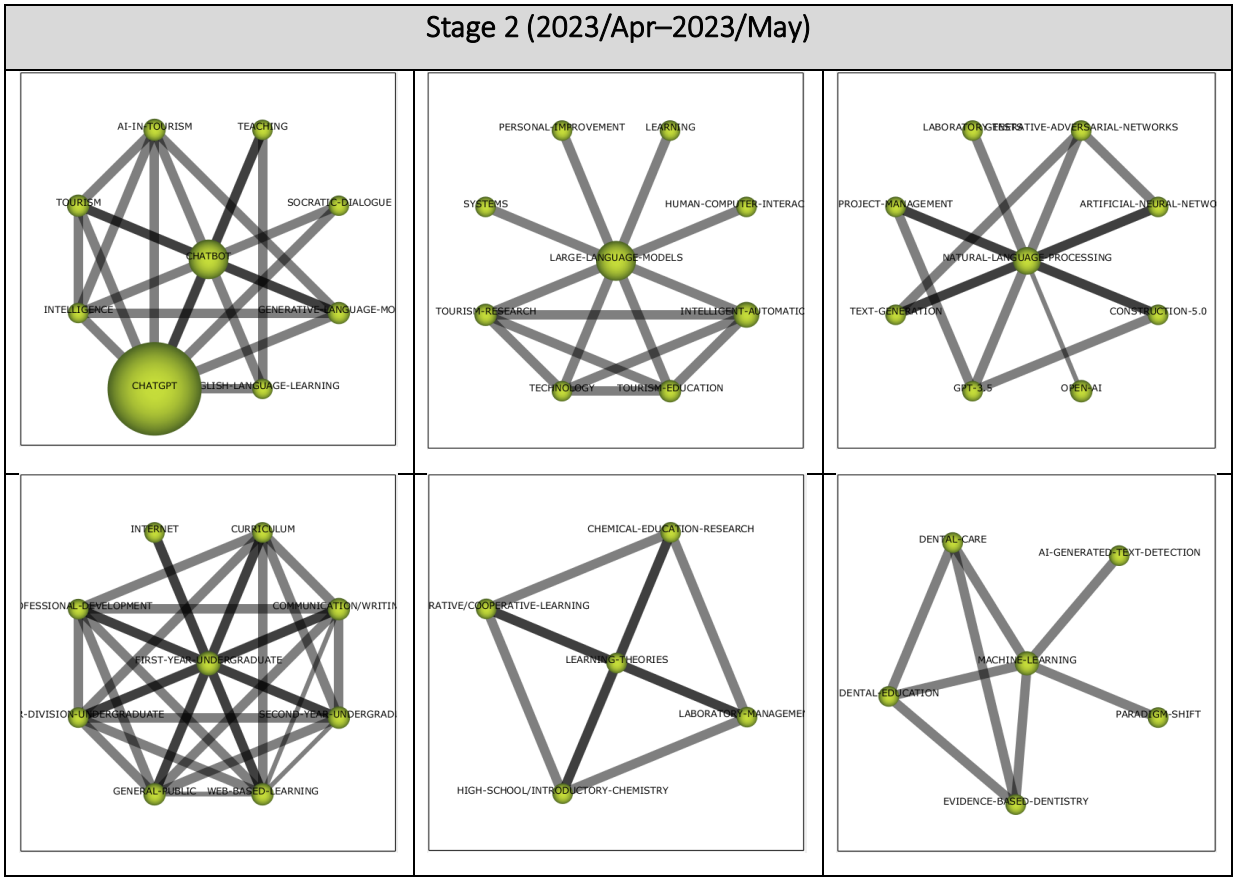


Figure 7. Thematic network structures (stage 2)

The central theme of Large-Language-Models was found to have relationships with the subthemes of *Intelligent-Automation, Tourism-Education, Technology, Tourism-Research, Systems, Personal-Improvement, Learning,* and *Human-Computer-Interaction*. The analysis also showed that *Tourism-Education* and *Tourism-Research* were strongly related. These studies on Intelligent-Automation and Tourism-Research (Ivanov & Soliman, 2023), Tourism-Education (Skavronskaya et al., 2023), Technology (Karakose et al., 2023; Scerri & Morin, 2023), Systems (Liu,Wright et al., 2023), Personal-Improvement (Haman & Školník, 2023a), Learning (Khan et al., 2023), and Human-Computer-Interaction (Jeon & Lee, 2023) support these findings with regard to the Large-Language-Models cluster network.

The central theme of Natural-Language-Processing was related to the *Text-Generation, Project-Management, Open-AI, Laboratory-Tests, Gpt-3.5, Generative-Adversarial-Networks, Construction-5.0,* and *Artificial-Neural-Networks* subthemes. These studies on Text-Generation (Ramos et al., 2023), Project-Management and Construction-5.0 (Prieto, Mengiste, & García de Soto, 2023), Open-AI (Khan et al., 2023), Laboratory-Tests (Cadamuro et al., 2023), GPT-3.5 (Ray, 2023), and Generative-Adversarial-Networks (Ramos, Márquez, & Rivas-Echeverría, 2023) support the results with regard to the Natural-Language-Processing cluster network.

The central theme of First-Year-Undergraduate was found to have relationships with the *Web-Based-Learning, Second-Year-Undergraduate, General-Public, Communication/Writing, Upper-Division-Undergraduate, Professional-Development, Internet*, and *Curriculum* subthemes. The themes in the cluster were also observed to have strong interrelationships. These studies on Web-Based-Learning (Fergus et al., 2023), Second-Year-Undergraduate (Humphry & Fuller, 2023), General-Public and Professional-Development (Emenike & Emenike, 2023), Communication/Writing (Humphry & Fuller, 2023), Upper-Division-Undergraduate (Emenike & Emenike, 2023), and Internet (Vaishya, Misra, & Vaish, 2023) support the results with regard to the First- Year-Undergraduate cluster network.

The central theme of Learning-Theories was related to the subthemes of *Laboratory-Management, High-School/Introductory-Chemistry, Collaborative/Cooperative-Learning*, and *Chemical-Education-Research*. Humphry and Fuller's (2023) study on Laboratory-Management and Collaborative/Cooperative-Learning supports these results with regard to the Learning-Theories cluster network.

The central theme of Machine-Learning was observed to have relationships with *Paradigm-Shift, Evidence-Based-Dentistry, Dental-Education, Dental-Care,* and *AI-Generated-Text-Detection* themes. In addition, strong relationships were observed among the Evidence-Based-Dentistry, Dental-Education, and Dental-Care subthemes. These studies on Paradigm-Shift (Wang, Paidisetty, & Cano, 2023), Evidence-Based-Dentistry and Dental-Education (Eggmann et al., 2023) support the findings with regard to the Machine-Learning cluster network.

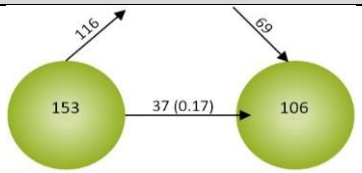
Overlapping map

Results regarding the number of keywords used during each period of analysis as well as the keywords that newly appeared, disappeared, or were reused in the subsequent period are presented in the overlapping-items graph in Figure 8a (Salazar-Concha et al., 2021). The analysis showed that a total of 153 keywords were used during the first period of analysis, and 116 of them were not reused during the following period while 37 of them were. During the second period of analysis, a total of 106 keywords were used. The number of keywords used for the first time during the second period was calculated as 69. However, the similarity index between the periods was determined as 0.17. The overlapping-items graph shows that the number of keywords used in ChatGPT research decreased during the second period, but the studies included new keywords. This changing trend in the use of keywords indicates that studies emanated from diverse fields. However, the increase in the number of newly-added keywords implies that ChatGPT research field was constantly developing, and the disappearance of some keywords indicates that the keywords were being constantly updated.

Thematic evolution structure

The relationships between the patterns of development in ChatGPT research field over the periods of analysis were determined and shown in the thematic evolution map (see Figure 8b). In the map, the size of the spheres reflects the number of publications, and the thickness of the lines connecting these spheres shows the strength of the relationship between the themes over periods (Cobo et al., 2012; Murgado-Armenteros et al., 2015).

a. Overlapping-items graph



b. Thematic evolution structure

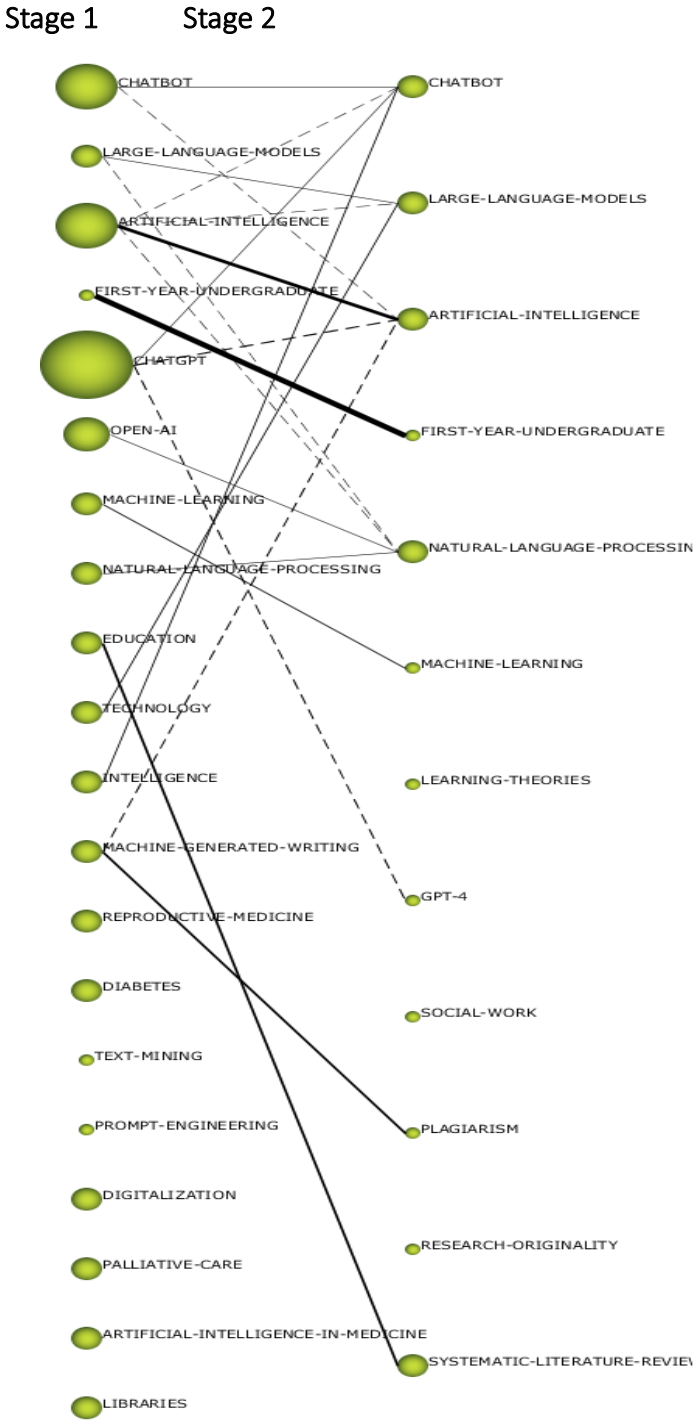


Figure 8. (a) Overlapping map; (b) Thematic evolution map

The analysis yielded 20 themes that appeared during the first period (2022/Dec–2023/Mar), which constituted 50.3% (n=84) of the total number of articles in the dataset. Among these themes, *Chatbot, Large-Language-Models, Artificial-Intelligence, First-Year-Undergraduate, Machine-Learning,* and *Natural-Language-Processing* continued to exist during the second period. The *ChatGPT* theme was replaced by the *Chatbot, Artificial-Intelligence* and *GPT-4* themes during the second period. The *Open-AI* theme was replaced by *Natural-Language-Processing* theme while the *Education* theme was replaced by the *Systematic-Literature-Review* theme. The *Technology* theme was replaced by the *Large-Language-Models* theme while the *Intelligence* theme was replaced by the *Chatbot* theme. The *Machine-Generated-Writing* theme was replaced by *Artificial-Intelligence* and *Plagiarism* themes. The *Reproductive-Medicine, Diabetes, Text-Mining, Prompt-Engineering, Digitalization, Palliative-Care, Artificial-Intelligence-In-Medicine* and *Libraries* themes appeared during the first period, but were not used during the second period. The highest h-index belonged to the *ChatGPT* theme during the first period.

The analysis revealed 12 themes that emerged during the second period (2023/Apr–2023/May), which comprised 49.7% (n=83) of the total number of articles included in the dataset. While six of these themes came from the first period, six of them appeared for the first time during the second period. The *Chatbot* theme emerged during the second period comprised the themes of *Artificial-Intelligence, ChatGPT* and *Intelligence*, which appeared during the first period. On the other hand, the *Large-Language-Models* theme comprised the themes of *Artificial-Intelligence* and *Intelligence* themes, which appeared during the first period. The *Artificial-Intelligence* theme comprised the themes of *Chatbot, ChatGPT* and *Machine-Generated-Writing* themes while the *Natural-Language-Processing* theme comprised the *Large-Language-Models* and *Artificial-Intelligence* themes. The *Learning-Theories, Social-Work,* and *Research-Originality* themes appeared for the first time during the second period and did not relate to any of the themes that emerged during the first period.

4. DISCUSSION

The present study conducted a science mapping analysis of research addressing the potential impact of ChatGPT on a variety of fields, and exhibited the strategic themes and evolving research orientations in this rapidly developing knowledge domain. In addition to delineating the current state-of-the-art research in the field, the study also reflected on the emerging topics of interest that would need further investigation as well as other weakly or insufficiently-addressed aspects of this contemporary phenomenon.

Since its first release for public use in November 2022, the potential impact and utility of ChatGPT has garnered incremental attention in the scientific world, and has already accumulated a great number of studies. Although these studies addressed a variety of issues, the current science mapping of the field showed that the studies particularly evolved around the themes of machine learning, large language models (LLMs), natural language processing (NLPs), and chatbots. This finding could be natural considering that ChatGPT was a large language model developed using machine learning and natural language processing technologies (Karakose, 2023; Liu, Han et al., 2023). One interesting finding is that these studies were conducted in the fields of education and medicine. One explanation for this

finding could be Richard and Dignum's (2019) assertion that AI-based technology designs are more broadly used in a variety of health-related contexts since these fields receive financial support much readily compared to other fields. The authors also underline the significance potential of AI-based technologies to enrich students' learning opportunities and environment. Another interesting finding was that the theme of artificial intelligence was not central to these investigations in ChatGPT knowledge domain although artificial intelligence emerged as a basic and transversal theme having a central and significant value for the development of this knowledge domain. This should be a significant point to be considered by future research.

The science mapping in the current study was performed over two periods of analysis to be able to observe the evolving research trends as well as the aspects that received insufficient or emerging research interest. The first period of analysis comprised publications from December 2022 to March 2023 while the second period included publications from April 2023 to May 2023. Since these publications were divided almost evenly between periods, as required for a thorough comparative analysis, it was evident that the number of publications in the last couple of months increased significantly. A closer scrutiny to the evolution of themes indicated that the studies published during the first period of analysis mostly focused on the themes of machine learning, reproductive medicine, education, and first year undergraduate programs since these themes emerged as motor themes that had driven the development of this knowledge domain. On the other hand, the themes such as LLMs, NLP, chatbot, and ChatGPT were not developed sufficiently in these studies although they had a significant relationship with this research field. However, the analysis of the themes having emerged during the second period showed that these weakly addressed themes during the first period have later garnered incremental research interest and became the central topics of investigation (i. e. motor themes) during the second period.

During the first stage of its development, ChatGPT had garnered particular interest in the field of medicine considering both the motor themes and the emerging themes revealed from the analysis. Although research emanating from the field of reproductive medicine was more prominent during this stage, the utility of ChatGPT in other fields such as palliative care and diabetes were emerging as new research orientations in addition to discussions on the impact/use of artificial intelligence in medicine. Researchers addressing the use of ChatGPT in the field of reproductive medicine (Ebrahimi et al., 2023; Chervenak et al., 2023; Grünebaum et al., 2023) underlined that the use of this chatbot to support research and practice in this field could be beneficial, but it should be responsibly used considering its constraints in tasks that require human intelligence and expertise, particularly regarding clinical utility. Another prominent theme during this initial stage was education. A closer scrutiny to the subthemes of education theme (e. i., healthcare communication, hospitals, doctors) showed that much of this research addressed medical education in addition to other aspects such as using media, computer software or electronic publications as well as questioning the efficacy of ChatGPT in supporting educational processes (Gilson et al., 2023; Katz et al., 2023; Lee, 2023). A comprehensive study by Farrokhnia et al. (2023) conducted a SWOT analysis of the educational utility of ChatGPT, and showed that ChatGPT could increase the efficiency of key educational processes and tasks such as facilitating personalized learning, promoting easier

access to information, and diminishing teacher workload. The researchers also underlined that ChatGPT had some limitations to fully support education such as the possibility of low-quality or inaccurate text-generation, the likelihood of bias, its lack of deep understanding and higher-order thinking, the risk of plagiarism incitement, and the possibility to purport social injustice in education emanating from the digital divide. These issues have also been fully or partly highlighted in research addressing ChatGPT in broader educational fields (Arif, Munaf, & Ul-Haque, 2023; Das et al., 2023; Gregorcic & Pendrill, 2023; Qadir, 2022; Yeadon et al., 2023).

During the second period of analysis, as mentioned earlier, studies featured those themes that are closely related to the design and the performance of ChatGPT such as large language models (LLMs), natural language processing (NLP), and chatbot while abandoning a focus on artificial intelligence. These results imply that discussions and investigations over ChatGPT was being departed from those in the field of artificial intelligence, and the focus was becoming more central to those features of ChatGPT as a language model that can process huge amounts of information to generate human-like texts. In addition to these two prominent themes that had driven research during this period, first year undergraduate programs and learning theories appeared as significant themes. Research focusing on the first theme seemingly addressed the potential threats or opportunities of ChatGPT in assisting students during their university education, particularly during the first years of adaptation to university life. For instance, Yeadon et al. (2023) investigated whether student plagiarism via ChatGPT generated texts in a writing course could be detected by independent markers and plagiarism detection programs, and found that it was almost impossible to detect plagiarism and ChatGPT generated essays received top grades. Although several recent developments have been introduced to detect AI-generated texts at present (e. g., ZeroGPT) and several others are probably being developed in the meantime, the authors cautioned that measures need to be taken in the era of AI as well as developing newer methods of instruction and assessment that are compatible with this new context of education, which is a widespread concern raised by several other researchers (Anders, 2023; Cotton et al., 2023; Dehouche, 2021; Gao et al., 2023). Similarly, Fergus et al. (2023) tested the efficacy of ChatGPT in answering a first-year undergraduate chemistry exam, and found that ChatGPT had serious limitations in answering questions that needed interpretation and application. The authors concluded that, in its current design, ChatGPT was not a high-risk technology that could promote cheating or academic dishonesty, particularly if the tasks were designed in a way that requires higher-order thinking skills. Regarding the learning theories theme, a similar tendency to discuss or investigate the implications of ChatGPT for the existing theories of learning, and elaborate on the need to design newer, AI-friendly or AI-supported techniques of instruction. One such study was conducted by Marquez et al. (2023) to enable the effective use of ChatGPT in chemistry laboratory classes. These researchers proposed new learning theories to achieve the transition of a traditional lab class into an AI-enhanced one, particularly predicating on cognitivism and constructivism. A closer look into the subthemes of learning theories theme (e. g., chemical education research, introductory chemistry, laboratory management) also shows that the theme was particularly prominent in the chemistry and laboratory educational context.

With the introduction of AI-based technologies like ChatGPT, two significant concerns were raised in the field of science and education: plagiarism and research ethics (particularly maintaining research originality), and the science mapping analysis revealed that these two themes appeared among the emerging themes of the second period. In addition to these two themes, increasing interest in the newer version of ChatGPT, i. e. ChatGPT-4, was evident, which should not be surprising given the astounding success of ChatGPT in many use cases it was tested short after its release. Besides, systematic research reviews were also among the emerging themes of this second period. As the ChatGPT research field has rapidly grown in volume in the last six months, tendency towards synthesizing the results of existing studies and interest in gaining a more holistic understanding into its impact seem to have increased among the scholars. To illustrate, Sallam (2023) accumulated the promises and the threats of ChatGPT for healthcare education and research while Li et al. (2023) particularly focused on the studies addressing the use of ChatGPT in healthcare and medical applications. Likewise, Singh and Singh (2023) conducted a review of ChatGPT studies in the business administration field, and presented some use cases to promote business applications while Zamfiroiu, Vasile, and Savu (2023) conducted a broader review to develop deeper comprehension into the uses and the effects of ChatGPT in the field of education and science. In addition to these reviews, some researchers took a different stance, and evaluated the performance of ChatGPT in generating systematic literature reviews (Haman & Školník, 2023b; Qureshi et al., 2023; Wang, Scells et al., 2023b). These studies revealed both the benefits and the risks of using ChatGPT for literature reviews, and highlighted the necessity for further developments such as ability to cite accurate references and avoid/eliminate the risk of plagiarism.

Despite this growing volume of research on the utility of ChatGPT in a variety of fields, the literature is still in its infancy, and the unprecedented breakthroughs in AI-based technologies such as ChatGPT or other LLMs have exhibited a brand-new territory to be explored by scholars from diverse fields. In fact, research into these newer technologies of the 21st century is like solving a jigsaw puzzle whose pieces are also rapidly changing in itself. In the face of this challenge, incessant research interest needs to be devoted to understanding and managing the proper integration of these technologies into every aspect of human life. This is particularly significant considering that these technologies are always like a double-edged sword bringing significant pitfalls as well as opportunities.

Limitations

Despite its several contributions to the literature, the current study also bears some limitations. For one thing, the current study is designed as science mapping research, and thus differs from traditional review studies in that science mapping particularly aims to uncover the evolving research trends, central and emerging themes in scientific knowledge domain. Therefore, the current study does not provide a synthesis of previous research findings. For the other, the current study might have missed some of the studies published in the field despite a rigorous search of two reputable databases: WoSCC and Scopus. As the research field is very young and develops very rapidly, several other studies might have been published after the data search was completed for the current study.

5. CONCLUSION AND IMPLICATIONS FOR FUTURE RESEARCH

The current study investigated the ChatGPT research field in order to delineate the evolving research trends and aspects that were weakly or insufficiently addressed in the literature. The results of the science mapping showed a growing interest into the opportunities and the risks of ChatGPT, particularly for the fields of education and medicine, and indicated that much research is warranted to discover the potential of GPT technology as an uncharted territory.

Given the state-of-the-art research on ChatGPT, there are numerous aspects that require further investigations in addition to several gaps in the existing literature. For one thing, the current analysis showed that ChatGPT research mostly emanated from the fields of education and medicine. Considering the features of ChatGPT to generate human-like texts and process huge volumes of information, this interest of educational and medical researchers into its utility is understandable. However, ChatGPT would also have implications for other fields such as law, arts, graphic design, or engineering to count a few, and future studies designed by the scholars working in these fields could contribute greatly to the literature. In addition, there is a growing interest in the use of ChatGPT for research and scientific publication, and there are several concerns over the ethical and responsible integration of this new chatbot to promote scientific quest and publications (Burger et al., 2023; Chen, 2023; Tülübaş et al., 2023). Therefore, future studies addressing these issues particularly with the collaboration of scholars from diverse backgrounds and fields could help develop measures to ensure its proper integration into the field of science.

DECLARATIONS

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Ethical approval Ethical approval is not applicable in the current study as it does not involve human participants.

Informed consent No informed consent was obtained in this study as it does not involve human participants.

Data availability Data can be provided upon request by the corresponding author.

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