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RESEARCH

A qualitative assessment of the accuracy of AI-LLM in academic research

Chanlang Ki Bareh[1]

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Abstract
The study delves into the implications of Artificial Intelligence (AI), Large Language Model (LLM) adoption on qualitative research, particularly thematic synthesis, by using content analysis from multifaceted perspectives, i.e., the author's qualitative assessments and SWOT analysis. Utilising a systematic literature search, the author examines 65 AI-generated themes identified by the AI-LLM tool'ChatPDF' from 17 pieces of literature, focusing on context accuracy, textual patterns, review depth, inclusivity of sensitive topics, word counts, and SWOT analysis. Findings show a 56.92% context matching, which indicates a deeper and relevant insight into the AI-generated themes, thereby fostering thematic progression, and 89.23% non-repetitiveness in textual patterns, pointing to non-repetitive nature of the texts within the theme descriptions. Review depths vary, indicating diverse levels of In-depth, average, and surface-level review. 17 of the 65 AI-generated themes (26.15%) did not include sensitive topics, with only a handful of 4.61% addressing sensitive topics, which may generate biased themes. On the other hand, the SWOT analysis highlights ChatPDF's strengths in speedy interpretation, text summarisation, decent contextual accuracy, non-repetitive textual patterns, trend or gaps identification, translation feature, average word counts, improved research structure and opportunities like reducing researcher burnout, ease of adoption, conversational ability, connect concepts, enhanced methodologies, equitable access, and enhancing collaboration with the possibility to improve researcher's experience. However, it needs to improve contextual understanding, minor text repetitions, sensitive topic inclusion, statistical data extraction, potential algorithmic biases, privacy concerns, conversion of non-OCR PDF files, and transparency in its trained datasets. AI-LLMs offer improvements in qualitative research, specifically in thematic progression. Researchers can leverage LLMs for diverse theme elaboration and summarisation through multiple prompts. At the same time, AI developers must enhance their systems' contextual accuracy by flagging errors or bias, adapting to varied study types, and improving statistical data extraction. Higher educational institutions and publishers should have strong policies to validate AI-generated content and provide training for ethical adoption while protecting users' privacy. This study contributes significantly to researchers who intend to use LLM in qualitative research. It addresses the impact of LLM across all stakeholders, i.e., researchers, AI developers, educational institutions and publishers, while emphasising its ethical, transparent, and safe adoption. This study further advances the discussion on the ever-changing roles of AI-human collaboration in academic research.

Keywords Artificial intelligence (AI) · Large language model (LLM) · ChatPDF · Qualitative analysis · AI ethical implication · SWOT analysis · Thematic review

1 Introduction

The adoption of Artificial Intelligence (AI) has ushered in a new world that allows machines to mimic human learning, problem-solving, and decision-making independently. AI is defined as an application or device embedded with algorithms and trained datasets that can identify and give their opinion about objects, understand human language, learn from new datasets, give recommendations, and

✉ Chanlang Ki Bareh
Shanlang88@gmail.com

[1] Nagaland University, Lumami, India

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respond independently, reducing the need for human intervention [31]. In 2024, a recent breakthrough in generative AI (Gen AI) has revolutionised the technology by creating original text, images, videos, and more that encompass deep learning models that can produce complex original content in response to prompts. Over the years, generative models have advanced considerably to handle complex data types, evolving with the emergence of three significant deep learning models, i.e., the development of Variational Autoencoders (VAEs) in 2013, which allow the generation of content variations in response to prompts,Diffusion Models in 2014, which create original visuals; and Transformer-based models that are designed to generate extended sequences of content, leading to the development of popular AI Large Language Tools like ChatGPT, GPT-4, etc. [31].

Artificial Intelligence (AI) generative tools aim to mimic human intelligence that can automatically solve problems and provide ready-made answers at the click of a button. AI impact is also felt in the research landscape. The application of AI in literature review assistants, data analysis software, citation generators, textual analysis, etc., has become integral to academic research processes. AI capabilities include drafting new texts, textual revisions, and synthesising literature [42]. Generative AI can even synthesise data types like language, image, video, software code, and molecular structures. These generative AI platforms work by inputting queries or prompts [32], thereafter, the generative AI provides the users with responses as accurately as possible. According to Yaroshenko and Iaroshenko [58], transformative AI tools like ChatGPT, Llama-2, Microsoft Bing, Jasper Chat, and Google Bard have transformed research processes, publishing, and librarianship. For instance, large language models (LLMs) can help with textual analysis, literature searching, data collection [13], academic content generation, accessibility, collaboration, and assessment, saving time and increasing the researcher's efficacy [11].

As evidenced by the literature, AI tools are becoming increasingly prevalent in literature reviews and thematic analyses [18]. However, this convenience comes with its own set of unprecedented challenges. According to IBM [31] and Nguyen et al. [42], the hype surrounding the usage of AI platforms might have taken off, but conversations have emerged around its ethics, biases, and research outcomes [18]. Nguyen and Goto [43] further remarked that AI usage can potentially lead to over-reliance, raising questions about the authenticity of academic work. Studies have focused on the technical details of LLMs' training data, architecture, and performance metrics [36, 56], but few have examined how well LLM can generate text. As remarked by Awasthi et al. [8], the contextual outputs of LLM are hard to quantify due to resource limitations and biases, which explains why human supervision is important. Although a study by Christou [20] had laid down the foundational understanding of AI usage in thematic analysis, yet there is less attention given to qualitative assessment made by humans from context accuracy, review depth, textual patterns, and inclusivity of sensitive topics, which will help improve the human interactions with the LLM outputs. The biased interpretation of results and the accuracy are crucial areas that have yet to be addressed. Without a vivid understanding of these qualities, AI-generated content remains questionable. Thus, this gap requires deeper exploration to ensure the ethical use of LLM research.

AI tools in academic research are deeply rooted [11, 13, 42]. While AI tools have come a long way in producing text that sounds like it was written by a person, there are concerns about how well they understand context, how deeply they review text, how they use patterns in text, and whether they are biased to sensitive topics, which may address the impact of LLMs on qualitative research. With the advanced growth of AI, understanding the presence of contextual accuracy and thematic analysis [20] by capturing the actual meaning from the original texts or how well it is accurate in generating the contexts remains critical. Furthermore, understanding its review depth may reveal the nuance of key debates or ideas that might have been generated only at the surface level. While the LLMs can extract textual patterns efficiently, they may produce repetitive words, phrases, and sentences that are not typical of human-generated text. So, a critical assessment may help identify whether the AI's generated texts are relevant or if they reflect the platform's algorithmic choices. Additionally, exploring the frequency of text generation will add additional knowledge to the text generation capacity of the LLM tool.

This study balances using AI-LLMs like ChatPDF to qualitatively review and identify the emerging themes in the areas of 'Privacy concerns of AI in libraries' to understand LLMs' subject-specific knowledge and reasoning capacity by employing content analysis through practical assessments and SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. A SWOT-based assessment may reveal how the AI tool is effective and add a mixture of the author's subjective interpretation of its thematic progression and review. Through these assessments, the study explores the alignment between the researcher's expectation and the LLM's theme outputs, which aim to comprehensively understand how AI technologies can be integrated ethically into the qualitative research arena. Furthermore, these assessments of AI-generated themes intend to provide guidelines for newer researchers who use AI-LLM tools to conduct qualitative research, specifically thematic review or analysis. The assessments from this study's SWOT analysis may make it easier for humans and AI-LLMs to work together. They may also give more information about how biased and

unethical the AI-LLM is without taking away the important role that researchers play in the qualitative research process. Thus, the following objectives intend to offer insights to the academic community, specifically researchers, research agencies, publishers, universities and developers, thereby ensuring the safe adoption of the LLM tools in qualitative research.

1.1. Based on the generative AI-LLM tool (ChatPDF) identified themes in the areas of 'Privacy concerns of AI in libraries.' The study tries to understand the thematic review and synthesis based on the author's point of view, including context accuracy, depth of review, textual patterns, inclusivity to sensitive topics, and word count analysis.

1.2. To find out the SWOT—strengths, weaknesses, opportunities, and threats that may arise from applying AI-LLM tool (ChatPDF) in thematically analysing research papers.

2 Literature review

2.1 Adoption of AI tools in research

In the academic and research context, the integration of generative AI tools helps streamline the teaching, learning and research work, allowing faculty and scholars to focus on quality research. According to Wang et al. [54], higher education institutions are increasingly exploring the use of AI applications. For instance, a survey reported that about 28.6% of the respondents have used or were planning to use generative AI in research, 23% agreed that their university adequately equipped them with AI tools. Although 63% of the respondents indicated they had yet to support students using generative AI [34]. Lee et al.'s study also demonstrated that about 69% of respondents were either somewhat or highly comfortable using generative AI tools for their work. This trend was also observed by Pratiwi et al. [45], with 47% of students who responded that their scientific work resulted from using AI. The use of generative AI like ChatGPT was also significant, with 84% of students using it for academic purposes like homework, tutoring, conceptual understanding, and research guidance. This indicates the role of AI tools in providing educational support to students, particularly in times of academic stress [51].

The impact of AI extends to improving academic writing. Research demonstrates that using AI academic writing tools has a domino effect on students' scientific work quality, leading to increased task completion efficiency [45]. A study by Wale [52] revealed that students had positive perceptions towards using Writerly and Google Docs, finding them effective for writing instructions, essay development, and supportive in overcoming nervousness and shyness in face-to-face conversations. Furthermore, Wale's [52] results indicated that students honed their academic writing performance through integrative writing evaluation programs.

While there was a positive outlook on the progressive improvement of the quality of AI tools in education, suggesting a potential for continued advancements in AI technology. Educating students on its uses is equally important, and institutions need to provide support and training, particularly in terms of academic integrity [34]. It should emphasise the importance of addressing workload management, anxiety, stress, and academic integrity in the context of AI adoption in academia [11]. To ensure inclusive and practical experiences for students, there is a need to balance the risks and rewards of AI technology in education, considering factors like language barriers, cultural differences, and privacy concerns, to ensure inclusive and practical education experiences for all students [54].

2.2 Ethical considerations of AI tools in research

The adoption of AI tools in research has significant ethical issues, such as transparency, bias, misuse, privacy, plagiarism, and copyright violations [11]. According to Bin-Nashwan et al. [11], this AI technology raised ethical concerns like academic dishonesty and plagiarism in the academic landscape. To this point, Yang et al. [57] remarked that the use of AI-generated content without careful human evaluation leads to plagiarism and academic dishonesty since these generative AI models ingest large texts in their training data, which may be drawn from unauthorised sources. To ensure academic integrity, a few scholars have suggested including the AI language model as a co-author in scientific papers (Lo, as cited in [11]). However, this likely results in similar content being generated without acknowledgement or citation, which can be counted as plagiarised content. Moreover, Danler et al. [23] opined that most AI tools use scientific sources in content generation, but there was no transparency in how they selected these sources, which may potentially introduce biases and question information processing criteria. Even Cox [21] raised concerns about the violation of academic integrity, specifically regarding bias, data fabrication, and falsification of facts. This facilitates a deeper exploration of the issues surrounding authorship, data ownership, data sovereignty, and intellectual property rights in AI-generated content.

The psychological effects of AI adoption in academia represent a critical area of concern, with participants expressing worries about their emotional and psychological responses to AI's introduction in academia due to anxiety or lack of awareness [32]. Consequently, the adoption of AI can have negative impacts, as highlighted by Bouteraa et al. [12], who revealed a significant positive relationship

between personal anxiety and the use of ChatGPT. Students experiencing high levels of academic-related anxiety may be drawn to AI-driven chatbots like ChatGPT to alleviate stress and enhance their academic outcomes. However, other consequences of AI dependency, noted by Zhang et al. include increased laziness, misinformation dissemination, impaired creativity, and diminished critical thinking. These outcomes impact the excessive reliance on AI technology in educational contexts, which significantly influences researchers' decisions to utilise AI language models in their work. It is essential to address workload management, anxiety, stress, and academic integrity within the framework of AI adoption in academia [11]. Therefore, balancing the risks and rewards associated with AI technology by considering factors like language barriers, cultural differences, and privacy concerns is imperative to ensure inclusive educational experiences for all students [54].

Furthermore, the lack of clear-cut guidance in acknowledging the use of AI in research may prompt new researchers to conceal its use, which poses a significant threat to research integrity [19]. Thus, it is crucial that publishers, editors, sponsors, and academic institutions clearly specify research ethics for authorship in terms of allowing or not allowing these tools as co-authors [11]. More research is needed to find out how AI tools affect students from different backgrounds [55] because some worry that AI technologies could hurt educational equality and access to resources. Wise et al.'s also point out the potential impact of ChatGPT on language diversity and the need to protect linguistic differences. Additionally, AI tools like LLM may not grasp the broader view of culture, thereby limiting diverse perspectives. Therefore, this calls for future research to delve deeper into the practical processes of scholars' behaviour in human AI-assisted academic work [55].

2.3 AI-LLMs in qualitative research

AI-LLMs with deep learning play a significant role in transforming qualitative research due to their ability to scale and achieve cognitive intelligence through Natural Language Processing (NLP) and deep learning capabilities. Indeed, generative pre-trained language models, like ChatGPT with parameter sizes exceeding 6 to 10 billion, have revolutionised AI-LLM capacity. This unique transformer model's ability to solve complex NLP problems allows it to yield specific outputs through prompt statements and fine-tuning, thereby improving its efficiency [36].

LLMs, particularly Generative Pre-trained Transformers (GPTs), are powerful tools for conceptual research. These LLMs analyse vast amounts of text-based data in depth to identify key themes and concepts more clearly [18]. Utilising deep learning models such as GPTs for literature reviews has begun gaining popularity in qualitative research, as these models autonomously identify key concepts and themes, thus helping to summarise extensive texts and refine the review process according to Watson et al.'s. (as cited in [18]). The main advantage of LLMs in qualitative research is their ability to automate repetitive tasks, improving the efficacy of data analysis and literature reviews. This automation promotes a nuanced understanding of qualitative data, enabling researchers to manage complex language structures, especially those derived from large datasets [59]. Moreover, LLMs are highly valuable because they empower researchers from diverse backgrounds to navigate complex academic language and resource disparities, fostering greater inclusivity and allowing for more diverse perspectives in the research arena [7]. LLMs assist researchers not only in identifying patterns and generating themes in deepening the understanding within diverse fields [8, 53]. Specifically, they excel at analysing unstructured data, such as open-ended survey responses and interview transcripts, thereby enriching the depth and breadth of qualitative investigations [53].

The advantages provided by LLM are invaluable, as researchers, especially in the fields of behavioural sciences, humanities, and social sciences, are often confronted with substantial amounts of unstructured qualitative data. While traditional or manual methods of identifying themes tend to capture limited insights, LLMs enhance the ability to identify patterns more effectively, thus freeing researchers to concentrate on interpretation and critical analysis [20]. In terms of explanatory power, while LLMs may lack profound human understanding, they can effectively flag complex language nuances, enabling researchers to uncover subtler meanings such as sarcasm or metaphor [7]. The integration of AI LLMs into qualitative research represents a paradigm shift, both now and in the future. Their capacity for data processing efficiency, support for thematic analysis, and enhancement of analytical insights ensure that qualitative researchers can manage complex datasets more effectively and inclusively.

2.4 Application of AI-LLMs in thematic analysis

Thematic analysis is a commonly used method in qualitative research that focuses on identifying and developing recurring patterns, or "themes," from various data sources, such as interviews, surveys, and observations remarked Brandau and Rebello 20]. This thematic analysis goes beyond merely organising the data, it seeks to understand and interpret the meaning of those patterns within their broader social, cultural, and environmental contexts [20]. The stages of thematic analysis typically include familiarisation with the data, coding, theme identification, evaluation, and defining

Table 1 List of keywords

Keyword code	A	B	C
Key terms & Phrases	1. Librar*	1. Artificial Intelligen*	1. Privacy concern*
Synonyms & Phrases	2. Digital Librar*	2. AI	2. Security concern*
	3. "Librar*"	3. Artificial intelligence	3. Privacy implication*
		4. "Artificial Intelligen*"	4. Ethical concern*
			5. Privacy risk*

themes, concluding with generating a report mentioned Braun and Clarke [20].

Large Language Models have introduced new possibilities for enhancing thematic analysis by providing valuable assistance throughout the research process. Some of the plausible reasons for LLMs usage in thematic analysis were found in the review article by [18, 20]. While thematic analysis includes the automation of the coding process, providing clear and concise summaries, categorising and organising data, which makes it easier for researchers to identify key themes and patterns in qualitative data. These transparent processes and structures can significantly improve the accuracy of thematic analysis, allowing researchers to focus on interpreting themes and their codes. Christou added that by engaging interactively with data using prompts, LLMs can help extract unseen insights by posing questions, which will assist in a deeper understanding of the findings [20]. Additionally, brainstorming with LLMs may enable researchers to produce new knowledge that contributes to building a theoretical framework or conceptual models based on existing literature [18].

Despite these significant improvements in thematic review, integrating LLMs also presents several challenges, such as a lack of control over the content generated, which might lead to unreliable patterns or themes that could potentially mislead the analysts. For example, Anis and French [7] opined that it can misinterpret the nuances of human language and social contexts due to its limited understanding of society. Also, its Generative Pre-Trained Transformer might have difficulty understanding the complexities of academic writing and may be unable to differentiate between reliable and unreliable sources [18]. Moreover, the lack of transparency in how AI makes decisions may complicate the interpretation of research outputs [19]. Due to the unknown nature of its training data to the larger audience, it may generate biases, which is why Christou [20] suggests that analysts remain vigilant and ensure ethical considerations when using AI LLMs. Integrating AI LLMs into writing literature or thematic reviews can significantly improve the efficiency of qualitative research. However, it is equally important to consider fabricated facts or themes that lack authenticity.

Table 2 Search parameters

Database filters	Search strings	Search hits
Scopus (Title, Abstracts & Keywords)	A1 AND B1 AND C1	34
	A2 AND B2 AND C2	7
	A1 AND B3 AND C3	13
	A3 AND B4 AND C4	8
	A3 AND B4 AND C5	3
Web of Science (All fields)	A1 AND B1 AND C1	27
	A2 AND B2 AND C2	3
	A1 AND B3 AND C3	8
	A3 AND B4 AND C4	20
	A3 AND B4 AND C5	15
	Total	**138**

3 Methodology

3.1 Database searches

The author employs the following keywords using Boolean operators and advanced operators (see Table 1) from global bibliographic databases (i.e., the Web of Science and Scopus databases).

The keywords listed in Table 1 were given a code to determine the synonyms and phrases of the key terms. This helps stay organised when conducting a systematic search for the literature. The search was performed on the 17th of May 2024, to include the latest publications (*see search records* @ http://surl.li/wgjfcu). Boolean operators like 'AND' were used to retrieve literature that contains relevant keyword combinations. The authors also employ advanced operators to avoid spelling errors, i.e., the truncation search, which uses an asterisk sign (*) to match zero or more characters within a word or at the end of a keyword, and the quotation search ("keyword") that yields precise keywords.

The first row in Table 2 highlights the database filters where the search was conducted. The bolded entries used in Table 2 refer to the specific keyword searches connected by the Boolean operator 'AND' in capital letters, which were used to retrieve literature from both Web of Science and Scopus based on their relevance to the research objectives. No sub-filters used when conducting the searches (For example, publication window, language, type of publication, etc.) from these two databases. The search strings yield a total of 138 bibliographic records, which were exported into (csv/xls) format from both Web of Science (WoS) and Scopus databases.

3.2 Study selection

Table 3 defines the eligibility criteria relevant to the objectives and ensures a focused retrieval of relevant literature for generating themes related to "Privacy Concerns of AI

Table 3 Eligibility protocols

Criteria	Inclusion
Literature type	All were included during the literature searches, but final reviews included—research articles, reviews, and conference papers
Context	The AI privacy concerns in libraries, which highlights the benefits, impact, usability, integration and challenges in libraries
Format	PDF for the AI chatbot tool (ChatPDF.com)
Timeline	None
Language	English

in Libraries". While screening these 138 pieces of literature, the author reads through each title and abstract. Out of the total (n = 65) number of Scopus literature, and (n = 73) number of WoS literature, only (n = 20) literature from both Scopus and WoS were accepted for full-text retrieval. The remaining were rejected because of duplication or due to their abstracts and titles failing to meet the author's preliminary selection. Thereafter, the author could not retrieve one (n = 1) full text, thereby leaving the author with 19 pieces of literature. Furthermore, two pieces of literature were rejected because (1 = Chinese language; 1 = not enough to support the context). Finally, 17 pieces of literature (see Table 4) were selected for qualitative analysis upon fulfilling the inclusion protocols (*see* Table 3).

3.3 Qualitative assessment of AI-generated themes

This study employs a balanced qualitative approach derived from the author's thematic assessments of the AI-generated themes by ChatPDF in the areas of *'Privacy concerns of AI in libraries'*. While the intent is not to explore in-depth into understanding the topic of privacy concerns in libraries, but because the library's role is crucial in promoting the responsible use of generative AI while protecting and maintaining the core values of access, privacy, and intellectual freedom [14]. The researcher used the AI-powered tool (www.chatpdf.com, *known as* 'ChatPDF') to generate codes and themes by uploading the 17 (.pdf) literature using the prompt below. It is essential to understand that AI themes and codes were generated from one study at a time, not from a folder where all 17 studies were stored. The prompt

Table 4 Descriptive analysis of selected literature

No	Source	Research type and method	Country	References
1	Library Hi-Tech	Q ualitative—Thematic analysis of interview transcripts	UK	[22]
2	Open Information Science	Quantitative—Closed-ended survey	India	[49]
3	Library Hi-Tech	Quantitative—Survey questionnaire with both open and closed questions	Taiwan	[30]
4	Journal of the Australian Library and Information Association	Qualitative—The review paper discusses scenarios developed by the author	UK	[21]
5	Journal of the Australian Library and Information Association	Qualitative—Literature review	Australia	[13]
6	University Library at a New Stage of Social Communications Development	Qualitative—Conference review paper	Ukraine	[58]
7	IFLA Journal	Qualitative—Qualitative analysis & review of AI policies	USA	[37]
8	Library Hi-Tech News	Qualitative—Literature review	Nigeria	[1]
9	Library Hi Tech News	Qualitative—Literature review	Nigeria	[2]
10	Library Hi Tech News	Qualitative—Literature review	Nigeria	[6]
11	University Library at a New Stage of Social Communications Development	Qualitative—Conference review paper	Nigeria	[3]
12	Heliyon	Qualitative—Interpretive Phenomenological Analysis (IPA) and Technology Acceptance Model (TAM) in semi-structured interviews	China	[57]
13	Library Hi Tech News	Qualitative—Literature review	Bangladesh	[38]
14	Journal of Library Administration	Qualitative—Literature review	USA	[14]
15	Library Hi Tech News	Qualitative—Literature review	India	[9]
16	Open Information Science	Quantitative—Survey approach	Zambia	[4]
17	DESIDOC Journal of Library & Information Technology	Qualitative—Literature review	India	[39]

inputted by the author into the ChatPDF chatbot implies an open-coding approach, prompting to generate codes and key themes that will focus on identifying implicit and explicit ideas (Namey et al., as cited in [5]). While a generative AI tool was used to generate the key themes presented in this study, the ChatPDF AI tool cannot be listed as a co-author according to the editorial board of Springer Nature, because this study intends to delve into the multifaceted qualitative assessments of these AI generative themes, thus rendering the lack of AI tool accountability for the work [47]. In this study, the author did not present the textual contents of the theme descriptions here because of the ethical issue which may arise from using a generative text in a research paper. Only the theme titles were presented herein for manual qualitative assessment.

> **Prompt:** *What are the key themes generated from this study? Please generate codes from sentences or parts of sentences that form these AI privacy themes in libraries. Kindly elaborate on these generated themes. Please specify the specific page number from which you extracted these codes and themes.*

The ChatPDF was selected as a tool because it is open to the public domain with its free account of up to 2 PDF files per day and uses smart dynamic routing for queries between GPT-4o and GPT-4o-mini models, therefore increasing the likelihood of using the tool by top institutions as highlighted in the ChatPDF landing webpage. Secondly, it is based on the ChatGPT API from OpenAI to generate the most relevant paragraph from any PDF files or extensions like (txt, mt, docx, pptx). As a large language model, OpenAI's ChatGPT allows users to pose prompts, queries or research questions, which is critical for researchers according to Danler et al. [23]. With ChatPDF, researchers can change the language of the answer in the conversation with a prompt. Finally, its ability to analyse and summarise multiple PDF documents, such as research articles, reports, books, legal and financial papers [16].

Furthermore, the incorporation of ChatPDF into qualitative methodologies, specifically in generating content for analysis, may provide unique insights for qualitative studies. According to Anis and French [7], LLMs are designed to help researchers in thematic analysis, thereby harnessing the quality of the right contexts. Another point to contextualise responses based on one interview held with an engineering student is that "commands without a profession provide more detailed explanations," highlighting how the specificity of prompts can influence response quality [50]. Unlike traditional tools used in qualitative research, ChatPDF offers an interactive platform by allowing researchers to interact in real time with the data, thereby allowing the researchers to gain deep insight into the context of the themes. While analytical tools are of great importance to the qualitative research process, such as NVivo, MaxQDA, and Atlas.ti, which have incorporated AI features, ChatPDF, which is based on deep learning models, presents unique features to its users.

All the extracted AI generative texts, downloaded in (.txt) format, were entered into an Excel sheet (*see Screenshots and Datasets* @ http://surl.li/alyvfd) for author assessments. Page numbers were also recorded for further reference. The author iteratively synthesises the findings following the qualitative content analysis [40], allowing the author to record for frequencies and percentages of their context matching, textual pattern, depth of review, word counts, and inclusivity to sensitive topics, which was partially guided by the review of Alhojailan [5] entitled “Thematic Analysis: A Critical Review of its Process and Evaluation”. Secondly, the author reads the full theme description to determine that it matches the extracted codes and the themes; thereafter, the author classifies their broader themes (see Table 5) for easy interpretation.

All ChatPDF’s generated theme titles, extracted codes, and descriptions were reviewed by the author for contextual differences or potential errors, which were influenced by the theoretical work of Christou [18, 19]. For example, historical accuracy, social relevance, cultural setting, broader implications, misrepresentation of concepts, theoretical background, and cross-referencing the generated themes with the actual page number from where the theme descriptions were interpreted. This helps identify contextual inaccuracies that might limit or amplify biases in its training datasets. Secondly, the author investigates the textual patterns [15, 51] that follow repetitions of concepts relevant to thematic review or progression, which are not typically found in manual writing. Furthermore, the word count analysis may also point to important themes and codes generated by LLM based on their frequencies. Thirdly, the author evaluates the depth of the review by reading through the theme descriptions and codes to determine whether it provides in-depth insights (For example, the ability to extract and interpret statistical data [50], additional debates, or extra comments within the contents or in-depth interpretation of AI-generated themes in relation to the codes). Also, supported by the contextual accuracies mentioned herein, the author categorised the depth of the review into three categories, viz., In-depth, Average, and Surface-level review. Lastly, while reviewing the AI-generated themes, the author remains attentive to the inclusion and exclusion of sensitive topics that would typically be addressed manually. This includes fair representation of issues like bias in bills, policies, and rights, providing more precise content descriptions, acknowledging local regions or third-world countries,

Table 5 Qualitative assessments of AI-generated themes

Broader themes	AI-Generated privacy themes	Context	Textual pattern	Review depth	Inclusivity	References
Transparency in data security	Transparency and Intelligibility of Collection Decisions	✓	✓	X	X	[22]
	Data sharing objections	✓	✓	∂	n/a	[21]
	Data Quality and Ethical Storage	∂	✓	X	X	[58]
	Data Privacy Concerns in Libraries	∂	✓	∂	n/a	[37]
	Data Security and Privacy Concerns	✓	✓	✓	n/a	[1]
	User privacy and data security	∂	✓	X	n/a	[2]
	Data protection mechanisms	∂	✓	X	n/a	[2]
	Transparent data usage rules	✓	✓	✓	n/a	[2]
	User Data Collection and Analysis	✓	✓	∂	n/a	[6]
	Data Security Concerns	✓	✓	∂	n/a	[6]
	Data Privacy and Security	✓	✓	∂	n/a	[38]
	Transparency and Data Privacy Concerns	∂	✓	X	X	[14]
	Data Governance and Management	✓	✓	✓	✓	[39]
	Fairness, Transparency, and Accountability	✓	✓	✓	✓	[39]
Ethical considerations	Ethical Concerns about Data Usage	✓	✓	✓	n/a	[22]
	Ethical Issues in Data Usage	✓	✓	X	X	[22]
	Ethical Considerations in AI Utilization	✓	✓	X	n/a	[49]
	Ethical Use of AI in Libraries	∂	✓	X	n/a	[58]
	Ethical Use of AI Systems	∂	✓	∂	n/a	[37]
	Ethical Considerations in AI Implementation	✓	✓	✓	n/a	[1]
	Ethical Implications of AI	Invalid	Invalid	Invalid	Invalid	[6]
	Ethical Considerations in AI Implementation	∂	✓	∂	X	[38]
	Ethical considerations and frameworks	✓	X	∂	n/a	[9]
	Ethical Implications and Concerns	✓	∂	∂	n/a	[4]
	Ethical and Privacy Considerations	∂	✓	∂	n/a	[39]
AI integration	AI Integration in Library Operations	∂	✓	∂	n/a	[49]
	Factors for Implementing AI Applications in Libraries	∂	✓	✓	n/a	[49]
	Voice assistant service	∂	✓	X	X	[21]
	AI Tools in Libraries	∂	X	X	n/a	[58]
	Revolutionizing Library Operations with AI	✓	✓	✓	n/a	[3]
	Chatbots for User Interaction	∂	✓	X	n/a	[3]
	Capabilities and Implications of AI Adoption in Nigerian Academic Libraries	✓	X	∂	n/a	[3]
	Challenges to AI Adoption in Nigerian Academic Libraries	✓	X	∂	n/a	[3]
	Incorporation of ICT in Library Development	∂	✓	∂	X	[3]
	Challenges in AI Adoption	✓	✓	✓	n/a	[4]
AI Literacy	Nudges for well-being	✓	✓	X	X	[21]
	Educating Users about AI	∂	✓	X	n/a	[58]
	AI Technologies in Education	X	✓	✓	n/a	[3]
	User Privacy and AI Literacy	∂	✓	∂	X	[38]
	AI Literacy and Awareness	✓	✓	X	n/a	[4]
AI policy & Regulation	Regulation and Privacy Protection	✓	✓	✓	✓	[13]
	Regulatory Landscape and Fragmentation	∂	✓	∂	n/a	[37]
	State and Local AI Policies Impacting Libraries	∂	✓	X	X	[14]
	Legal and Ethical Issues in AI Use	∂	✓	X	X	[14]
	Ethical Commitments and Professional Ethics	✓	✓	∂	n/a	[14]
Privacy protection	User Privacy Protection	✓	✓	✓	n/a	[57]
	Information Security Concerns	∂	✓	X	X	[57]
	Privacy protection concerns	✓	✓	✓	n/a	[9]
Privacy & Societal value	Privacy Concerns in Libraries	✓	X	X	n/a	[30]
	Privacy as a Central Library Value	✓	✓	∂	n/a	[13]
	Societal Value of Privacy	✓	✓	✓	n/a	[13]

Table 5 (continued)

Broader themes	AI-Generated privacy themes	Context	Textual pattern	Review depth	Inclusivity	References
Algorithmic Biasness	Algorithmic Bias and Fairness	∂	✓	X	n/a	[1]
	Monitoring for biases in AI-generated replies	✓	✓	✓	n/a	[2]
Perceived benefits	Enhancing Information Processing and Search Efficiency	✓	✓	✓	n/a	[3]
	Perceived Benefits of AI in Libraries	✓	✓	X	n/a	[4]
Confidentiality of user's data	Confidentiality and privacy	∂	✓	X	X	[21]
	Confidentiality Principles	X	✓	X	X	[57]
Big Data & Machine learning	Big Data and Data Mining for Information Extraction	✓	✓	✓	n/a	[3]
	Machine Learning for Automated Adaptation	✓	✓	✓	n/a	[3]
Digital divide	Digital Divide and Exclusion	✓	✓	✓	n/a	[6]
Forum Moderation	Moderation automation	✓	✓	X	X	[21]
Inclusivity and Accessibility	Inclusivity and Accessibility	∂	✓	∂	X	[38]
Lack awareness	Lack of awareness among librarians	✓	✓	✓	n/a	[9]
Role of Libraries in AI Research	Role of Libraries in AI Research	∂	✓	X	X	[58]
Technological limitations	Technological infrastructure limitations	✓	✓	✓	n/a	[9]

'✓'—Denotes the accuracy of context, the non-repetitive nature of the textual pattern, the in-depth review, and inclusiveness to sensitive topics

'X'—Indicates the contextual error, repetition of the textual pattern, the surface-level review, and the exclusion of sensitive topics

'∂'—Represent partially matched contexts, partial repetition of the textual patterns, and average review depth

'n/a'—The absence of sensitive topics within the themes

'Invalid'—Incorrect codes/themes generated by the AI tool

and highlighting subjects or participants involved in the studies. Through these manual qualitative assessments, the author can effectively identify the accuracies in AI-generated themes.

3.4 SWOT analysis

Through SWOT analysis, this study offers a fresh perspective on factors related to the ChatPDF's strengths, weaknesses, opportunities for adoption, and threats to ethically deploy the AI-powered tool within the qualitative research. To the author's knowledge, limited studies have assessed AI tools using SWOT analysis like anaesthesiology and perioperative [44], diagnostic imaging [41], ChatGPT [46] and higher education contexts [24]. Furthermore, identifying weaknesses and threats at this stage when AI tools increasingly attract interest will help address challenges and mitigate risks associated with AI tool adoption. This can help prevent adverse outcomes and unintended Consequences [24].

4 Finding and reporting

Table 4 presents the list of selected manuscripts in chronological order for transparency. The table highlights the descriptive analysis of each piece of literature, such as their sources, type of study and method, country of origin or affiliations, and author-publication year.

Literature included in the review were research articles, reviews, and conference papers. No publication windows were selected during the search phases; however, it was observed that selected publications ranged from (2018 up to May 2024). This may explain the recent upsurge of AI and privacy studies in library spaces. The rise of research is also explained by the maximum number of qualitative studies (n = 14). The lack of quantitative studies, attitudes, and experimental studies has yet to take hold in the research areas. Concerning these (n = 17) studies on AI and privacy concerns in libraries, the Library Hi-Tech News, whose aim is to report on the recent development of technologies in libraries, published the maximum number of studies (n = 6); this was followed (n = 2) studies from Library Hi-Tech journal; Open Information Science; Journal of the Australian Library and Information Association, and conference paper from the University Library at a New Stage of Social Communications Development. Regarding the study's origination or affiliation with the selected studies, Nigeria has the maximum with (n = 4), India (n = 3), followed by the UK and USA (n = 2 each), and countries like Taiwan, Australia, Ukraine, China, Bangladesh, and Zambia contributed one paper each.

4.1 AI privacy concerns in libraries: qualitative assessment

To determine the quality of the AI-generated themes, the author presents the descriptive analysis in relation to the seventeen broader themes, which the author classified after reading the AI-generated theme descriptions. For this assessment, only the theme titles were presented herein for reference in Table 5.

Table 5 presents the 65 themes, manually classified into 17 broader themes by the author, which were subjected to qualitative assessments from the author's point of view based on context accuracy, textual pattern, review depth, and inclusivity to sensitive topics. In descending order, it was found that (n = 14) of the AI-generated themes fall under the 'Transparency in Data Security' broader theme. This was followed by numerous entries under Ethical Considerations (n = 11); AI Integration (n = 10); AI Literacy (n = 5); AI Policy & Regulation (n = 5); Privacy Protection (n = 3); Privacy & Societal Value (n = 3); Algorithmic Biasness (n = 2); Perceived Benefits (n = 2); Confidentiality of User's Data (n = 2); Big Data & Machine Learning (n = 2); Digital Divide (n = 1); Forum Moderation (n = 1); Inclusivity and Accessibility (n = 1); Lack Awareness (n = 1); Role of Libraries in AI Research (n = 1); Technological limitations (n = 1).

4.2 Context accuracy

The findings reveal that out of the 17 literature subjects to analysis, a total of 65 themes were generated by ChatPDF. The author detected a significant 56.92% accuracy in context matching, indicating the vast majority of extracted codes and theme descriptions aligned with the overarching themes. This degree of accuracy underscores its ability to merge multiple 'codes' extracted from the study and train its datasets to be focused, suggesting the effectiveness of the ChatPDF in capturing the essence of the generated themes.

However, the presence of partially matched contexts at 38.46% indicates certain discrepancies in the context matching. For example, A theme such as "Voice assistant service" failed to address the context surrounding the chatbot service (voice assistant service) accessibility, equality of service, potential impact on jobs, and interpersonal relations in the reference consultation. Another instance of three themes by Bridges et al. [14] did not discuss in their theme descriptions the various states in the United States that adopted AI bills and the absence of library references in local, national, and international bodies.

It was also observed that only a handful, 3.07%, of themes had contextual errors or did not match the extracted codes or descriptions. For example, the "AI Technologies in Education" theme only mentions the AI impact from the context of teaching–learning and research. In contrast, it failed to include the following sentences where the study discusses the AI impact on the library, specifically on the use of innovative tech like metadata creation, translated search, and search integration. Also, one theme, "Ethical Implications of AI", was marked as "Invalid" because the code extracted for interpretation was taken from the reference section, which was not meant for thematic synthesis. This partial summarisation and its inability to identify particular sections/paragraphs of textual information from a research paper reflect ChatPDF's lack of processing relevant contexts.

While the current findings show significant insights into the role of context in thematic analysis, understanding the identification of contextual inaccuracies is imperative to avoid misunderstandings or misinterpretations of meaning or concepts. A context matching of 56.92% for the AI-generated themes indicates an effective synthesis of contexts. On the other hand, the presence of 38.46% partially matched contexts suggests further scope for improvement in contextual accuracy. This trend is understandable at this initial stage, which involves connecting concepts to form new ideas for a literature review that serves as a tool to connect theoretical understanding with the methodology of a research paper. Similar to these findings, an empirical study by Dowling and Lucey [25] found that LLMs like ChatGPT are better at generating new research ideas compared to their performance in literature reviews,this parallel finding indicates mixed limitations in the performance of AI concerning contextual understanding.

Further extending this notion, Haman and Školník [26] raise ethical concerns about ChatGPT's ability to conduct literature reviews. They argue that while AI can assist, it cannot replace human judgement or accountability due to the potential inclusion of contextual inaccuracies in theme extraction. This aligns with the current study's concerns regarding partially matched contexts, emphasising the need for researchers to oversee the reliability of AI tools such as ChatPDF. Concerning these partially matched contexts, Liu et al. [35] conducted an experiment on how AI understands context from natural language descriptions to evaluate different Neural Machine Translation models using real-world shellcode examples. They found that boosting contextual information significantly improves the diversity of responses, but too much context may be counterproductive.

A discussion by Anis and French [7] suggests that AI should assist humans rather than replace them. This was further supported by Christou [20], who observes that AI's algorithmic behaviour, which focuses on frequency over depth, might hinder the extraction of deeper insights relevant to thematic analysis. Both studies argue for a balanced

collaboration between LLMs and humans rather than entirely relying on the tool as the sole platform for qualitative research and analysis. This collaborative approach is supported by Bates and Abdesslem [10], who discuss the influence of contextual factors on algorithmic accuracy and emphasise how a researcher's honesty impacts perceptions of AI performance. Their findings suggest that enhancing the user's experience and awareness can improve contextual accuracy in AI outputs, further reinforcing the symbiotic relationship between AI tools and human researchers to create new knowledge.

4.3 Textual pattern

The analysis of textual patterns refers to the repetitive and non-repetitive nature of texts across the themes, which comes in the form of repeated texts, phrases and narrative structure, suggesting a rich description of thematic elements. It was observed that out of the 65 themes, the findings reveal a predominantly 89.23% non-repetitive nature of the text, indicating a diverse elaboration of the themes. This shows the ChatPDF capability to summarise the extracted codes effectively and avoid echo chambers. However, a small percentage of 7.69% indicates the repetitive textual patterns in specific themes, which violates academic integrity on themes like “Privacy Concerns in Libraries”, “AI Tools in Libraries”, and three other themes. In a theme from the study of Barsha and Munshi [9] on “Ethical considerations and frameworks”, it was observed that the theme description was remarkably similar to the original text from the study. This leads the author to believe ChatPDF’s inability to understand plagiarism practices to a certain extent. Only one theme was found to be invalid, and another, “Ethical Implications and Concerns”, was partially repetitive. This flags a potential area for improvement to reduce the redundancy of generated text outputs.

This significant non-repetitive nature of the platform assists with thematic progression. Theme progression refers to the development of a theme over a period of time across different textual patterns or within the structure of a narrative. This suggests how a theme changes in meaning throughout the literature [15, 51]. For instance, this study's large percentages of non-repetitive words, phrases, and sentences observed in the AI-generated themes indicate the platform's ability to generate diverse lexical combinations that aid in understanding the theme. The predominance of diverse theme descriptions implies strong text structuring around central ideas.

This was supported by studies that aim to understand thematic structure and thematic progression towards the development of well-structured, meaningful texts. A study by Susilowati et al. [51] found that the high frequency of 1708 occurrences out of 2426 clauses highlights the importance of textual repetition in establishing coherence and focus. Additionally, the theme reiteration pattern with 480 occurrences not only maintains readers' focus but also helps guide them to grasp the core arguments and navigate through the text smoothly. While Chang [15] maintains that constant thematic progression or textual repetition in themes may help maintain focus within a text, its excessive use can also hinder the development of concepts or readability. This is why Chang [15] emphasises the need to balance repetition for coherence with the necessity of maintaining readers' engagement and understanding of the texts.

4.4 Review depth

The depth of review refers to the author’s observation of the different narratives, remarks, statistical data excerpts, etc., that qualify the theme description for an in-depth, average-level or surface-level review. Within this assessment, about 32.30% of the themes exhibit an in-depth exploration, indicating a thorough description or interpretation. For instance, a theme from Subaveerapandiyan and Gozali [49] on “Factors for Implementing AI Applications in Libraries”, where the codes extracted from the actual study were short and consisted of only two–three words, making it hard to grasp the concepts, but the summarisation of these codes were perfectly executed.

However, about 29.23% were average-level reviews, and a significant 36.92% were at surface-level, suggesting an overview summarisation or introductory interpretation. For instance, a theme on “Ethical Issues in Data Usage” failed to extract relevant content remarked by a library commentator regarding the ethical issues with Elsevier, who functions as a data broker, and the risk of job replacement by chatbot. Another example of the themes “Ethical Considerations in AI Utilization”, “AI Literacy and Awareness”, and “Perceived Benefits of AI in Libraries” is that ChatPDF were unable to extract the excerpts of statistics that support the extracted codes. Conversely, the presence of more than one-third of surface-level reviews may suggest an introductory exploration to various emerging themes, especially when most of the literature subjected for analysis was theoretical. The balance achieved with themes of average depth ensures that its trained dataset was of varied interests and levels of expertise, which makes it challenging to understand the full potential of ChatPDF.

In this author's assessment, roughly one-third of the themes show a deep exploration, reflecting a comprehensive description or interpretation. However, a portion of the themes was reviewed at an average level, while a significant number were addressed at a surface level, offering only an overview or introductory interpretation. While AI-LLMs

are known for their ability to qualitatively analyse large amounts of text to generate meaningful facts and improve data analysis [8, 59], this capability is beneficial for literature reviews, particularly thematic analysis. According to Christou [20], this rapid data analysis allows researchers to focus more on interpretation, thereby saving time and energy when conducting literature reviews.

This study shows the limitations of ChatPDF in interpreting quantitative data, which is crucial in drawing meaning to construct a theme in qualitative research. The results show that it performed poorly in the ability to incorporate the meaning of data or numerical data into the description of the AI-generated theme, thus limiting its capability to function as a data analysis interpreter; while it may be argued that it is not intended for this purpose, other studies have shown otherwise. In the study of Dowling and Lucey [25], the quality of LLM, like ChatGPT's output, is heavily influenced by the input of private data and researcher expertise. In contrast, the use of private data only scores comparatively low. This shows that LLM works best when its trained datasets are combined with the data provided by the researchers. However, it may be noted that AI-LLMs like ChatPDF, which are specifically intended to interact with PDF files, may lack the ability to provide underlying context for the datasets or the awareness of the data presented within the tables or figures of the study. An interview with one engineering student praised the capacity of Gemini in data analysis, while the other three did not provide any comments on the study of Supriyadi and Pahmi [50]. This study by Supriyadi's and Pahmi's may reveal the users' lack of engagement. However, it is equally important to understand that in this study, the author inputted only one prompt into the platform, which may limit its performance and impact users who lack perceptions or awareness of the interactive nature of LLMs. Nonetheless, this may also hint at ambiguity regarding the platform's in-depth analytical capabilities.

4.5 Inclusivity to sensitive topics

Regarding the inclusivity to sensitive topics, it was found that a majority, 67.69%, of the contents from which the themes were generated did not contain sensitive topics, while 26.15% did not include sensitive topics. Only a handful of the three themes (4.61%) addressed delicate issues or sensitive topics when elaborating on the themes. This approach shows the minor unconscious effort of the ChatPDF to tackle sensitive topics. For instance, the theme description of "Data Governance and Management" mentions the trust-based relationship between the library and its users/stakeholders, which allows for a clearer interpretation of the theme. Another theme, "Fairness, Transparency, and Accountability", went above and beyond to highlight the library's commitment to mitigating risks of biases or discrimination and fostering a culture of trust and integrity in their AI initiatives. The third theme, "Regulation and Privacy Protection", considers the societal value, i.e., by focusing on the user's privacy rights. However, only one theme is invalid, but the absence of 17 themes (26.15%) inclusivity to sensitive topics or issues suggests a potential gap in addressing the nuances of sensitivity across all thematic areas, which could have been detected if done manually.

Some examples of non-inclusive of sensitive topics were observed with the theme, "Role of Libraries in AI Research", which shows the algorithmic bias to the roles of libraries on ethical standards. Another bias was observed with "Incorporation of ICT in Library Development", where the theme description did not incorporate the lack of technical skills and knowledge coming from a country like Nigeria. Themes like "Information Security Concerns" and "Confidentiality Principles" generated from the study of Yang et al. [57] also exhibit exclusion to certain sections/paragraphs of a study. For instance, the codes extracted for the theme "Confidentiality Principles" were extracted from Sect. 3.2, where the author refers to the "Interviewees/Participants" to maintain the confidentiality of the interviewee's privacy and data in the study. This would have been avoided if the open coding were done manually. Insensitivity was also detected in the three themes, "Ethical Considerations in AI Implementation", "Inclusivity and Accessibility", and "User Privacy and AI Literacy", of Mahmud [38], where the geographical region (Bangladesh) was not taken into consideration. All these exclusions towards the geographical region, considerations of study sections/chapters from where the codes were extracted, biases in generative contents, and inability to refer to external sources cited within the study suggest a lack of focused approach on topics where sensitivity is relevant.

Regarding the inclusivity of sensitive topics, it was found that a majority of 17 themes (26.15%) did not include sensitive topics, with only a handful of three themes (4.61%) addressing sensitive topics. The unknown nature of the training data to the larger public may generate biases as depicted in these findings, which is why Christou [20] suggests that analysts be alert and ensure ethical considerations when using LLMs. Integrating AI LLMs into writing literature or thematic reviews can significantly improve the efficacy of inclusiveness to sensitive topics in qualitative research. However, while doing so, the researchers must consider fabricated facts or themes that lack authenticity [7].

Including sensitive topics in thematic reviews is important for a thorough understanding of the subject matter, which can enhance the depth and relevance of the concepts, especially in social sciences and humanities research. Including sensitive topics can expose researchers to ethical

issues, which will improve the quality of the research process [28]. It improves not just the quality but also the methodological approaches. For instance, for a thematic analysis to be robust, it requires systematic steps such as familiarisation with the data, generation of codes, capturing significant patterns, reviewing the accuracy of data, and aligning with narratives before developing each theme [5]. This approach, combined with AI LLMs, may ultimately contribute to more inclusivity unlike deep learning models where the processes of thematic analysis may not be streamlined. In summary, one should be cautious enough to understand the use of AI LLMs in thematic analysis or reviews and manually cross-reference each theme or code by reading the actual paragraphs to maintain ethical standards in research.

4.6 Descriptive analysis of word counts

The analysis of the total word counts generated from an AI-powered tool provides transparency and text generation capability. The findings from this supplementary counting of words were intended to complement the author's qualitative analysis by providing additional depth [27]. As per Fig. 1, it was observed that most of the themes (n = 10) with the extracted codes range between (0–50 word counts with the mean value of 15.6 words) in light grey colour were able to generate an average word count of 56.5, indicating the ability of ChatPDF to generate texts that are nearly four-fold the length of extracted codes. Analysing the top three scorers where the text generation was high, shows the total word counts on the theme, "Confidentiality of user's data", with the 61-word counts generated out of the 7-word counts of codes. This was followed by "Forum moderation", with 105-word counts generated out of the 21-word counts of codes. Thereafter the theme, "Privacy protection", with 105-word counts generated out of the 21-word counts of codes. Among the top three lowest scores, the theme "AI policy & regulation", could only generate 172-word counts from 178 total word counts of codes. The second lowest was "Algorithmic biasness", with 86-word counts generated from 59-word counts of codes. The theme followed this, "Role of libraries in research", with 11-word counts generated from 7-word counts of codes. Among the most word counts, the "Transparency in Data Security", theme showed a significant increase with 540 total words out of the 227 total word counts of codes. The theme "Ethical Considerations", was also a major focus, with 434-word counts for theme description from 256-word counts of codes, highlighting the importance of ethical frameworks in technology. This was followed by the theme, "AI Integration", with 414-word counts, which suggests a broad exploration of AI applications and their implications in libraries. The detailed word count generated may suggest the significance of themes and evolving discourse aimed at addressing the ability of LLM tool to generate appropriate word counts with reference to the paragraph from where the codes were extracted.

4.7 SWOT analysis

SWOT analysis is used for strategic planning and helps make informed decisions by identifying strengths, weaknesses,

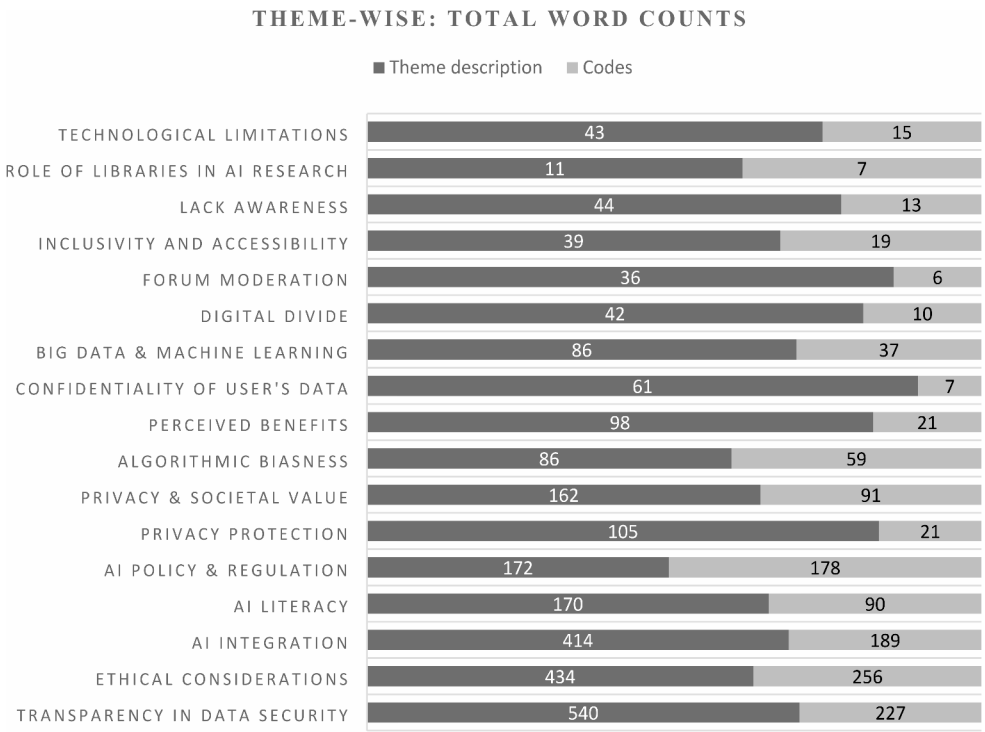

Fig. 1 Analysis of theme-wise total word counts

Table 6 SWOT analysis of AL-LLM

SWOT	Positive	Negative
Internal	**Strength** #1. Speedy interpretation and summarisation of literature within seconds reduce the time taken to read and understand the literature #2. ChatPDF's automation ability to generate new themes from the extracted code allows for the development of novel research ideas #3. A majority of 56.92% context accuracy was detected, indicating that the vast majority of extracted codes aligned with the overarching themes from the actual studies #4. The findings reveal a 89.23% non-repetitive nature of the text, indicating AI-LLMs' capability to summarize the extracted codes effectively and avoid echo chambers. This also suggests its efficacy in lexical diversity #5. The summarisation of multiple pieces of literature helps identify new trends and gaps in the research areas #6. ChatPDF's language translation allows for a broader understanding of literature written in other languages #7. Most themes can generate an average word count of 56.5, indicating the ability to generate relevant insights that align with the author's needs #8. ChatPDF's content generation ability streamlines the writing process and improves the overall research structure	**Weakness** #1. The ChatPDF Plus version involves an upfront cost #2. Partially matched contexts detected up to 38.46% may lead to misinformed contexts or concepts, thereby lacking authenticity #3. ChatPDF datasets may be trained to examine only a few paragraphs from the literature to answer the most immediate prompts, thus missing out on concepts that might be relevant to constructing a theme #4. A small repetitive textual pattern was observed (7.69%) with the AI-generated themes, leading the author to believe in the AI's inability to understand plagiarised texts, which violates academic integrity #5. A surface-level review of more than one-third of the AI-generated themes may suggest inherent biases from its training datasets. This resulted in biased themes, which raise doubts about the full potential of ChatPDF's qualitative synthesis #6. A significant 17 (26.15%) of 65 AI-generated themes lack the inclusion of sensitive topics, leading to a limited understanding of nuance, which could result in inaccurate thematic outputs. For example, the exclusion of geographical regions or interpretations from reliable sections/paragraphs of a study #7. It was observed that ChatPDF can extract minor statistical data but not in-depth information by inputting accurate prompts. Thus, it requires the author's intervention to ensure it accurately represents the underlying meaning of the data #8. It was observed that ChatPDF had difficulties processing PDF files that did not contain or had disabled Optical Character Recognition (OCR) text
External	**Opportunities** #1. Reduce burnout by skimming answers related to the prompt #2. Allow for conversational ability by inputting multiple prompts, making it highly scalable #3. Provide an avenue for qualitative synthesis of literature according to the author's needs #4. Provide a systematic workflow specifically for new researchers #5. Quickly generate and link new concepts that are helpful at the initial stage of research #6. Create an opportunity to enhance qualitative research methodologies, leading to innovation and the creation of new knowledge #7. Ensure ease of adoption in higher education institutions #8. ChatPDF's ability to generate text can help facilitate a better understanding of literature, fostering AI-human collaboration #9. ChatPDF offers the option to chat with multiple pieces of literature, thereby allowing simultaneous interaction with various literature within a folder #10. Improve access for third-world countries and marginalized communities through its free 2 PDF daily #11. Enhance its contextual accuracy by improving its algorithms, which will further enhance qualitative research #12. Improving user experience, awareness, and honesty may enhance AI contextual accuracy	**Threats** #1. There may be a tendency to rely heavily on AI generative tools, which may diminish the researcher's critical thinking and potentially weaken cognitive skills #2. One must consider the ethical challenges such as copyright and accountability of AI-generated outputs #3. Fabricated themes or codes from ChatPDF's trained datasets or public data may raise concerns about the integrity of the outputs #4. It may raise questions about the researcher's integrity who uses AI in their research work among collaborators, editorial boards, and the academic community #5. ChatPDF may knowingly reveal the researcher's sensitive personal information. This raises privacy and security concerns, as mentioned in its privacy policy, Sect. 4: "We may share or transfer your information in connection with, or during negotiations of, any merger, sale of company assets, financing, or acquisition of all or a portion of our business to another company [17]." #6. It may replace traditional jobs that are directly or indirectly related to qualitative research processes #7. Researchers who rely on AI-assisted work regularly may face difficulty if the algorithms or codes of the models change overnight due to the evolving landscape in AI #8. There may be skepticism about the reliability of AI-generated research outputs, which might hamper the academic community and society

opportunities, and threats. It gathers internal insights and considers external factors that offer a comprehensive view [33]. The author assesses the AI generative themes by ChatPDF using SWOT analysis in Table 6, particularly from its ability to synthesise themes.

The strength of ChatPDF lies in its ability to speed up literature interpretation and the The strength of ChatPDF lies in its ability to speed up literature interpretation and the summarising of large texts to generate themes and codes from a single piece of literature or a group of PDF files,

thereby assisting researchers in connecting the key concepts that may lead to the development of novel themes. It helps extract deeper insights and identify trends and gaps in AI-generated themes through its contextual accuracy (56.92%) and lexical diversity via non-repetitive content (89.23%) for more explicit descriptions that align with thematic development. Like this study, Danler et al. [23] remarked to AI tools remarkably respond to research questions, demonstrating a sophisticated understanding and synthesis of scientific literature. ChatPDF's translation feature and capacity to generate an average word count of 56.5 for most themes indicate the ability to generate diverse texts that align with the concepts. To this, Wang et al. [54] talked about AI's customisable feature to the extent of offering language translation services, making education more accessible to those with language barriers.

Similarly, it provides multiple opportunities for researchers by reducing burnout through skimming generated content through its numerous conversational prompts provided by ChatPDF, thereby making it highly scalable based on individual needs. It offers a structured and systematic workflow, especially for new researchers who want to quickly understand the context or link meaning in the early stages of research. This new approach to qualitative research may enhance methodologies, thereby fostering innovation and promoting AI-human collaboration. To this, Bates and Abdesslem [10] suggest that enhancing the user's experience can improve contextual accuracy in AI outputs, which further strengthens the symbiotic relationship between AI tools and human researchers to create new knowledge. ChatPDF also allows for a better understanding of concepts by interacting with multiple literatures (e.g., pdf, txt, docx, md, pptx, etc.) in a folder. Additionally, it democratises AI access for minor communities through its free 2 PDFs per day [16].

While it has the potential to improve its contextual accuracy through algorithmic enhancements, it still has weaknesses, such as an upfront cost for a premium version, which may limit accessibility for researchers with limited income. Also, the partially matched contexts (38.46%) may lead to misinformed theme descriptions, which points to ethical loopholes like biased outputs. Similarly, literature has pointed to various ethical loopholes of AI tools like biased response, violate academic integrity, and privacy [11, 34]. ChatPDF datasets often analyse short excerpts or irrelevant paragraphs that are not part of the study, which may ultimately miss key concepts that could aid in theme construction. Its algorithms might have a few errors by repeating the same textual patterns in a few of the AI-generated themes, suggesting that ChatPDF might struggle with generating new texts, thereby generating plagiarised content. For example, an AI-generated theme on "Ethical considerations and frameworks", in this study showed remarkable similarity to the original text from the literature, which violates research integrity. Its trained datasets, in one-third (36.92%) of surface-level reviews of AI-generated themes, show biases due to a lack of sensitivity to nuanced topics, thereby affecting thematic accuracy. Additionally, it struggles to extract in-depth statistical data and requires researcher intervention to ensure an accurate representation of the data's actual meaning. Finally, it has trouble processing PDFs without the Optical Character Recognition (OCR) feature, which hinders its ability to attract more users.

ChatPDF utility is not without threats to researchers and the academic community. Its usage could impact critical thinking due to over-reliance. Other literature also considered that over-reliance on AI generative tools might diminish the researcher's critical thinking and potentially weaken cognitive skills [42, 51]. There are ethical concerns, such as accountability due to the lack of acceptance of AI as a co-author. Alongside issues of fabricated theme description based on an irrelevant section of the pdf file, where the author refers to the "Interviewees/Participants" confidentiality of personal identity in the study. This exclusion of sensitive topics within the theme may undermine its reliability and credibility within academic circles. It also raises concerns about the user's privacy and security of personal information, especially as highlighted in its privacy policy under Sect. 4, which mentions the sharing of personal information and may use cookies and other web tracking to collect and store information [17]. There is a threat to the automation of traditional tasks in qualitative research, which could impact jobs. With the ever-evolving nature of AI models, it may pose a challenge for researchers due to sudden changes in government policy or algorithms. Furthermore, there may be skepticism among the academic community regarding the reliability of AI-generated research outputs, which could harm qualitative research. Therefore, researchers must responsibly integrate AI tools like ChatPDF into their thematic review to improve the quality of research outputs.

5 Practical implications

The following shows multiple implications for researchers, AI developers, higher educational institutions, and publishers who are the main stakeholders in academic research:

5.1 For researchers

5.1.1 Role in thematic progression

While AI-LLMs speed up thematic analysis and literature reviews in qualitative research, yet ChatPDF's are subject to

deficiencies. For instance, a partially matched context and a lower error rate led to contextual falsification, which may result from biased datasets, indicating that LLMs cannot yet replace human judgment. Therefore, it may be suggested that researchers use LLMs for theme generation at the early stage of thematic analysis due to their efficiency in identifying connections between concepts, followed by a thorough manual review of the entire paper to ensure accuracy and address contextual errors.

5.1.2 Diverse elaboration of themes

The study reveals a significant non-repetitive nature of the AI-generated themes, indicating a diverse elaboration of the themes. This shows the LLM's capability to effectively summarise the extracted codes effectively by avoiding echo chambers. In the long run, this will enable researchers to use LLMs to generate non-repetitive dynamic text, which may contribute to producing engaging narratives in thematic development.

5.1.3 Quick summaries of prior research

The analysis indicates that approximately one-third of the AI-generated themes were reviewed in-depth, thereby allowing researchers to employ LLM tools for literature reviews or quickly generate summaries of prior research, particularly in thematic progression. However, new researchers should be cautious when conducting thematic analysis using LLMs, especially if statistical data extraction or analysis is required.

5.1.4 Necessitate multiple prompt intervention

Additionally, a significant 36.92% of themes were generated at surface-level, suggesting that AI-generated themes may lack depth, which necessitates manual intervention during thematic development. To reduce this, researchers should employ multiple prompts to extract vivid and detailed nuances from LLM models when conducting literature reviews or thematic analysis. Even though the quality of AI-generated themes may continue to improve, human cognitive ability remains crucial to ensure the reliability of literature reviews and thematic analysis.

5.1.5 Gaps in sensitive topics

The findings highlight the need to include sensitive topics in thematic analysis. For example, about 26.15% of the themes lack the cognitive ability to consider perspectives from diverse demographics and underdeveloped regions. Hence, researchers should exercise caution when using LLMs in literature review or thematic analysis by manually reviewing the conceptual background of papers to identify gaps, sensitive topics or issues that may impact the subjects under study, socio-cultural, economic, political contexts, or ethical considerations to ensure authenticity and gain reviewers' trust.

5.1.6 AI as an assistant tool

Ultimately, AI-LLMs should function as an assistant rather than a replacement for human judgment. Therefore, balancing the symbiotic relationship between AI & Human judgement is paramount to retaining researcher's critical thinking.

5.1.7 Statistical Insights

ChatPDF is designed to interact with PDF files, but it lacks the ability to extract statistical data to provide underlying context. Therefore, including private datasets alongside its trained datasets may generate precise information presented within the study's tables or figures.

5.2 For AI developers

5.2.1 Need to recognise study (pdf) sub-sections & flag errors

For AI developers, integrating LLMs like ChatGPT's into qualitative analysis software should prioritise human oversight to improve AI's ability to recognise different sections or subsections of a paper (e.g., methodology, references, ethical considerations statement, etc.) and flag potential inaccuracies when the deep learning model is uncertain about contextual nuances.

5.2.2 Adapt to varied study types and trust in AI

In research, enhanced LLM tools could streamline the thematic analysis of large datasets without being restricted to specific study types (e.g., qualitative or quantitative studies), thereby saving time and broadening the scope of trained datasets. For AI developers, finding this balance could make their models more adaptable to changes in future trends relating to qualitative research. Over time, addressing these issues may assist in establishing trust in AI for academic writing and aspects of content-generation fields, such as legal documentation and journalism, where originality is paramount.

5.2.3 Dynamic textual generation and plagiarism prevention

The presence of minor textual repetition failed to prevent plagiarised content, therefore leaving room for further improvement to maintain research originality. As a result, more reliable summarisation feature with dynamic textual patterns could be developed to preserve academic integrity and intellectual property, making LLMs more trustworthy for professional and scholarly use.

5.2.4 Coherence & OCR enhancement

Future AI models could be trained to minimise textual repetition for greater coherence and engagement by improving their optical character recognition (OCR) capabilities, enhancing the usability of AI-LLM tools for scanned PDF files, and aiding the deep learning model in meaning comprehension.

5.2.5 Statistical data handling

One should be cautious when conducting thematic analysis using LLMs, especially if statistical data extraction or analysis is required. For AI developers, this presents an opportunity to design their models with the capacity to generate nuances of statistical outputs presented within the paper's figures, tables, and arithmetic numeracy.

5.2.6 Addressing bias in thematic analysis

AI developers and companies offering qualitative software services must address AI biases related to sensitive topics, review depth and contextual inaccuracies by ensuring their algorithms or trained datasets are balanced, dynamic and diverse. This may allow the AI models to engage more accurately with nuanced subject matter without overdoing it.

5.3 For higher educational institutions and publishers

5.3.1 Validation and disclosure

Due to the partial contextual inaccuracies of AI themes, universities and publishers must emphasise the critical validation of AI-generated content and establish policies that mandate clear disclosures of AI involvement in research work.

5.3.2 Ethical concerns on context and sensitive topics

Higher educational institutions and publishers must train researchers and raise awareness about the ethical incorporation of diverse viewpoints (e.g., sensitive topics or contextual accuracies) into their qualitative research while incorporating AI technologies, thereby standardising systematic approaches to thematic analysis and literature reviews in accordance with existing/new standards on AI-Human collaborations.

5.3.3 Integration with guidelines

Educational institutions, such as universities, can integrate LLMs for literature review and thematic analysis with proper guidelines or clear policies on their ethical usage, which align with current global and local standards to maintain transparency in research.

5.3.4 Privacy concerns

While LLMs may collect personal data, which may concern researchers' privacy, universities should provide training and privacy-enhanced tools to reduce the risks of data exposure by negotiating with AI tool providers before subscription to preserve both the personal and non-personal data of researchers, as well as the research data input into the LLM tools.

5.3.5 Training on ethical adoption

Institutions and publishers should train researchers on how to effectively use LLM tools and workflows in the research arena to ensure their ethical adoption complements human labour rather than replaces it.

These implications could significantly impact qualitative research. By addressing these current implications, researchers can improve the contextual accuracy, review depth, textual patterns, and sensitivity to critical topics in thematic analysis. This may foster transparency, ethical and inclusive practices in qualitative research. Ultimately, AI-LLMs should function as an assistant rather than a replacement for human judgment.

6 Limitation and future study

However insightful this study was, it was not free of limitations, which suggests avenues for future research. The study was limited to only one AI tool, i.e., ChatPDF. It did not consider the other AI tools with similar features or more. In the methodology section, the selection of literature for qualitative assessments was based on the limited search terms relevant to the objectives examined in this study. Therefore, the platform may have unintentionally excluded valuable studies. Thirdly, the AI-generated themes in Table 5 only

aim to provide exploratory insights into the emerging privacy themes on the applications of AI in libraries. However, it should be used cautiously, considering its internal weakness and external threats, as observed in Table 6. Fourthly, the author's thematic identification or review perspective may influence the qualitative assessments of the AI-generated themes. For example, the author's observation might have unintentionally missed a few contextual accuracies or inaccuracies, inclusiveness to sensitive topics, review depth, and textual patterns.

Although efforts were made to ensure objectivity, the findings presented in this study must be considered cautiously due to the interactive nature of ChatPDF. The single prompt used in this study was limited to a single response from a single paper. Suppose that multiple prompts were input into the chatbox of a single paper or a folder. In that case, numerous answers might be generated that may or may not fit the context accuracy or inclusivity of sensitive topics. For example, when using LLMs similar to ChatPDF, it is important to give clear prompts by asking it to, *"As a researcher or an expert, discuss the emerging themes and codes with descriptions on the topic, 'privacy concerns of Artificial Intelligence (AI) in libraries' while keeping the context accurate and reliable,"* to maintain the contextual accuracies of the content generated. Likewise, the researcher might find relevant and precise AI-generated content by inputting private datasets in combination with multiple prompts. Another limitation of assessing textual patterns was the exemption of other linguistic patterns, which may form the underlying meaning of the AI-generated themes. The study is also limited only to the author's assessment of the model's application layer without considering the technical specification of how the model works.

Further research, including a broader practical approach to LLMs, must build upon the limitations already provided in this study. Additional studies are needed to understand the role of (free vs. paid) in qualitative research. By incorporating robust search terms and strategies, researchers can focus on an improved version of the current methodology, which will ultimately enrich the quality selection of literature for thematic review or analysis. Further investigation may explore the researcher's AI usage and insight into varied AI features or conduct a longitudinal study to observe trends in the evolving role played by human-AI collaboration. Incorporating the cross-sectional study by exploring the model's technical specs in relation to the empirical evidence from the AI outputs may address ethical issues by mitigating potential biases and false content. All these limitations outlined the future glimpse into the possible research of AI-LLMs integration in qualitative research.

7 Conclusion

The adoption of AI-LLM tools in research presents varied lenses from the author's point of view. On one way, they present opportunities and strengths by enhancing its efficacy for innovative insight in qualitative research, particularly in identifying themes or developing codes or thematic descriptions. On the other hand, it also has certain challenges and threats, such as hampering the researcher's critical thinking, ethical responsibility, and the credibility of research outputs due to over-reliance, which may lead to skepticism within the academic community. That is why Hossain et al. [29] highlighted a need to give students equal access and impart AI literacy by prioritising ethical concerns and the importance of original work. Furthermore, Subaveerapandiyan et al. [48] also advocate on transparency concerning AI usage, promoting a culture of critical thinking and incorporating AI ethics into the curriculum that may suit the unique challenges in varying academic disciplines.

While AI generative tools such as ChatPDF can serve as valuable assistance in the research process, it is pertinent that researchers navigate their use cautiously, considering the SWOT perspectives presented in this study's findings. By adhering to ethical standards, researchers can harness AI's benefits while safeguarding their work's integrity. The academic community must engage in an ongoing discussion about the impact of AI in qualitative research to foster a balanced approach that will enhance productivity without compromising the quality of research or ethics. As for the AI tool developers, it is imperative to balance the areas like generating content with accurate context and consider the nuances of sensitive topics without overdoing it while preserving user's privacy. SWOT analysis also provides guidance to educational institutions, publishers and research agencies seeking to adopt similar tools for their students and scholars. Addressing these challenges will guarantee the trust and reliability of research outputs in an increasingly human-AI-driven research work. As we move forward with this ever-changing AI scenario, the academic community needs to recognise the reliability of thorough research work and never undermine the traditional roles of humans in the research processes.

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Author contributions The author assumes full responsibility for the entire research process, which encompasses conceptualization, methodology, literature review, data collection, analysis, and the discussion and interpretation of the results.

Data availability Links to the datasets were given in the methodology section.

Declarations

Competing interests The authors declare no competing interests.

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