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E-mail: info@medrang.co.kr
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Factors Influencing User Satisfaction with University Library Websites in Myanmar

Thet Mon Swe*
Department of Library Science, School of Information Management, Research Center for Chinese Science Evaluation (RCCSE), Wuhan University, Hubei, China
E-mail: thetmonswe.kya@gmail.com

Siluo Yang
Department of Library Science, School of Information Management, Research Center for Chinese Science Evaluation (RCCSE), Wuhan University, Hubei, China
E-mail: 58605025@qq.com

ABSTRACT

This study aims to develop a comprehensive technological framework anchored in a theoretical model to assess user satisfaction with university library websites (ULWs) in Myanmar. Adopting a quantitative approach, data were obtained via convenience sampling and subsequent inferential analysis. The target population for this study investigated users of various ULWs in Myanmar who were utilizing six university libraries. Of the collected responses, 273 valid surveys were analyzed using SPSS (version 25) and AMOS. Tools such as structural equation modeling and confirmatory factor analysis played pivotal roles in data interpretation and hypothesis validation. The proposed model highlights the significance of information quality, system quality, and librarian services in influencing both perceived usefulness (PU) and perceived ease of use (PEOU), culminating in user satisfaction. Notably, information quality and librarian services primarily impact PU, while system quality is more influential on PEOU. Interestingly, while PU has a direct bearing on user satisfaction, PEOU does not. Moreover, demographic elements such as age, gender, and education level introduce considerable differences in the utilization of ULW services. Drawing from the study's findings, recommendations are made for ULW managers in Myanmar to bolster services, aligning with user preferences. The resulting framework offers tangible benefits to Myanmar's educational sector, including academia, government entities, librarians, and policy framers. This pioneering research delves into the realm of ULWs in Myanmar's higher education sector. Practically, the research underscores the necessity for stakeholders, encompassing Myanmar's library experts and governing bodies, to elevate the standard of ULWs. Theoretically, a salient takeaway is the direct linkage between heightened usefulness and increased user satisfaction.

Keywords: user satisfaction, university library websites, information system success model, technology acceptance model, Myanmar

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***Corresponding Author:** Thet Mon Swe
https://orcid.org/0000-0002-9290-6744
E-mail: thetmonswe.kya@gmail.com

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1. INTRODUCTION

In Myanmar, the development of information and communication technology lags behind other ASEAN countries (Aung, 2018; Awang & Abidin, 2013; Aye, 2016; Tun, 2022). Myanmar, as a developing nation, faces technological insufficiencies and a dearth of advanced strategies. Consequently, challenges in human resource management are more pronounced, especially in the education sector, than in developed countries (Khine et al., 2021). Myanmar university libraries marked their foray into the digital space with the launch of university library websites (ULWs) in December 2013. This was facilitated by the E-Library Myanmar Project, primarily targeting major institutions (Nyein, 2016). With concerted efforts from librarians and precise guidance from information technology (IT) experts, many university libraries managed to offer services via their dedicated websites. Moreover, a predominant feature of Myanmar's ULWs is their intent to provide free institutional repositories for users. Under the purview of the Ministry of Education, Myanmar boasts approximately 164 government-affiliated colleges and universities. While these institutions maintain library collections and staff faculty members, only a handful have embraced the digital age with library websites and digital library (DL) systems. As a result, there is a prevailing emphasis on collection development rather than digital services tailored to user needs.

The Department of Higher Education within the Ministry of Education aspires to furnish university library services to a broad spectrum of users – from academic faculty and teachers to researchers and students. However, they face hurdles in updating institutional repositories on university websites and grapple with the challenges of introducing digital services in academic libraries. This study narrows its focus to six universities, as detailed in Table 1 (providing links to the library websites of these institutions). Situated in Yangon, Myanmar's former capital, these university libraries are among the country's most prominent. They offer a plethora of academic resources, including databases, institutional repositories, and a range of other services. Even though many universities have initiated library websites, a significant portion of users remains unaware of these online services (Swe & Yang, 2021). As a result, university libraries should actively promote and familiarize users with their digital offerings. Previous studies have examined aspects such as collection development, usability, and user satisfaction (US) (Aye, 2016; Oo et al., 2022). Given the evolving landscape of university website services in Myanmar, a deeper exploration into the US model is warranted.

Table 1. Website link of six universities

No.	University	Hyperlink
1	University of Yangon	https://www.uy.edu.mm
2	Universities' Central Library	https://uclmyanmar.org
3	Yangon University Foreign Language	https://www.yufl.edu.mm
4	University of Computer Studies Yangon	https://www.ucsy.edu.mm
5	Dagon University	https://www.dagonuniversity.edu.mm
6	East Yangon University	https://eyu.edu.mm

2. LITERATURE REVIEW

Globally, academic circles have dedicated substantial research to the pivotal realm of ULWs (Babar et al., 2020; Gao & Zheng, 2012; Liu & Xia, 2022). The pressing need for academic libraries to engage and offer services to their patrons online has heightened the importance of these studies. Catering to diverse user needs, college library websites should prioritize enhanced usability (Narnaware & Rokade, 2022). Libraries need to consider how to integrate popular old services with new components that emerge as a result of changing circumstances, and library websites are a good place to start (Lim, 2023). Developers of library websites will be able to better serve users with resources and services, make them more relevant, and enhance accessibility by establishing more direct routes—all of which will elevate the quality of information services—by utilizing data on actual user activity. Any library can enhance its website and draw readers to its content by gathering and evaluating statistics on user activity on the library website (Shevchenko, 2020). Several developed nations have published extensive research on ULWs, including topics such as the applicability of the technology acceptance model (TAM) to different age groups (Guner & Acarturk, 2020), webometric analysis (Brahma & Verma, 2018; Narnaware & Rokade, 2022), and gamification measures (Lim, 2023). Similarly, evaluations have been performed on Nigeria's National Virtual Library (Gbaje, 2007), academic library websites in Nigeria (Abifarin & Imavah, 2018; Gbaje & Kotso, 2014), and regarding information architecture usability on websites of Sri Lankan academic libraries (Silvis et al., 2019).

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Notably, despite being in close geographic proximity to these nations, Myanmar lacks comprehensive studies focusing on user perspectives related to ULWs. To date, no library professional in Myanmar has concentrated on ULW usage or the associated satisfaction factors. Initiated in 2013, the E-Library Myanmar project has been essential in the ULW movement's growth over the last ten years (Fraser et al., 2019; Nyein, 2016). This initiative, backing several major academic institutions, has facilitated the establishment of DL systems in Myanmar. While some studies on digital transformation have been undertaken (Nyein, 2016), critiques persist concerning E-Library services. Worryingly, a sizeable demographic comprising undergraduate students and scholars remains uninformed about Myanmar ULW services (Swe & Yang, 2021). Hence, assessing user awareness becomes imperative to truly gauge US concerning ULW. The rich tapestry of international research offers inspiration and innovative methodologies for exploring the dynamics of Myanmar's ULWs in relation to US. Consequently, this study stands as a foundational reference for various relevant academic explorations into ULWs.

2.1. Theoretical Background

US stands as a paramount metric when gauging the success of IT implementations (Keikhosrokiani et al., 2020; Zaitul et al., 2018; Zviran & Erlich, 2003). Furthermore, the value of foundational skills training cannot be understated; such training amplifies US and promotes increased voluntary engagement with the system, although not necessarily more intensive usage (Zaitul et al., 2018). The quality of communication between users and technical personnel, as underscored by previous information system (IS) research, holds significant sway over the acceptance, evaluation, and ultimate utilization of an IS (Gefen & Keil, 1998; Naeem et al., 2023). In the ever-evolving digital landscape, librarians are called upon to be adaptive, embracing new technologies to optimize user service experiences (Igbinovia, 2021). This pivot toward new technologies is not just a matter of modernization; it is grounded in research that scrutinizes technology acceptance factors, especially in developing nations, shedding light on concepts such as the Internet of Things. Evaluating technology acceptance is integral to gauging the success of an IS. Esteemed IS researchers have posited that a user's acceptance of technology is intrinsically linked to their intention to use and the actual utilization of said technology (Marangunić & Granić, 2015). According to the McLean and DeLone model of IS success, US and utilisation are significantly impacted by the quality of the system, the information, and the services (Chen, 2011; Swe & Yang, 2021). The research pinpoints perceived usefulness (PU) and perceived ease of use (PEOU) as key determinants in IS implementation (Gefen & Keil, 1998). Elaborating on this, Davis et al. (1989) highlighted challenges related to user accessibility of computer systems and the ensuing repercussions on organizational performance. This intricate dance of acceptance and rejection of computer based IS is influenced by a diverse array of beliefs, attitudes, and satisfaction levels. Often, these determinants are deployed as a robust theoretical or psychometric foundation. A critical distinction is made between the TAM and the Theory of Reasoned Action (TRA), with the former emphasizing the pivotal roles of PU and PEOU in shaping users' attitudes, intentions, and actual computing behaviors. In essence, PEOU underscores the notion that individuals can achieve more with the same effort, thereby directly impacting PU. Models such as the one proposed by Saeed and Abdinnour-Helm (2008) lean on the principles of TAM and the Information System Success Model (ISSM), revealing the weight of information quality (IQ) and system integration on IS utility.

Further studies, such as findings by Wixom and Todd (2005), highlight the academic proclivity to merge TAM with US theories. Pioneering works by researchers, for example Chen et al. (2016), Chen and Tsai (2019), and Soltani-Nejad et al. (2020), have sought to integrate the TAM with other models, creating robust frameworks to understand user intentions and satisfaction in various digital platforms. Ali et al. (2019) integrated TAM and ISSM to examine e-learning success, specifically hypothesizing among undergraduate students in Pakistan. Jin and Xu (2021), leveraging both ISSM and structural equation modeling (SEM), found that a number of factors significantly influenced US, including the quality of the system, the information it contains, and the services it provides. This in turn impacted loyalty toward paid knowledge platforms, as gauged by perceived value. Abdul Rahman and Mohezar (2020) underscored influential factors on DL, including perceived quality, instrumental support, PEOU, user expectations, satisfaction, net benefits, and PU. Lan and Chen (2022) combined TAM and ISSM to investigate the impact of attitudes, satisfaction, and continuing usage of telehealth services on middle-aged and older individuals living in remote places. Oktal et al. (2016) evaluated the National Judiciary Information System, revealing that IQ was the pivotal latent variable in the SEM. When one considers the vast landscape of IT/IS adoption theories,

several stand out, notably: the Unified Theory of Acceptance and Use of Technology, the Theory of Planned Behavior, and the TAM by Davis et al. (1989). Within this theoretical milieu, IT/IS evaluation models emerge as essential tools, helping to elucidate user requirements and pinpoint crucial dimensions and factors for system development, ultimately fostering user acceptance and satisfaction. This study, in its quest for depth and clarity, leans on two central models.

2.1.1. Model of Information System Success

Success in IS according to the DeLone and McLean paradigm underwent enhancements and refinements as noted by Seddon (1997). DeLone and McLean's initial 1992 framework captured temporal and causal relationships among six key factors, namely, system and organizational impacts, as well as IQ, use, individual impact and satisfaction of users. Within this model, system quality (SQ), IQ, and US were components of a causal variance model aimed at predicting subsequent IS utilization. Evaluating information and SQ entails discerning inaccuracies, recognizing that even the most technically superior systems can sometimes yield unproductive information. Concurrently, US, influenced by system and IQ, emerges as an independent variable in this variance model. Furthermore, system and IQ also help shape PU – a well-established predictor of future IS usage (Davis, 1986; Davis et al., 1989). The model received further refinements in 2003 by DeLone and McLean, introducing additional parameters such as service quality, system use, and net benefits (Karaman & Bölen, 2015). The quality of information is not just about its intrinsic value; it is also about perception and utilization, with user expectations playing a defining role. Aung (2018) and Soltani-Nejad et al. (2020) posited that a website's design significantly affects how satisfied users are with it.

2.1.2. Technical Adoption Model

The TRA served as the model for the TAM. Davis et al. (1989) developed this paradigm even further. As a primary framework within IS theory, the TAM is characterized by several components: PU, PEOU, behavioral intention to use, and actual system usage. The main factors that determine whether or not users adopt ISs are PU and ease of usage. According to Bandura (1982), PU is the degree to which a person believes that by employing a particular technique, akin to Bandura's self-efficacy theory, job performance would be enhanced. On the other hand, PEOU was defined by Rogers and Shoemaker (1971) as the degree to which a person thinks a system requires no effort. They also posited that the TAM could account for approximately 40% of the determinants influencing IT adoption. Numerous studies have analyzed and validated the TAM in the context of DL spanning different geographical regions. For instance, Sheikhshoaei and Oloumi (2011) argued that the TAM is not ideally suited for social and organizational factors but is more apt for individual-centric factors. They emphasized the importance of IT training to equip employees with the necessary skills, underscoring the necessity of periodic skills updates. In their study of undergraduate students' use of DL at a Namibian institution, Kiana et al. (2021) identified US as pivotal for system support. Their research further underscored that enhancing US bolsters the success of ISs, while high quality systems invariably lead to increased satisfaction. Given this theoretical backdrop, the current study leveraged the TAM to craft hypotheses and design questionnaires, further details of which can be found in Table 2 (Dickinger & Stangl, 2013; Fathema et al., 2015; Izuagbe et al., 2016; Karaman & Bölen, 2015; Khan & Bhatti, 2017; Kiana et al., 2021; Maditinos et al., 2008; Noh & Chang, 2020; Pawinun & Asundi, 2002; Sahi, 2015; Sheikhshoaei & Oloumi, 2011; Silvis et al., 2019; Venkatesh & Bala, 2008), indicat-

Table 2. Construction factors for user satisfaction with university library website

Construct	No. of items	Adapted
Information quality	5 Items	Karaman & Bölen (2015); Fathema et al. (2015); Maditinos et al. (2008)
System quality	5 Items	Karaman & Bölen (2015); Fathema et al. (2015); Maditinos et al. (2008)
Librarian service	6 Items	Pawinun & Asundi (2002); Sheikhshoaei & Oloumi (2011); Khan & Bhatti (2017); Kiana et al. (2021)
Perceived usefulness	6 Items	Izuagbe et al. (2016); Fathema et al. (2015); Venkatesh & Bala (2008); Dickinger & Stangl (2013)
Perceived ease of use	6 Items	Fathema et al. (2015); Venkatesh & Bala (2008); Dickinger & Stangl (2013)
User satisfaction	6 Items	Noh & Chang (2020); Silvis et al. (2019); Sahi (2015); Dickinger & Stangl (2013)

ing the following hypotheses and research model development.

2.2. Information Quality

The caliber of information can be assessed through parameters such as usefulness, accuracy, reliability, and timeliness. Furthermore, a high quality of information indicates that it is pertinent, dependable, accurate, and presented in an easily understood way. Such high-quality information is typically viewed favorably by users, who find it helpful and valuable, which enhances their entire system experience. IQ was required to determine which library resources were most popular in order to enhance access to them (Shevchenko, 2020). Users are more inclined to trust the system and find it helpful for their particular needs when they believe the information is accurate and pertinent. Consequently, there may be a rise in user happiness, engagement, and system utilization. Adeyemi and Issa (2020) emphasized that the quality of information is pivotal when devising and implementing university web portals to ensure US. They advocate for university stakeholders – from management to IT experts – to prioritize assessing the quality of content on their web portals. Sharma et al. (2011) observed that users who are aware of the plethora of e-resources in their domain are more inclined to exploit online resources, bolster infrastructure, and participate in structured programs. This awareness, according to Sharma et al. (2011), increases the level of user pleasure. According to Soltani-Nejad et al. (2020), there is a strong correlation between US in DL and characteristics like information, system, and service quality. Zorba (2013) noted the dual roles of library websites, which can either serve informational purposes or act as marketing tools. The content requirements vary from departmental outlets to broader university platforms. In summary, high-quality information that is accurate, relevant, reliable, and well-presented positively affects opinions of users regarding practicality and convenience of usage. By ensuring the provision of high-quality information, systems and technologies can enhance US, engagement, and overall user experience. Given these insights, we put out the following hypotheses:

H1. Improving IQ positively affects users' perceptions of its utility.

H2. Improving IQ positively affects users' PEOU.

2.3. System Quality

Higher quality, dependability, and usefulness generally raise the possibility that consumers will find a system to be easier to use. It is important to remember, nevertheless, that users' subjective assessments of usability can be impacted by a range of factors other than SQ. For instance, even a sophisticated system of the highest caliber could be viewed as challenging to use if the user interface is poorly made or if the user is not equipped with the required knowledge or abilities to operate it. Similar to this, if a system has an easy-to-use interface, even a lower-quality system could be seen as user-friendly. Superior SQ and user interface design are crucial in ensuring the delivery of high-quality information (Tun, 2021a). Academic libraries must invest in refining SQ, reconfiguring resource structures, overhauling operational processes, and ensuring seamless maintenance. This emphasis stems from the fact that SQ is crucial for optimizing web environments and addressing user demands (Zhai & Wang, 2016). Service quality stands as a paramount determinant of library website performance. Therefore, educational institutions must prioritize SQ to positively impact US with E-Library resources (Chang et al., 2015). Zhou (2014) contended that the perceived utility of a system largely hinges on its quality. Concurrently, the caliber of information has a significant bearing on US. To keep users engaged and contented, it is imperative for service providers to dispense reliable, up-to-date, and pertinent data. Satisfaction, as Zhou (2014) elucidates, is a metric reflecting the discrepancy between service quality and user expectations. Drawing from this discourse, SQ amplifies PEOU via PU, trust bolsters PU, and in turn, PU augments user contentment (Oktal et al., 2016). In conclusion, SQ has a significant impact on how users perceive a system's usefulness and effortlessness of use. A high-quality system that performs well, provides the desired functionality, and is user-friendly can enhance the overall user experience, increase US, and favorably affect how beneficial and simple consumers perceive something to be. In light of these discoveries, we propose these hypotheses:

H3. PEOU benefits from high SQ.

H4. PU benefits from high SQ.

2.4. Librarian Service

To effectively advocate for the importance of libraries in today's digital age, librarians must arm themselves with modern technological skills. By focusing on user-centric terminology, librarians can align their services with common language and terms, ensuring accessibility and promoting engagement within academic environments

(Benedetti, 2017). Additionally, librarians can offer training sessions or workshops to educate users on information literacy skills, efficient search strategies, and proper citation practices. By empowering users with knowledge and skills, librarians enhance both PU and PEOU, making the library services more valuable and user-friendly. Besides this, PU greatly influences librarians' attitudes toward IT. Jabeen et al. (2017) discovered that users expressed dissatisfaction with the assistance they received from librarians in navigating DL resources. Interestingly, these users were adept at utilizing various search engines and had gained substantial familiarity with library databases via librarian-provided services, such as accessing journals, articles, and full-text databases crucial for their courses. Emphasizing the significance of library orientation, Kiana et al. (2021) found a notable correlation between library training and DL usage. In the context of university DL, librarians play a pivotal role, particularly in offering specialized training sessions and facilitating research endeavors (Soltani-Nejad et al., 2020). In conclusion, librarians have a significant impact on how helpful and easy users believe library services to be. Their expertise, assistance, and guidance contribute to users' perceptions that the service is valuable, relevant, and easy to use, ultimately enhancing the overall user experience. Therefore, the following hypotheses are formulated:

H5. There is a positive correlation between PU and librarian service.

H6. In terms of PEOU, librarian service is beneficial.

2.5. Perceived Ease of Use

Across the globe, libraries provide services mostly through websites and the Internet. Web designers have a responsibility to create websites that are visually appealing, engaging, and easy to use (Brahma & Verma, 2018). Ease of use makes it easier for users to extract value from the system, which in turn increases their perception of its usefulness. For example, a user-friendly project management tool that simplifies task management, collaboration, and reporting can be perceived as more useful by its users. Users are more satisfied with a system overall when they find it straightforward to use. Easy-to-use systems reduce frustration, minimize errors, and increase user confidence and control. Users appreciate systems that require less effort to accomplish tasks and allow them to achieve their goals efficiently. A positive user experience resulting from a high level of ease of use contributes to US. For instance, a seamless and intuitive e-commerce website that enables users to easily find and purchase products, that provides secure payment options, and offers clear and helpful product information can lead to higher US (Mamakou et al., 2024). For a system to be truly user-friendly, it should be intuitive, allowing users to seamlessly access information and services. A DL's accessibility directly motivates its users (Masrek & Gaskin, 2016). These scholars posit that PEOU—a core tenet of the TAM—strongly resonates with US. Similarly, Thong et al. (2002) posited that PEOU indirectly enhances PU, mediated by the intention to use. To summarize, there is a positive correlation between PEOU and PU in addition to US. Users are more likely to find and accept systems that are convenient to use, which increases satisfaction with the system. Designing systems with a focus on usability and providing a smooth user experience can enhance both PU and US, leading to improved user engagement and overall system success.

Hence, we propose:

H7. PU benefits from PEOU.

H8. PEOU positively affects US.

2.6. Perceived Usefulness

Perception of usefulness is the term for the user's perception of how beneficial a system or technology is in facilitating their tasks or achieving their goals. When users perceive a system as useful, they believe that it can effectively meet their needs, provide value, and help them accomplish their objectives. For example, if an e-commerce platform offers a wide range of products, competitive prices, and convenient shopping features, users are more likely to perceive it as useful. Masrek and Gaskin (2016) found that PU enhances the service of DL or job performance. Madle et al. (2003) emphasized the importance of usability testing for DL, especially in assessing the graphical interface, navigational ease, and user acceptability. Thong et al. (2002) suggested that PU has more influence over a DL than does PEOU. Additionally, PEOU indirectly sways intention to use, mediated through PU. US refers to the overall positive evaluation and contentment that users experience when interacting with a system or technology. When users perceive a system as useful in fulfilling their needs and goals, it contributes to their satisfaction. If a system effectively provides the features, functionalities, and benefits that users expect, it increases their satisfaction. For instance, if a user service software enables quick issue resolution, responsive communication, and personalized support, it enhances US. In summary, when users perceive a system as useful, it positively influences their

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satisfaction. Users are more likely to be satisfied when a system meets their expectations, helps them achieve their goals, and provides value. Designing systems with a focus on delivering PU can contribute to enhanced US, leading to increased user engagement, loyalty, and overall system success. Consequently, we propose the following:

H9. PU positively affects US.

To sum up, the main goal of this research is to develop and build a novel model that investigates the factors that influence users' satisfaction with the websites of Myanmar universities' libraries. Drawing inspiration from the preceding discourse, this research endeavor seeks to sculpt a high-quality framework tailored for Myanmar's ULWs. The objective is not just a theoretical exercise but a practical overhaul—reimagining university libraries to underscore the role of their digital portals, meeting user needs, and ensuring satisfaction. This research model aims to elevate the standards of ULWs in Myanmar by diving deep into user feedback, as seen in Fig. 1.

3. OBJECTIVES AND QUESTIONS

The literature evaluation unequivocally demonstrates that a thorough investigation is required to assess the chosen ULWs. Based on the available features, websites were categorized into three groups: high, medium, and poor (Dhar & Gayan, 2022). Nevertheless, the researchers did not employ any webometric indicators in their study, which was restricted to evaluating web content and creating a model for US based on six ULWs in Myanmar. Since then, as online technologies have advanced quickly, so have website functions. New technologies have entered the web development scene, including bots, semantic web, and artificial intelligence. Furthermore, the listing did not contain things like "upcoming events and activities" or "an online forum for discussion."

This study, therefore, aims to delve into the factors affecting user awareness and satisfaction concerning ULWs. The research performs the following objectives and answers the research questions:

1. To determine the influence of user demographics on ULW usage.
2. To verify the factors that impact how PU and PEOU contribute to user contentment.
3. To assess the relationship between various determinants of US.
4. To present an innovative model outlining US for Myanmar's ULWs.
5. To offer actionable recommendations to bolster Myanmar ULW infrastructure.

RQ1. Is there a significant difference in the usage of ULWs when grouped according to profile variables?

RQ2. Which factors play a significant role in determining US?

RQ3. How do user requirements and positive feedback contribute to ULW development?

4. METHODOLOGY

Zviran and Erlich (2003) emphasized the importance of employing diverse models and metrics to gauge US in empirical research pertaining to ISs. Consequently, the present study employed a survey methodology in order to accomplish its objectives. The research adopted a quantitative approach and harnessed the convenience sampling method within a cross-sectional survey design. Methods such as confirmatory factor analysis (CFA) and exploratory factor analysis used SEM in stages to validate and test the proposed hypotheses. There are 164 colleges and universities associated with the government, as was previous-

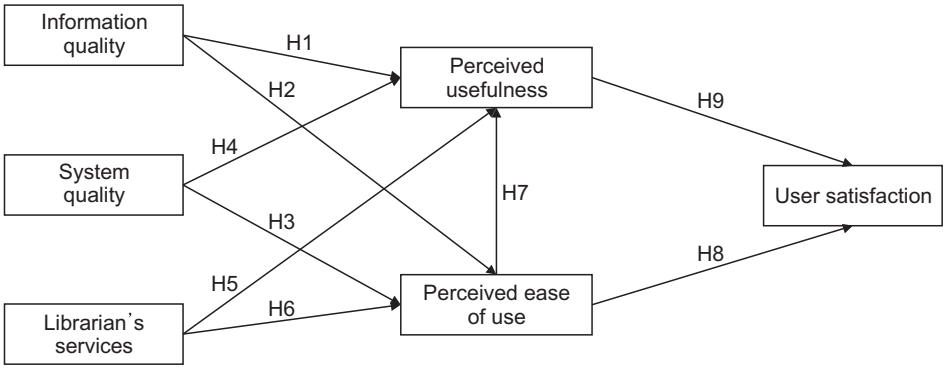


Fig. 1. Model of research.

ly mentioned in the introduction section. However, some of these institutions only have websites that are connected to an online library. This study specifically selected 273 individuals from the websites of six universities' libraries. Given that 273 respondents provided data for this study, both requirements for choosing the right sample size are met (Kumar et al., 2022). To assess the frequency of users' engagement with library websites, the instruments were self-administered questionnaires utilizing a 5-point Likert measure, where 5 signified "strongly agree" and 1 denoted "strongly disagree."

The investigation form was bilingual and available in both Myanmar and English. To ensure the content validity of the English version, it underwent scrutiny by professionals from the Department of English. For the distribution of the data collection instrument, the researcher procured the requisite permissions from the respective university rectors. Following this, with the support of university librarians, the questionnaires were disseminated. After development, the instrument was subjected to a pilot study with 15 participants encompassing library staff, educators, and students across different academic levels. The survey was conducted in Myanmar, utilizing printed forms, from February to March 2021 (Appendix). The participants' disciplines mirrored the academic landscape of Myanmar, encapsulating fields such as arts and sciences (Table 3). Out of the total received questionnaires (332), after omitting outliers, 273 valid responses were retained for analysis. The data subsequently underwent scrutiny through descriptive statistics methodologies, with metrics such as percentage, mean, and standard deviation. The hypotheses were evaluated by using SEM and CFA techniques.

Table 3. Demographic profile of participants

Contrast	Frequency
Gender	
Men	31 (11.4)
Women	242 (88.6)
Age (yr)	
≤24	67 (24.5)
25-29	63 (23.1)
30-35	48 (17.6)
36-45	41 (15.0)
46-55	54 (19.8)
Major	
Science	117 (42.9)
Art	156 (57.1)
Education level	
Undergraduate	16 (5.9)
Graduate	217 (79.5)
Postgraduate	40 (14.7)
Name of university library website	
University of Yangon	46 (16.8)
Universities' Central Library	55 (20.1)
Yangon University of Foreign Languages	38 (13.9)
Dagon University	47 (17.2)
University of Computer Studies Yangon	44 (16.1)
East Yangon University	43 (15.8)
Total	273 (100)

Values are presented as number (%).

5. RESULTS

From the analyzed data, the gender distribution showed 11.4% male and 88.6% female respondents. This evident gender disparity might be given credit for the constraints of the COVID-19 outbreak as well as the tumultuous political scenario in Myanmar under the military regime (Banerjee, 2023). With individuals avoiding physical contact during this period to inhibit virus transmission and students, and faculty actively participating in the civil disobedience movement against the military government, disruptions were evident. In particular, many males faced boycotts. Further buttressing this gender bias, the 2014 Myanmar Census reported a higher female than male population (Tun, 2021b).

5.1. Demographic Profile of the Respondents

Given these contexts, the gender skew in the present study concurred with the prevailing societal dynamics. Age wise, the respondents were distributed as follows: 24.5% below 24 years, 23.1% between 25-29, 19.8% between 46-55, 17.6% between 30-35, and 15.0% between 36-45. Academically, a vast majority (79.5%) were graduate students, followed by postgraduates (14.7%) and undergraduates (5.9%). Disciplinary distribution revealed 57.1% from arts and 42.9% from sciences. Analyzing specific ULW engagement, 20.1% of participants used the universities' central library (UCL), 17.2% Dagon University, 16.8% University of Yangon, 16.1% University of Computer Studies Yangon, 15.8% East Yangon University, and 13.9% engaged with Yangon University of Foreign

Table 4. Preliminarily descriptive analysis of data normality

Item	Descriptive statistic			
1	Indicator	Standard deviation	Skewness	Kurtosis
2	IQ1	0.513	-0.108	0.745
3	IQ2	0.532	-0.451	0.372
4	IQ3	0.524	-0.208	-0.275
5	IQ4	0.52	-0.195	0.25
6	IQ5	0.474	-0.362	1.043
7	SQ1	0.43	-0.549	1.945
8	SQ2	0.465	-0.471	0.998
9	SQ3	0.454	-0.571	1.04
10	SQ4	0.461	-0.45	1.186
11	SQ5	0.527	-0.769	1.758
12	LS1	0.426	0.26	2.473
13	LS2	0.452	0.291	1.752
14	LS3	0.415	0.449	2.612
15	LS4	0.448	0.181	1.989
16	LS5	0.459	0.197	1.716
17	LS6	0.471	0.259	1.358
18	PEOU1	0.442	-0.612	1.361
19	PEOU2	0.475	-0.509	0.407
20	PEOU3	0.435	-0.407	2.063
21	PEOU4	0.456	-0.496	1.219
22	PEOU5	0.425	-0.607	2.002
23	PEOU6	0.436	-0.63	1.54
24	PU1	0.432	-0.5	1.989
25	PU2	0.455	-0.326	1.64
26	PU3	0.448	-0.326	1.821
27	PU4	0.453	-0.092	1.923
28	PU5	0.432	-0.361	2.2
29	PU6	0.444	-0.173	2.087
30	US1	0.436	-0.154	2.293
31	US2	0.452	-0.187	1.895
32	US3	0.464	-0.442	1.112
33	US4	0.534	-1.007	2.365
34	US5	0.453	-0.092	1.923
35	US6	0.454	-0.031	1.931

IQ, information quality; SQ, system quality; LS, librarians' service; PEOU, perceived ease of use; PU, perceived usefulness; US, user satisfaction.

Languages. Further details are located in Table 3.

5.2. Preliminary Descriptive Analysis of Data

According to Kline (2011), a Z score (standard deviation) that falls between -0.3 and 0.3 should be deleted. For data to be considered normally distributed, kurtosis should lie between -7 and +7, and skewness should lie between -2 and +2. These criteria can be viewed in Table 4. The results indicate that all questionnaire items possess standard deviation. Table 4 displays skewness and kurtosis values ranging from -2 to 2. Based on this data normality, respondents appear to have a strong conviction that IQ can meet their requirements for ULW usage, as seen in the standard deviations for IQ 2, 3, 4, and 1. Additionally, respondents also expressed positive beliefs regarding US 4 and SQ 5.

5.3. Results of Factor Loading and Cronbach's Alpha

The Kaiser-Meyer-Olkin value for factor analysis stands at 0.912, with a chi-square value of 4,613.195. In line with Fornell and Larcker (1981), the Cronbach's alpha lies between 0.875 and 0.93. All composite reliability values exceed 0.8, surpassing the recommended threshold of 0.7 (Hair et al., 2019). The factor loadings for each item in the measurement model, as shown in Table 5, range from 0.652 to 0.904. Hair et al. (2019) suggest that factor loadings below 0.50 indicate items that may need removal. However, with factor loadings above 0.50, as in this case, all criteria for convergent validity are met, as illustrated in Table 5.

5.4. Result of Pearson's Correlation

The findings indicate that all variables exhibit a strong positive correlation at the 0.01 significance level.

The correlation coefficients range from 0.536 for IQ and PEOU to a peak of 0.731 for SQ and IQ. Shaded cells within Table 6 denote the nine causal relationships illustrated in the proposed research model (Fig. 2). It is impor-

Table 5. Analysis results of factor loading and Cronbach's alpha

Factor	PU	LS	PEOU	IQ	US	SQ	CA
PU5	0.81[a)]	0.092	0.258	0.24	0.212	0.227	0.938
PU4	0.792[a)]	0.233	0.22	0.13	0.224	0.221	
PU6	0.774[a)]	0.13	0.351	0.215	0.18	0.208	
PU3	0.751[a)]	0.163	0.259	0.271	0.249	0.16	
LS5	0.139	0.904[a)]	0.099	0.1	0.206	0.106	0.938
LS4	0.107	0.897[a)]	0.088	0.109	0.252	0.012	
LS6	0.163	0.867[a)]	0.057	0.053	0.245	0.162	
PEOU5	0.245	0.095	0.847[a)]	0.135	0.13	0.226	0.905
PEOU6	0.272	0.043	0.793[a)]	0.146	0.161	0.3	
PEOU4	0.366	0.147	0.775[a)]	0.3	0.025	0.111	
IQ3	0.199	0.089	0.185	0.842[a)]	0.181	0.192	0.882
IQ2	0.219	0.119	0.217	0.829[a)]	0.07	0.209	
IQ4	0.253	0.087	0.103	0.664[a)]	0.188	0.46	
US2	0.24	0.236	0.078	0.114	0.846[a)]	0.093	0.895
US1	0.248	0.29	0.143	0.191	0.78[a)]	0.039	
US5	0.147	0.289	0.093	0.096	0.767[a)]	0.226	
SQ4	0.29	0.166	0.296	0.214	0.109	0.779[a)]	0.875
SQ3	0.2	0.173	0.294	0.433	0.118	0.706[a)]	
SQ2	0.297	0.041	0.245	0.382	0.226	0.652[a)]	

PU, perceived usefulness; LS, librarians' service; PEOU, perceived ease of use; IQ, information quality; US, user satisfaction; SQ, system quality; CA, Cronbach's alpha.
[a)]Factor loadings are above 0.50.

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Table 6. Analysis result of Pearson's correlation

Factor	LS	PEOU	PU	US	SQ	IQ
LS	1					
PEOU	0.292[a)]	1				
PU	0.410[a)]	0.678[a), b)]	1			
US	0.577[a), b)]	0.372[a)]	0.561[a), b)]	1		
SQ	0.353[a)]	0.651[a), b)]	0.658[a), b)]	0.458[a)]	1	
IQ	0.308[a)]	0.536[a), b)]	0.569[a), b)]	0.429[a)]	0.731[a), b)]	1

LS, librarians' service; PEOU, perceived ease of use; PU, perceived usefulness; US, user satisfaction; SQ, system quality; IQ, information quality.
[a)]Correlation is significant at the 0.01 level (2-tailed). [b)]Factor loadings are above 0.50.

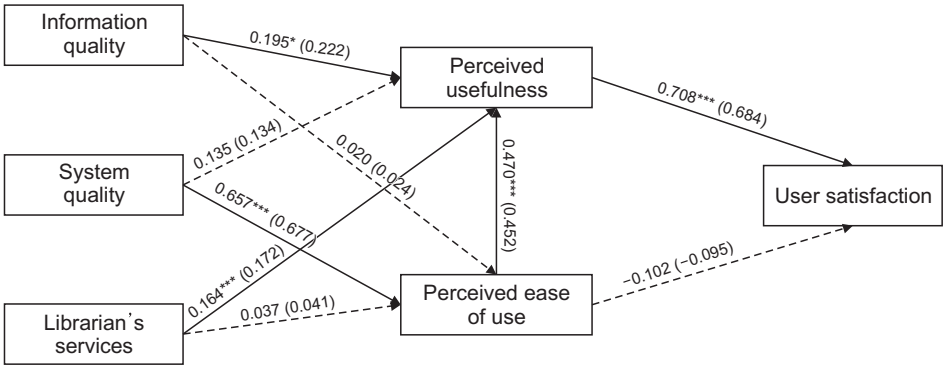


Fig. 2. Research model with hypothesis results. *p<0.05, ***p<0.001.

tant to note that while these correlations are substantial, they do not necessarily confirm the presence of strong causal relationships, as highlighted by Kline (2011).

5.5. Results of Convergent Validity, AVE, and Composite Reliability

The average variance extracted analysis (AVE) values ranged between 0.709 and 0.836, which are well above the guideline of 0.5 (or 50%) as suggested by Hair et al. (2019) (refer to Table 7). All the indicators were found to be significant, with the standardized regression weights for all indicators surpassing 0.768. Consequently, the dataset demonstrates robust convergent validity and a high level of internal consistency reliability.

5.6. Results of Discriminant Validity

Hair et al. (2019) emphasized that assessing discriminant validity, which determines differences among correlated factors, is crucial for validating constructs. In Table 8, all the square root values of AVE exceed the correlation estimates for each construct, and these values are highlighted in bold.

Based on the analysis, the proposed research model demonstrates robust discriminant validity, making it suitable for subsequent SEM analysis. This can be referenced in Table 8.

5.7. Result of Model Fit Indices

The fit indices for the measurement model are as follows: goodness-of-fit index (GFI)=0.886, adjusted goodness-of-fit index (AGFI)=0.842, normed fit index (NFI)=0.928, incremental fit index (IFI)=0.956, comparative fit index (CFI)=0.956, and the root mean square error of approximation (RMSEA)=0.074 with x^2/df=2.479. In the subsequent analysis of the structural model's fit indices, the results yielded x^2/df=2.836, GFI=0.872, AGFI=0.827, NFI=0.916, IFI=0.944, CFI=0.944, and RMSEA=0.082. Given that GFI and AGFI values exceed 0.8, NFI, IFI, and CFI values surpass 0.9, and with RMSEA exceeding 0.08 for both the measurement and structural models, these indicators point toward a good fit. These findings can be cross-referenced in Table 9. Consequently, this suggests that the research model for this study offers an acceptable fit to the data at hand.

Table 7. Analysis results of convergent validity, AVE, and CR

Factor name	Item name	Standardized regression	AVE	CR
LS	LS4	0.917	0.836	0.939
	LS5	0.942		
	LS6	0.884		
IQ	IQ2	0.845	0.715	0.883
	IQ3	0.853		
	IQ4	0.839		
SQ	SQ2	0.825	0.745	0.897
	SQ3	0.911		
	SQ4	0.851		
PEOU	PEOU4	0.865	0.762	0.906
	PEOU5	0.888		
	PEOU6	0.871		
PU	PU3	0.863	0.794	0.939
	PU4	0.865		
	PU5	0.883		
	PU6	0.871		
US	US1	0.866	0.709	0.879
	US2	0.888		
	US5	0.768		

LS, librarians' service; IQ, information quality; SQ, system quality; PEOU, perceived ease of use; PU, perceived usefulness; US, user satisfaction; AVE, average variance extracted analysis; CR, composite reliability.

Table 8. Analysis results of discriminant validity

Factor name	PU	PEOU	IQ	SQ	LS	US
PU	0.891					
PEOU	0.733	0.873				
IQ	0.654	0.595	0.845			
SQ	0.701	0.713	0.822	0.863		
LS	0.418	0.315	0.336	0.386	0.914	
US	0.604	0.411	0.476	0.488	0.611	0.842

PU, perceived usefulness; PEOU, perceived ease of use; IQ, information quality; SQ, system quality; LS, librarians' service; US, user satisfaction.

Table 9. Analysis result of model fit indices

	X^2/df	GFI	AGFI	NFI	IFI	CFI	RMSEA
Acceptable fit	<5	>0.8	>0.8	>0.9	>0.9	>0.9	<0.08
Measurement	2.479	0.886	0.842	0.928	0.956	0.956	0.074
Structural	2.836	0.872	0.827	0.916	0.944	0.944	0.082

GFI, goodness-of-fit index; AGFI, adjusted goodness-of-fit index; NFI, normed fit index; IFI, incremental fit index; CFI, comparative fit index; RMSEA, the root mean square error of approximation.

 https://doi.org/10.1633/JISTaP.2024.12.2.1

5.8. Results of Hypotheses and Research Mode

Table 10 presents the outcomes of the hypothesis testing. H1 and H5 indicate that librarian services significantly influence both PU (β=0.164, p<0.001) and IQ (β=0.195, p<0.05). Additionally, SQ considerably affects perceived usability (β=0.657, p<0.001). There is also a marked influence of PEOU on PU (β= 0.470, p<0.001), and PU notably impacts US (β=0.708, p<0.008), leading to the approval of H3, H7, and H9. Furthermore, both librarian services (β=0.037, p<0.05) and IQ (β=0.020, p<0.05) positively impact PEOU, while SQ has a notable influence on PU (β=0.135, p<0.05). However, H2, H4, and H6 were not supported. The data also contradict H8, indicating that PEOU does not significantly influence US. All these insights from the hypothesis testing can be viewed in Fig. 2.

6. DISCUSSION

6.1. Contribution of Theory

This research provides numerous noteworthy theoretical advances to the literature on ULWs, particularly in relation to US. First, this research aims to bridge the existing gaps between theory and practice specific to ULW services in Myanmar. Additionally, this study illuminates the multifaceted nature of US, revealing how it hinges on the prevailing quality of the ULW system, information, librarian service, PEOU, and utility. Several theories underscore the study's findings. For instance, our results echo Gefen and Keil (1998), Davis et al. (1989), and others, suggesting that IQ significantly influences PU (Lan & Chen, 2022). Similarly, research by Mahmood et al. (2000), Zviran and Erlich (2003), Xu and Du (2018), Izuagbe et al. (2019), and then more recent studies resonates with our discovery that librarian services contribute to this PU. The relationship between service quality and PEOU has been substantiated by Senaratne and Samarasinghe (2019). Notably, the influence of PU on US was also observed in the findings of Zviran and Erlich (2003), who found that numerous ISs failed or were underutilized over the past five years. A plausible explanation for this could be the inactivity of the websites when users access ULW (Firdaus et al., 2019).

However, some of our findings diverge from established theories. For instance, contrary to expectations, IQ did not influence the PEOU of ULW services. This might be attributed to ULWs' services. Similarly, librarian services did not have a significant impact on PEOU. This aligns with Wolfe et al. (2010), who found that users often relied more on search engines such as Google rather than ULWs. They also observed that users lacked the patience to await librarians' responses, often feeling more knowledgeable than the librarians. Furthermore, SQ was not a significant influencer of the PU for ULW US. Cho et al. (2019) made a similar observation in their study on e-government services. The possible reason could be the enhanced user productivity offered by the current systems, ensuring seamless access. Last, while we anticipated a significant effect of PEOU on US, the results revealed no such influence. Zviran and Erlich (2003) also reported a similar result in their study of IS in the US literature: "Users will not be as willing to use a system if they believe that it is not satisfactory from their perspective." Bandura (1982) and Lepper (1985) also reported similar findings in their studies on self-efficacy and motivational issues, both from psychological perspectives, and stating that efficacy is a

Table 10. Analysis results of hypotheses

Hypothesis	Relationship	Effect	Path coefficient	Result
H1	IQ → PU	+	0.195* (0.222)	Accepted
H2	IQ → PEOU	+	0.020 (0.024)	Rejected
H3	SQ → PEOU	+	0.657*** (0.677)	Accepted
H4	SQ → PU	+	0.135 (0.134)	Rejected
H5	LS → PU	+	0.164*** (0.172)	Accepted
H6	LS → PEOU	+	0.037 (0.041)	Rejected
H7	PEOU → PU	+	0.470*** (0.452)	Accepted
H8	PEOU → US	-	-0.102 (-0.095)	Rejected
H9	PU → US	+	0.708*** (0.684)	Accepted

IQ, information quality; PU, perceived usefulness; PEOU, perceived ease of use; SQ, system quality; LS, librarians' service; US, user satisfaction.
*p<0.05; **p<0.01; ***p<0.001.

major factor underlying intrinsic motivation.

Besides this, nothing observed on ULW is comprehensive or the end-all when it comes to tools or methods for ensuring US (Lim, 2023). In conclusion, our findings demonstrate that PU directly correlates with heightened US. If universities aspire to amplify US on their websites, these platforms should not only be inherently useful but should also offer seamless technical support, demand minimal setup, and be intuitively easy to learn (Zaitul et al., 2018). Interestingly, in the context of DL, PU emerged as a more reliable indicator of US than usability, aligning with studies by Madle et al. (2003), Oktal et al. (2016), and Chaloeyprach and Ketmuni (2021). This reinforces previously established patterns in research focusing on user acceptance and IT adoption (Guner & Acarturk, 2020). Importantly, PEOU and usefulness act as intervening variables bridging SQ, IQ, and librarian services to US concerning ULW service usage.

6.2. Managerial Contributions

Given that a ULW epitomizes a university's academic standing, one can gauge the institution's reputation through its ULW. Achieving optimal US is a continual endeavor, requiring sustained research to understand how user feedback evolves over time (Mahmood et al., 2000). In light of this, university heads should actively encourage website administrators and library specialists to elevate both the information and SQ of the ULW.

A collaborative approach involving university rectors, website administrators, librarians, and other library professionals is vital to ensure high-caliber ULW services in Myanmar. As we look forward, there is an evident need to enhance the information and SQ of ULW services in Myanmar. Addressing this requires a comprehensive strategy encompassing adequate budgets, skilled technicians, and effective dissemination of ULW services by librarians and library professionals. Furthermore, it is imperative for university librarians and academic staff in the Department of Information Studies to continually assess their library websites. They should gauge user engagement and satisfaction levels and provide annual reviews of ULW advancements to the Department of Higher Education (under the aegis of the Ministry of Education). By implementing such practices, users will become more familiar with ULW services through insights from research surveys. This will eventually foster increased awareness and satisfaction levels, propelling the stature of ULW services in Myanmar.

6.3. Research Limitations and Prospects for the Future

The present study's scope is confined to a cross-sectional examination, focusing solely on factors influencing US. Notably absent is a comprehensive understanding of international ULW users' perceptions and a ranking of which ULW offers the highest US in Myanmar. Given the rapid evolution of technical support, there is a pressing need for future studies to adopt qualitative and longitudinal approaches. Another limitation of this research pertains to its focus on only six universities. Expanding the study to encompass additional universities in Myanmar could provide a more holistic view of US in relation to the country's ULW ecosystem. Furthermore, a potential avenue for exploration is the integration of mobile apps tailored for ULWs, emphasizing information and SQ designs. This proposition not only underscores the relevance of mobile technologies in today's digital landscape but also suggests a forward-thinking approach to further embed IT within Myanmar's academic sector.

Moreover, US is influenced by a wide range of factors from many perspectives. Among them, the concepts based on library service fields are mentioned for further direction. According to Sureshchandar et al. (2002), there are differences between US and service quality, but they are also closely related, thus improving one will probably improve the other. Other scholars have employed single-item scales to operationalize US, while others have employed multiple-item scales. Oh (2013) proposed a conceptual model consisting of fifteen items to calculate the public library's satisfaction index. This model considers three factors: service quality (50%), customer satisfaction (40%), and loyalty (10%).

Using LibQUAL+TM, Twum et al. (2021) investigated the concept of service quality and offered factual data on variables impacting library patron loyalty. The image of a library brand is influenced by service effect, information access, personal control, and user loyalty. For the library to cultivate a favorable brand reputation and patronage, management must always raise the calibre of its services. According to Oh (2023)'s recommendation, users' perceptions of service quality in public libraries focus on three dimensions: library personnel, resources and user services, and facilities and equipment. The results indicated that users were generally satisfied not only with the library services and expressed loyalty towards the libraries, but also that service quality positively influenced customer satisfaction, which impacted user loyalty. Similarly, Oh (2020) also analyzed data from 1,015 public library users

in South Korea to investigate their perceptions of service quality, satisfaction, and loyalty. The results showed high satisfaction levels, loyalty, and perceived service quality, with significant impacts observed between these variables. Therefore, Oh (2020; 2023) observed that user loyalty was found across different demographic groups.

7. CONCLUSION

This present study finds a significant relationship between US and PU. It provides fresh insights into US concerning websites from the users' viewpoint, enriching the TAM and ISSM literature. If universities wish to enhance US, focusing on increasing the PU of their websites could be an effective strategy. An analysis of user demographics, including gender, age, major, education level, and specific ULW usage, showed significant disparities. Notably, females, users under 24, those between 25 and 29 and between 46 and 55, students of the arts, graduate students, and users of the UCL website were most frequent, answering RQ1.

Empirical evidence demonstrates that factors such as IQ and librarian services in ULWs influence US through their PU. Interestingly, SQ is tied to both PEOU and US. Of prime importance, the research underscores that PU strongly impacts US. Thus, better IQ, easier system access, enhanced librarian services, and increased usefulness all lead to greater satisfaction, answering RQ2.

In contrast, PEOU was not a major determinant of US concerning ULW services. In a DL setting, while PEOU and usefulness acted as mediators for US, US primarily hinged on the quality and relevance of the information provided by ULW. As most users are adept with digital tools, the initial focus should be on the quality of information in ULW. Comprehensive and updated information is pivotal for US. A system's usability can drive its frequency of use, which in turn impacts US. Librarian services play a crucial role in this; their expertise in guiding user searches based on SQ is vital. Hence, librarian services should prioritize usefulness over usability. To continually improve, librarians must communicate ULW status to higher authorities, answering RQ3.

Based on the findings, users found the ULW highly useful in terms of IQ, librarian services, and PEOU for their research. Myanmar ULW's SQ was the only aspect perceived as easy to access. On the other hand, users did not see ULW IQ, librarian services, or SQ as highly usable or useful. The PEOU did not significantly contribute to their research satisfaction.

It is worth noting that many ISs fail or are underutilized. Regrettably, at least one IS breakdown was reported in the last five years. Stakeholders and web administrators should ensure consistent website availability to match user expectations. It is also important to select the right evaluation methods to gauge the system's utility concerning user needs. This research provides invaluable insights for Myanmar's academic governmental institutions, helping administrators and librarians devise more efficient strategies.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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APPENDIX

Note. The survey was originally conducted in English. While there may be grammatical errors in the survey statements, these have been intentionally retained to reflect the original responses accurately.

S/N	Information quality of university library websites	Factor numbers
1.*	The information on library websites is reliable, current, and of high quality.	Q1
2.	As for me, university library website's information quality is sufficient, interactive, and provides detail.	Q2
3.	I recommend university library website's information quality have high quality.	Q3
4.	For me to use, university library website's information quality makes it simple for me to complete my coursework and study projects.	Q4
5*	I recommend university library website's information quality have usefulness for my research assignments and tasks.	Q5
S/N	System quality of university library websites	Factor numbers
1.*	System of library websites have convenience and good design.	SQ1
2.	Convenience of Library Websites System are easy to use, accessible, understand, and website pages quickly open.	SQ2
3.	Design of library website system such as interface design, navigate, organization of information, graphics and texts, webpage links and searching results are attractive, clear, and easy to understand, customized, grouped and categorized.	SQ3
4.	For me to use, university library website's system quality easily accomplishes my tasks and assignments related to research.	SQ4
5.*	I appreciate the quality of information found on the university library website for use in research projects and tasks.	SQ5
S/N	Perceived usefulness	Factor numbers
1.*	Library websites services have usefulness services for users.	PU1
2.*	I believe that the facilities offered by the university library website are very helpful in saving time and completing duties such as research assignments.	PU2
3.	I clarify that the university library's website should be useful in order to increase the number of people who utilise it.	PU3
4.	I assert that the services offered by the university library website are more beneficial than those of other search engines and improve the quality of my academic work.	PU4
5.	I advocate utilizing the resources on the university library website to complete my duties and research assignments.	PU5
6.	I recommend accessing the university library's website frequently for tasks and research assignments due to its value.	PU6
S/N	Perceived ease of use	Factor numbers
1.*	Library websites services have Ease of Use services for users.	PEOU1
2.*	I advise applying the university library's website since it is easy to use and has helped me complete activities, assignments, and research faster.	PEOU2
3.*	I recommend that services offered by the university library website are easy to use, which improves library website usage.	PEOU3
4.	I recommend that Ease of Use of services provided by the university library website are more trustworthy than those of other search engines and improve the calibre of my academic work.	PEOU4
5.	I recommend that perceived ease of using the resources on the university library website satisfies my tasks and research assignments.	PEOU5
6.	I strongly recommend making frequent use of the university library website's services for my research projects and chores due to its user-friendly interface.	PEOU6

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S/N	Librarians' services	Factor numbers
1.*	Users using librarian services must obtain the necessary information.	LS1
2.*	A programme for new librarians offered by the library facilitates resource searches.	LS2
3.*	I recommend that librarian's orientation program essential for users.	LS3
4.	I recommend that librarian's orientation program makes usefulness for my search.	LS4
5.	I recommend that make use of library resources simple, the librarian's orientation programme offers guidance.	LS5
6.	I recommend that librarian's orientation program makes easily for my search.	LS6
S/N	User satisfaction	Factor numbers
1.	On the websites of university libraries, I advocate prioritising user satisfaction above usefulness.	US1
2.	I recommend that user satisfaction makes ease of use university library websites services.	US2
3.*	For me to use, university library websites services satisfy my research assignments and tasks.	US3
4.*	If you are satisfied university library website services, please identified your selected university library website services have excellent.	US4
5.	I recommend that user satisfaction on university library websites directly influence such as the quality of the system, the information, the perceived use of the librarian's assistance, the perceived simplicity of use, and the actual utilization.	US5
6.*	I recommend that user satisfaction relatively influenced through perceived ease of use and then usefulness on university library websites services.	US6

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Development of Flavouring Ontology for Recommending the Halal Status of Flavours

Siti Farhana Mohamad Hashim*
Center for Artificial Intelligence Technology, Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, Selangor Darul Ehsan, Malaysia
E-mail: p73051@siswa.ukm.edu.my

Shahrul Azman Mohd Noah
Center for Artificial Intelligence Technology, Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, Selangor Darul Ehsan, Malaysia
E-mail: shahrul@ukm.edu.my

Juhana Salim
Center for Artificial Intelligence Technology, Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, Selangor Darul Ehsan, Malaysia
E-mail: js@ukm.edu.my

Wan Aida Wan Mustapha
School of Chemical Science and Food Technology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Selangor Darul Ehsan, Malaysia
E-mail: wanaidawm@ukm.edu.my

ABSTRACT

There has been a growing interest in halal-related ontology research in recent years, as ontology has gained recognition in the halal industry. This paper discusses the development of a flavouring ontology that will assist halal management auditors in predicting the halal status of flavours in order to process food producers' applications for halal certification. The development of a flavouring ontology is based on multiple references, because the auditors of halal management divisions must consult a variety of sources independently in order to determine the halal status of flavourings. The process includes 1) determining the ontology goal and scope, 2) building ontologies, and 3) evaluating the ontologies. The researcher used Protégé to design the ontologies, and Phyton was used to develop a prototype based on flavouring ontology. The developed ontology consists of four classes, nine sub-classes, and 11 relationships. The evaluation of the ontology using the prototype revealed that the majority of experts were satisfied with the information generated by the ontology in the prototype, particularly in relation to synonyms and the hierarchical structure of a flavour. However, the experts suggest improvements in terms of flavour metadata, especially on raw materials and natural occurrence data, so that the flavour information retrieved is comprehensive and accurate.

Keywords: flavouring ontology, flavour, ontology development, halal status, flavouring traceability system, flavour metadata-Malaysia

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***Corresponding Author:** Siti Farhana Mohamad Hashim
https://orcid.org/0009-0009-9329-8638
E-mail: p73051@siswa.ukm.edu.my

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1. INTRODUCTION

Ontology has gained acknowledgement from academics and industries in diverse fields (Brusa et al., 2006). Ramli and Noah (2016) assert that ontology represents entities that exist inside a certain domain of reality, such as health, agriculture, and manufacturing. Since ontology has gained acknowledgement from academics and industries, there are several definitions of what ontology is (Brusa et al., 2006). Ontology, in the fields of computing and information sciences, refers to a collection of fundamental elements that express concepts, such as classes, attributes, and relationships among class members. According to Gruber (2009), the definitions of representational primitives encompass details regarding their meanings and the constraints imposed on their logically coherent implementation.

Ontology is widely used in industries to improve knowledge management, integrate information, and facilitate decision-making processes. Ontologies are particularly beneficial in areas such as manufacturing, where they contribute to the standardization of product information and streamline communication among different stakeholders. Moreover, ontologies are crucial in enhancing the performance of intelligent systems, hence facilitating progress in domains such as robotics, process automation, and quality control.

1.1. Ontology in the Halal Industries

Nowadays, ontology has gained attention in the halal industry. According to Omar et al. (2013), the halal industry has experienced the most rapid global growth within the business landscape of Malaysia. Nevertheless, the issuance of the halal certificate is a time-consuming process (Muhammad et al., 2020). According to an interview with halal management auditors, the auditors encountered difficulties detecting the halal status of ingredients, notably flavourings, because most flavourings do not have halal certificates in the application of halal certification of food products. Thus, the absence of halal certificates required the halal management auditors to trace the halal status of the ingredients in order to process the application of the halal status. One significant limitation is the lack of uniformity in the terminology employed by food manufacturers and halal management auditors. This inconsistency poses challenges for halal management auditors in effectively verifying the halal status of ingredients, particularly in cases involving flavourings (Hashim et al., 2017).

1.2. Issues of Flavourings

In order to decide the halal status of flavourings, the halal management auditors need to identify the raw materials used together with their sources, whether they are derived from animals, plants, or chemicals (Ali et al., 2017). Determining the source of raw materials is crucial in the traceability of halal status (Ali et al., 2017; Hashim et al., 2017). Technical and sharia aspects are required to determine the halal status of raw materials for flavouring (Hashim et al., 2016; Omar & Jaafar, 2011; Shafii & Siti Khadijah, 2012). The technical components include ingredient specifications, production process charts, life storage duration, laboratory result analysis, allergy information, and storage methods. From a sharia perspective, it is imperative to adhere to certain restrictions pertaining to the cleanliness of materials, abstinence from alcohol, absence of blood, absence of pork, and ensuring their harmlessness. However, both technical and sharia aspects require the knowledge of experts to decide on the halal status of flavourings (Hashim et al., 2017). Various sources of information are required to suggest the halal status of flavourings, such as the Handbook of Fenaroli, Chemical Entities of Biological Interest (ChEBI), and academic journals related to flavouring. According to the halal management auditors, they have to refer to the sources separately as the sources are not aggregated in a single repository. Thus, there is no integration of the sources for halal auditors to refer to in order to determine the halal status of flavourings.

1.3. Problem Statement and Scope of Research

Due to the variety of sources used to determine the halal status of flavourings, which may cause conceptual inconsistencies between the terms used in the resources, ontology is one of the practical ways to solve the issue. This phenomenon is also evident in a previous study undertaken by Omar et al. (2013) regarding the development of a system for verifying the halal status of ingredients, which engaged in constructing an E-Numbers ontology by integrating data from multiple databases. Their research sought to assist the Muslim community in confirming the halal status of products in the market with E-Numbers. The integration of several E-Numbers databases was facilitated through the utilisation of ontology. This approach was motivated by Jagadish (1990)'s assertion that ontologies play a crucial role in integrating heterogeneous databases while providing a consistent vocabulary. The rationales behind the variety of reference sources used in developing a flavouring ontology are as follows:

1) It gives comprehensive coverage that provides different perspectives and coverage of a domain.
2) It allows users to cross-validate information, such as if multiple sources confirm the same facts or relationships, which increases confidence in the accuracy of the ontology.
3) It helps to reduce the risk of missing important concepts or relationships.
4) It can avoid bias if users do not rely solely on a single source.

As a result, in this research, the ontology provides a standardised and formal representation of knowledge, allowing for the harmonisation and integration of diverse flavouring databases. By establishing a common vocabulary and a shared understanding of the relationships between different terms, ontology facilitates accurate and consistent determination of the halal status of flavourings. It enables halal management auditors to effectively analyse and interpret information from multiple sources, reducing the complexity and subjectivity involved in assessing the halal compliance of flavourings. Ultimately, an ontology-based approach empowers the halal management auditors to make informed decisions and streamline the process of determining the halal status of flavourings, thus enhancing the efficiency and reliability of the halal certification process for food producers. The research aims to answer the following research questions:

1) What are the steps for developing the flavouring ontology?
2) What are the concepts and rules of the flavouring ontology for supporting the halal certification process?
3) How does the flavouring ontology meet the requirements and needs of the halal auditors?

This paper aims to describe the process of developing a flavouring ontology by adapting the steps suggested by Noy and McGuinness (2001). The paper is organised as follows: Section 2 discusses the flavouring domain, Section 3 discusses the methods involved in developing the flavouring ontology, and Section 4 discusses the implementation of the ontology with Protégé and the evaluation of the flavouring ontology. Finally, Sections 5 and 6, respectively, present the discussion and the conclusions of this work.

2. THE FLAVOURING DOMAIN

Flavourings are substances or mixtures of substances that are added to foods and beverages to enhance or modify their taste or aroma. They are used to provide specific flavours or mimic the natural flavours of various ingredients. Flavourings can be derived from natural sources, such as fruits, vegetables, herbs, spices, or animal products, or they can be artificially synthesised using chemical compounds. Flavourings are extensively used in the food and beverage industry to enhance or modify the taste and aroma of various products. They are commonly found in processed foods, beverages, confectionery goods, baked goods, snacks, sauces, and seasonings. Flavourings can be categorised into three main types (U.S. Food and Drug Administration, 2022):

- Natural Flavourings: These are derived from natural sources and undergo physical processes such as extraction, distillation, or fermentation. They can be obtained from plants, animals, or microorganisms.
- Artificial Flavourings: Also known as synthetic or artificial flavours, these are chemically created to mimic natural flavours. They are often produced through laboratory processes and can provide a wide range of flavours.
- Nature-Identical Flavourings: These are synthesised in the laboratory using chemical compounds to mimic specific natural flavours. They are chemically identical to the flavour compounds found in nature.

Flavouring plays a significant role in determining the halal status of a food product (Rahman et al., 2021). In the context of halal certification, flavourings must comply with specific guidelines and criteria to ensure they are permissible and suitable for consumption according to Islamic dietary laws. The following are some reasons why flavouring is important in halal status:

1) Ingredient Compliance: Flavourings, whether natural or artificial, can be derived from various sources, including both halal and non-halal origins. Verifying the origin of flavouring ingredients is of utmost importance in order to ascertain the absence of any forbidden compounds, such as alcohol or animal-derived ingredients, that fail to meet the criteria for Islamic slaughtering.
2) Cross-Contamination: Flavourings may be processed or manufactured in facilities that handle non-

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halal ingredients or products. This can lead to cross-contamination, where traces of non-halal substances can inadvertently be present in the flavouring. It is essential to ensure that the flavourings used in halal-certified products are free from any cross-contamination with non-halal ingredients.

3) Awareness of Halal Sensitivities: Flavourings can be complex mixtures of various compounds, and it is important to ensure that all the ingredients used in the flavouring are halal. Even a small percentage of non-permissible ingredients can impact the overall halal status of the product. Understanding the sensitivities and requirements of halal consumers regarding flavourings is essential to maintain the integrity of halal certification.
4) Traceability and Transparency: The halal certification process requires meticulous traceability of ingredients and their sources. This includes verifying the origin and halal compliance of flavourings used in the product. Transparent documentation and information about the flavouring ingredients and their sources are vital for auditors and certification bodies to ensure compliance with halal standards.
5) Consumer Confidence: Halal certification provides assurance to Muslim consumers that the product meets their dietary requirements and religious beliefs. Ensuring that the flavourings used in halal-certified products are compliant with halal guidelines builds trust and confidence among consumers, leading to increased market acceptance and demand.

By considering the halal status of flavourings and ensuring their compliance with halal requirements, food producers can uphold the integrity of their halal-certified products and cater to the needs of Muslim consumers seeking halal options.

In this research, we proposed an ontology for flavouring designed to serve as a comprehensive and structured knowledge base, aiming to assist halal management auditors in their critical tasks related to ensuring compliance with halal standards in the food and beverage industry. Halal certification involves meticulous scrutiny of ingredients, production processes, and sources, with specific attention given to the presence of any non-halal or haram components, which can render a product non-compliant. By incorporating the flavouring ontology into their auditing procedures, halal management auditors can streamline the evaluation process, expedite ingredient assessments, and enhance the accuracy and consistency of halal certification decisions. The ontology's structured and interlinked nature facilitates quick and reliable searches, enabling auditors to identify potential non-compliant ingredients or cross-contamination risks more efficiently. Additionally, the ontology can aid auditors in monitoring the usage of permissible flavouring agents, ensuring that they are within acceptable limits and comply with halal guidelines. The following section describes the method for developing the flavouring ontology.

3. METHODOLOGY

This section presents the process of developing a flavouring ontology to determine the halal status of flavourings. Previous research has explored various methodologies for the methodical development of ontologies. For instance, among the proposed methodologies are Uschold and King (1995), Grüninger and Fox (1995), KACTUS (Bernaras et al., 1996), METHONTOLOGY (Lopez et al., 1999), SENSUS (Swartout et al., 1997), and the Ontology Development 101 Method (Noy & McGuinness, 2001). The aforementioned approaches successfully established ontologies in diverse domains, including enterprise (Grüninger & Fox, 1995; Uschold & King, 1995), chemistry and environment, knowledge management, and computer science (METHONTOLOGY; Lopez et al., 1999), military air campaigns (SENSUS; Swartout et al., 1997) and vinology (Noy & McGuinness, 2001). There are three approaches to identifying concepts: top-down (KACTUS; Bernaras et al., 1996) and (Noy & McGuinness, 2001), bottom-up (SENSUS; Swartout et al., 1997), and middle-out (Grüninger & Fox, 1995; Uschold & King, 1995). We chose to adapt the Ontology Development 101 method proposed by Noy and McGuinness (2001), as the methodology is generic and flexible to represent knowledge in various domains. Although the method was first introduced back in 2001, it is still relevant and popular among ontologies developers and widely used in various domains (Alsanad et al., 2019; Chimalakonda & Nori, 2020; Järvenpää et al., 2019; Siebra & Wac, 2023; Wu et al., 2021). Some key features in the Ontology Development 101 Method can be adapted in the development of flavouring ontology as follows:

1) It applies a top-down approach, which is identifying the most general and essential concepts before delving into more specific details.
2) It emphasizes the importance of consulting multiple reference sources to ensure the ontology is compre-

hensive and well-grounded. This variety of reference sources helps ontology developers to gather knowledge about the domain and verify the accuracy of their representation.

3) It encourages iterative development where developers iteratively enhance and optimise the ontology through feedback, new information, and evolving requirements.
4) It encourages input from domain experts that is considered valuable for ensuring the ontology is accurate and relevant.

The method to develop a flavouring ontology comprises four steps: Specification – Ontology Goal and Scope; Specification – Domain Description; Conceptualisation – Define the Classes and the Class Hierarchy; and Conceptualisation – Define the Properties of Classes. The following sub-sections provide a detailed discussion of each step.

3.1. Specification: Ontology Goal and Scope

The definition of ontology goal and scope is the first step of the specification phase, as illustrated in the 101 Method (Noy & McGuinness, 2001). The scope of the ontology determines the specific inclusions and exclusions. It is crucial to reduce the amount of data and concepts that need to be analysed for a certain field, particularly considering the intricacy of the semantic nuances. This ontology mainly focuses on determining the halal status of flavouring and the synonym of the flavouring term.

Enumerating the competency questions is a method for establishing the scope of the ontology. It can be accomplished by formulating a series of inquiries that an ontology-based knowledge base should possess the capability to provide answers for. Table 1 presents the competency questions pertaining to the topic of flavouring. The ontology must possess the capability to address these informal inquiries, which aim to evaluate the alignment between the ontology and its intended objectives.

Table 1. Sample of competency questions

No.	Competency question
1.	Find halal status for Isovaleric Acid
2.	Find synonyms for Fumaric Acid
3.	Find the type of raw material for Buchu
4.	Find a botanical name for Blackberry
5.	Find synthesis for Glycine
6.	Find natural occurrence for Benzyl Acetate

These competency questions are some of the required information that halal auditors need to know in order for them to check the halal status of flavourings that do not have their own halal certification. These competency questions also guide the researcher in developing the ontology within the scope. For the information on flavouring, there are some metadata elements that the halal auditors need to know, such as halal status, synonyms, type of raw material, botanical name, synthesis, and natural occurrence.

3.2. Specification: Domain Description

We begin with the domain analysis task, where the halal certification manual was studied and revised. We gathered information regarding the process of processing the application for halal certificates. Besides this, we also explored whether there are existing ontologies that serve as a reference for constructing our initial ontology. Through our efforts, we utilised the analytical task to convert listed terms into the conceptualised structure for the flavouring ontology. Drawing from the existing ontology with diverse listed terms served as a blueprint to steer the development of our inaugural ontology. In addition, we met with experts who are the auditors from Jabatan Kemajuan Islam Malaysia (JAKIM)'s Halal Management Division to corroborate the veracity of the issues raised. The halal management auditors were chosen because they were experts in the halal certification processing field. The halal management auditors and researchers who bring information to support these tasks have assimilated the issues. For instance, during the interview, the halal management auditors confirmed that flavouring information, such as types of raw materials and halal status, is an important element in the flavouring domain. At the same time, the researchers brought technical knowledge support, such as ontology mapping, to this task. Ontology mapping is a process of integrating information from various sources (Kazani et al., 2023). There are several sources involved in developing the flavouring ontology, as showsn in Table 2 (Jabatan Kemajuan Islam Malaysia, 2015).

Ultimately, we established the intermediate representations utilised for knowledge acquisition, with Table 3 displaying fundamental terms within the flavouring domain.

From Table 3, the basic terms of the flavouring domain are the important metadata required for halal auditors to trace the halal status of flavourings. These basic terms of the flavouring domain were manually extracted and defined through brainstorming sessions with domain

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Table 2. Sources in developing the flavouring ontology

No.	Reference source	Description
1.	ChEBI Ontology: ChEBI Ontology was developed by EMBL's European Bioinformatics Institute, which is the centre for 'big data' in the field of biology	Researchers used the ChEBI ontology to look at the basic structure and hierarchy of flavouring agents, and to act as the existing ontology based on previous studies by Omar et al. (2013), who modeled the E-Numbers Ontology using the ChEBI ontology as an existing ontology
2.	Fenaroli's *Handbook of Flavours Ingredients*, published by CRC Press	Researchers used Fenaroli's *Handbook of Flavours Ingredients* as the main reference in modeling flavouring ontology
3.	E-Numbers websites: • http://www.faia.org.uk/e-numbers	Researchers used this E-Numbers website based on a previous study by Omar et al. (2013), who used the website that the authority has reviewed
4.	Manual procedure for Malaysia Halal certification (third revision) 2014 (JAKIM, 2015)-BPH, JAKIM	Researchers referred to the Halal Certification Manual to look at the halal regulations used to generate flavouring ontology rules
5.	Flavour domain expert at Faculty of Science and Technology UKM and Auditor at BPH JAKIM	Researchers consult experts to obtain expert knowledge and views regarding the metadata required to trace the halal status of flavours

ChEBI, Chemical Entities of Biological Interest; EMBL, European Molecular Biology Laboratory; BPH, Bahagian Pengurusan Halal; JAKIM, Jabatan Kemajuan Islam Malaysia; UKM, Universiti Kebangsaan Malaysia.

Table 3. Basic terms of flavouring ontology

Basic term	Description
Flavouring agent	Flavouring agents consist of flavour substances, extracts, or preparations that can provide taste, odour, or both to food products
E-Numbers	Food additive codes are typically present on food labels across the European Union
Types of raw materials	These refer to the three types of raw material: animal, plant, and chemical
Halal status	Refers to the halal status of flavouring agents, whether Halal, Haram, Syubhah, Unknown, or Halal with conditions (e.g. Halal if the content of alcohol is less than 0.5%)
Animal	Refers to the types of raw materials for a flavouring agent
Chemical	Refers to the types of raw materials for a flavouring agent
Plant	Refers to the types of raw materials for a flavouring agent
Description	Explanation about the flavouring agents
Synthesis	The production of chemical compounds by reaction from simpler materials
Botanical name	A scientific name of a particular plant species. It must conform to the system of botanical nomenclature as prescribed by the International Code of Nomenclature for algae, fungi, and plants
Natural occurrence	Natural and without artificial help, which refers to the occurrence of flavouring agents

experts and also by referring to the flavouring handbook, which is the Handbook of Fenaroli.

3.3. Conceptualisation: Define the Classes and the Class Hierarchy

The class hierarchy for ontology can be developed in three possible ways: top-down, bottom-up, or a combination of both (Noy & McGuinness, 2001). We chose the combination of both as a development process to define a few top-level concepts and a few specific concepts. The first step is to define the top-level concepts. The top-level concepts represent the most general concept, encompassing all entities or objects within the domain (Lopes et al., 2022). In the domain of flavouring as shown in Table 4, we identified four top-level classes through discussion with the domain experts regarding the competency questions mentioned in Table 1 and also from the output from brainstorming session with domain experts, which is a list

Table 4. Description of classes for flavouring ontology

Class	Description
E-Numbers	Classes for E-Numbers, which consists of several E-Numbers such as E620, E621, E630, E633, E637, and E640
Flavouring agent	Classes for flavouring agent, which consists of bitter agent, sour agent, sweetening agent, and salty agent
Halal status	Classes for Halal Status, which consists of Halal, Haram, Syubhah, Unknown, and Halal with conditions (Halal if alcohol less than 0.5%)
Types of raw materials	Classes for types of raw materials, which consist of animal, plant, and chemical

Table 5. Description of subclasses (Level 1) for flavouring ontology

Class	Subclass (Level 1)	Description
Flavouring agent	Bitter agent	Flavouring agents have a bitter taste Examples: Isobutyl salicylate, phenylacetaldehyde, benzyl acetate
	Salty agent	Flavouring agents have a salty taste Examples: Monosodium glutamate, sodium guanylate, inosinic acid
	Sour agent	Flavouring agents have a sour taste Examples: Octanoic acid, benzoic acid, allyl propanoate
	Sweetening agent	Flavouring agents have a sweet taste Examples: Allyl hexanoate, L-glutamic acid, ethyl maltol
Types of raw materials	Animals	Flavourings obtained from animal raw materials Examples: Glycine, pyrole, inosinic acid
	Plants	Flavourings obtained from plant raw materials Example: Buchu, cocoa, roselle
	Chemicals	Flavourings obtained from chemical processes Examples: 2-Acetylfuran, 2-octanone, sodium hexametaphosphate

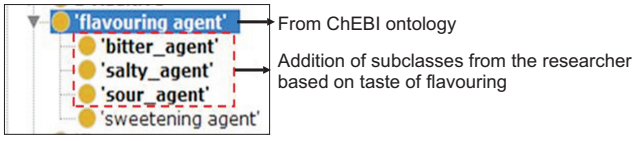


Fig. 1. Subclasses of flavouring agent. ChEBI, Chemical Entities of Biological Interest.

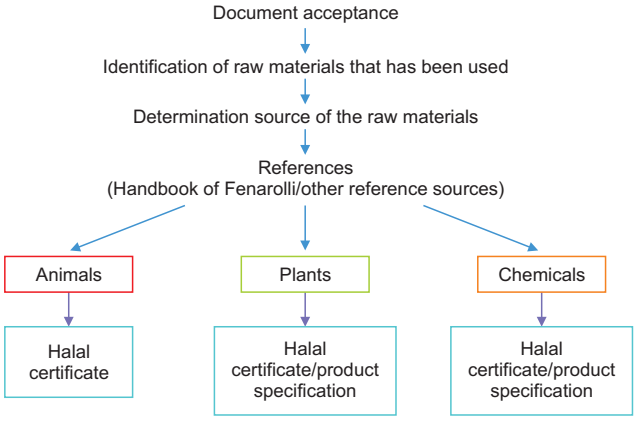


Fig. 2. Structured flow to trace halal status of flavouring.

of basic terms for the flavouring ontology. The four top-level classes for the flavouring ontology are E-Numbers, Flavouring Agent, Halal Status, and Types of Raw Material.

These four top-level classes of flavouring ontology give a general picture to the researcher for building this flavouring ontology and play an important role as the main hierarchy in the ontology development. The next step is to define the subclass (Level 1) for the top-level concepts, as shown in Table 5.

The subclasses (Level 1) for Flavouring Agents consist of four types: Bitter Agent, Salty Agent, Sour Agent, and Sweetening Agent. The 'Sweetening Agent' subclass was obtained directly from the hierarchy in the ChEBI ontology (Fig. 1). In contrast, the remaining subclasses were classified based on the taste criterion of the flavouring. The researcher also acquired consent from the expert regarding adding the remaining subclasses during the interview.

The subclasses of raw materials in Table 4 include animals, plants, and chemicals. The categorisation of raw

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materials was determined by the specific raw materials utilised in the production of the flavouring. These raw materials were acquired through an interview conducted with the halal management auditors in order to establish a systematic process for verifying the halal status of the flavouring (Fig. 2).

After this, the researcher also needs to define the subclass (Level 2) for the concept 'Chemicals,' as shown in Table 6.

For the subclass of 'Chemicals,' the researcher obtained the concept of 'Chemicals,' which consists of 'Alcohol' and 'Non-Alcohol,' through an interview with the halal management auditors.

3.4. Conceptualisation: Define the Properties of Classes

The properties of classes need to be defined, because the classes themselves do not offer sufficient knowledge to address the competency questions listed in Table 1. Therefore, once we have defined the classes, we must also define the properties of the classes as well. There are two types of properties: data properties and object properties. The sources of information for these two types of properties are based on Fenaroli's *Handbook of Flavours Ingredients*, ChEBI Ontology, and E-Numbers websites. The data properties connect individuals with some values. The list of data properties is shown in Table 7.

On the other hand, the object properties connect individuals with individuals. The list of object properties is shown in Table 8.

The object property hasSuggestedHalalStatus is obtained through an inferencing process where the researchers developed five rules to generate the halal status for a flavour. These rules were developed based on the halal conditions in the Malaysian Halal Certification Manual, which the halal management auditors explained to the researchers. The rules and their explanation are shown in Table 9.

The primary factor involved in predicting the halal status of flavourings is the raw components used. These five rules were formulated based on the categorisation of raw elements found in the flavouring agents, including animal, plant, and chemical substances. Regarding flavouring agents derived from animals, we establish two rules: If the flavouring agent is obtained from an animal other than pork, the halal status of the flavouring is likely halal; nevertheless, if the flavouring agent is derived from pig, the halal status of the flavouring is haram. Then, regarding flavouring agents derived from plants, we provide a single rule: If a flavouring agent is derived from a plant, its halal

Table 6. Description of subclasses (Level 2) for flavouring ontology

Subclass (Level 1)	Subclass (Level 2)	Description
Chemicals	Alcohol	Chemicals contain varying percentages of alcohol Examples: Allyl alcohol, isobutyl acohol, nerol
	Non-alcohol	Chemicals which are free from alcohol Examples: Acetic acid, monosodium phosphate, nitric acid

Table 7. Description of data properties for flavouring ontology

Property	Description	Example
hasBotanicalName	Refers to the botanical name of flavouring. An object property defining a relation between flavouring agents with their botanical name	Blackberry hasBotanical Name Rubus L
hasDescription	Refers to the description of flavouring. An object property defining a relation between flavouring agents with their description	Glycine hasDescription odourless and has a slightly sweet taste
hasNaturalOccurence	Refers to the natural occurrence of flavouring. An object property defining a relation between flavouring agents with their natural occurrence	Glycine hasNaturalOccurence: gelatine and silk fibroin are reportedly the best natural sources of this amino acid
hasSynthesis	Refers to the synthesis of flavouring. An object property defining a relation between flavouring agents with their synthesis	Glycine hasSynthesis from chloroacetic acid and ammonia; from protein sources, such as gelatine and silk fibroin

Table 8. Description of object properties for flavouring ontology

Property	Description	Example
hasENumbers	An object property indicates that some flavouring agents may have E-Numbers as ingredients	Glycine hasENumbers E640
hasFlavouring	An object property indicates that some E-Numbers have flavouring agents	E620 hasFlavouring L-glutamic acid
hasSuggestedHalalStatus	An object property that explicitly addresses the halal status of flavouring	Glycine hasSuggestedHalalStatus Haram
hasSynonym	An object property defining a relation between flavouring agents with their synonyms	Glycine hasSynonym glycocoll
hasRawMaterial	An object property that defines the type of raw material for flavouring	Glycine hasRawMaterial pork
hasRMHalalStatus	An object property defining a relation between raw materials of flavouring agents with their halal status	Pork hasRMHalalStatus Haram

Table 9. Ontology rules to predict halal status of flavouring

1) Rule 1: Animal≠Pork
IF instance **x** member-of Flavouring Agent, **y** member-of Animal, **y** is NOT a Pork, AND **x** hasRawMaterials **y**, THEN **x** hasHalalStatus Probably Halal

$$\forall x, \forall y, x \in Flavouring\ Agent \sqcap y \in Animal \sqcap y \neq Pig \sqcap x\ hasRawMaterials\ y \rightarrow x\ hasHalalStatus\ Probably\ Halal$$

Flavourings are derived from animals' raw materials, but if the animals are not pigs, then the halal status is 'Probably Halal'

2) Rule 2: Animal=Pork
IF instance **x** member-of Flavouring Agent, **y** member-of Animal, **y** is a Pork, AND **x** hasRawMaterials **y**, THEN **x** hasHalalStatus Haram

$$\forall x, \forall y, x \in Flavouring\ Agent \sqcap y \in Animal \sqcap y = Pig \sqcap x\ hasRawMaterials\ y \rightarrow x\ hasHalalStatus\ Haram$$

Flavourings are derived from animals' raw materials, but if the animals are pigs, then the halal status is 'Haram'

3) Rule 3: Plant
IF instance **x** member-of Flavouring Agent, **y** member-of Plant, **y** is a Cacao AND **x** hasRawMaterials **y**, THEN **x** hasHalalStatus Halal

$$\forall x, \forall y, x \in Flavouring\ Agent \sqcap y \in Plant \sqcap x\ hasRawMaterials\ y \rightarrow x\ hasHalalStatus\ Halal$$

If flavourings are derived from plants' raw materials, then the halal status is 'Halal'

4) Rule 4: Chemical=Alcohol
IF instance **x** member-of Flavouring Agent, **y** member-of Chemical, **y** is an Alcohol, AND **x** hasRawMaterials **y**, THEN **x** hasHalalStatus Halal with Condition

$$\forall x, \forall y, x \in Flavouring\ Agent \sqcap y \in Chemical \sqcap y = Alcohol \sqcap x\ hasRawMaterials\ y \rightarrow x\ hasHalalStatus\ Halal\ with\ Condition$$

Flavourings are derived from chemicals' raw materials, but if the chemicals are alcohol, then the halal status is 'Halal with Condition'

5) Rule 5: Chemical=Non-alcohol
IF instance **x** member-of Flavouring Agent, **y** member-of Chemical, **y** is a Non-Alcohol, AND **x** hasRawMaterials **y**, THEN **x** hasHalalStatus Halal

$$\forall x, \forall y, x \in Flavouring\ Agent \sqcap y \in Chemical \sqcap y \neq Alcohol \sqcap x\ hasRawMaterials\ y \rightarrow x\ hasHalalStatus\ Halal$$

Flavourings are derived from chemicals' raw materials, but if the chemicals are non-alcohol, then the halal status is 'Halal'

status is considered halal. Lastly, we have established two rules regarding the use of chemical-derived flavouring agents: If the flavouring agent is derived from alcohol, its halal status is considered halal under certain conditions, and if the flavouring agent is derived from a non-alcoholic chemical, its halal status is considered halal.

4. RESULTS AND DISCUSSIONS

4.1. Implementation of the Flavouring Ontology into the Halal Status Flavouring Traceability System

After completing the modelling of the flavouring ontology, the ontology is integrated into the Halal Status Fla-

 https://doi.org/10.1633/JISTaP.2024.12.2.2

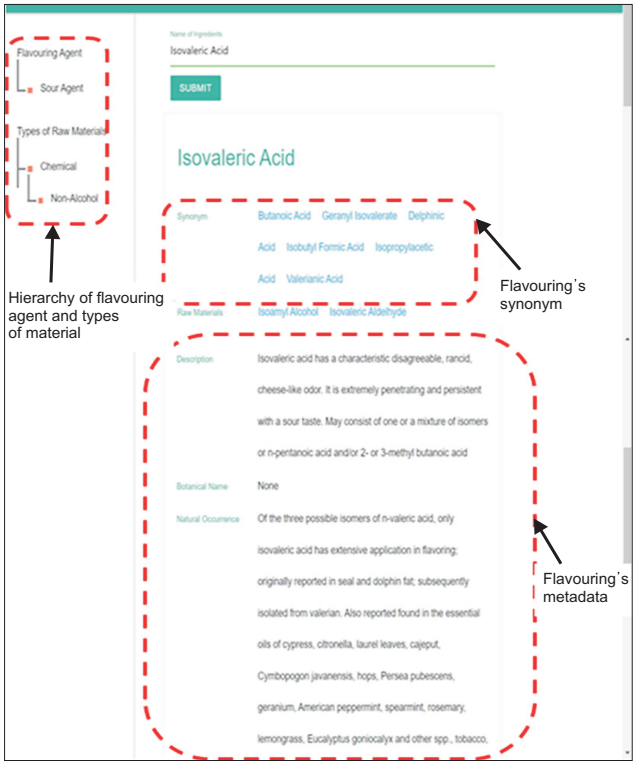


Fig. 3. Search result of flavouring agent from Halal Status Flavouring Traceability System.

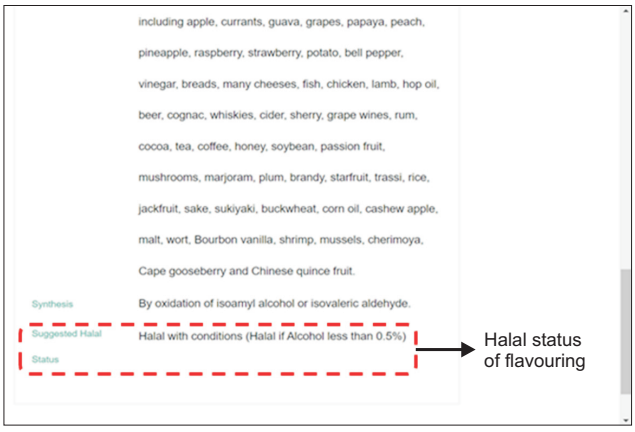


Fig. 4. 'Suggested Halal Status' metadata of flavouring agents from Halal Status Flavouring Traceability System.

vouring Traceability System. Fig. 3 shows an example of a search result for flavouring information.

Based on Fig. 3, the search result for the flavouring agent Isovaleric Acid consists of metadata of flavouring, which are: 'Synonym,' 'Raw Materials,' 'Description,' 'Botanical Name,' 'Natural Occurrence,' 'Synthesis,' and 'Suggested Halal Status' (Fig. 4). The search result for flavouring agent also provides information about the flavour's hierarchy that helps auditors to know the classification of flavouring agents, and also the hierarchy about types of raw material for flavouring agent that helps auditors to know the raw materials of flavouring agent. As for the metadata regarding 'Suggested Halal Status' as shown in Fig. 4, it is generated due to the inferencing rules discussed in Table 9.

4.2. Evaluating Flavouring Ontology through Halal Status Flavouring Traceability System

The flavouring ontology was evaluated using a Halal Status Flavouring Traceability System prototype. An evaluation of use in an application was proposed by Noy and McGuinness (2001) and implemented in the works of Porzel and Malaka (2004) and Kalfoglou and Hu (2006). The evaluation was carried out by soliciting comments from domain experts purposively selected after using the prototype. The involvement of domain experts during the evaluation process was to ensure the usability and practicality of the ontology for the Halal Status Flavouring Traceability System. The domain experts may evaluate the compatibility of the ontology with their processes in predicting the halal status of flavours, specifically for processing applications for halal certification from food manufacturers, by providing valuable comments on this matter. A total of nine experts participated in this evaluation: three lecturers from the Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, who are experts in ontology engineering; three lecturers from the Faculty of Science and Technology Universiti Kebangsaan Malaysia, who are experts in the flavouring domain; and three experts from the Halal Management Division of Department of Islamic Development Malaysia, recognized for their expertise in the halal certification process. The involvement of nine experts for this evaluation is to ensure a comprehensive and diverse assessment of the ontology. By involving a panel of experts with varied backgrounds and expertise, including auditors from JAKIM's Halal Management Division and researchers with technical knowledge in ontology mapping, the evaluation process can benefit from a range of perspectives and insights. This multi-faceted evaluation approach allows for a thorough examination of the ontology's effectiveness in predicting the halal status of flavours and its practical utility in the context of halal certification processes. Additionally, the inclusion of multiple experts helps in validating the ontology and ensuring its credibility and trustworthiness. Assessing the ontology based on using a prototype involved three evaluation criteria: Completeness, Clarity, and Pre-

ciseness.

According to Tankeleviciene and Damasevicius (2009), completeness refers to the condition where all parts of an ontology are present and each element is thoroughly explained. The completeness of the flavouring ontology is assessed based on the comprehensiveness of the concepts found. The evaluation results provided by experts indicate that the flavouring ontology lacks sufficient data on flavouring and requires improvement. For instance, raw materials and natural occurrences require more information. Other recommendations by the experts are as follows:

1) To include information like "What method is used in the manufacturing of the commercial flavours? Either extracts from natural ingredients or completely synthetically derived." This information is very important in order to determine the halal status of flavourings.
2) In halal certification, sharia is the pillar in determining the law/status of raw materials. This means that raw materials must comply with the halal criteria stipulated by Islamic law.
3) In the context of food hygiene and safety, authoritative sources such as the Food Act 1983 and Food Regulations 1985 are required to ascertain the appropriateness of items used in food handling. Hence, the experts have recommended the inclusion of both Acts/Regulations in the flavouring data.

The concept of clarity can be described as the measure of how successfully the intended message is conveyed (Tankeleviciene & Damasevicius, 2009). The clarity of the flavouring ontology is determined by the degree to which the terminologies contained within it are clear and comprehensible. The experts' evaluation findings indicate a need for more clarity in the flavouring ontology's representation of flavouring data. For example, for the 'Suggested Halal Status' data, if the status of a flavouring is 'Haram' (i.e. forbidden), it is necessary to state the reason why the flavouring is 'Haram.'

Lastly, the concept of preciseness is characterized by the presence of accurate definitions and hierarchies within an ontology, resulting in a reduced number of unwanted models (Tankeleviciene & Damasevicius, 2009). The preciseness of the flavouring ontology is evaluated based on the presence of appropriate terms inside the ontology. However, some of the metadata about flavours are not accurate. For example, Butanoic Acid is listed as a synonym for Neryl Isovalerate, which is incorrect. Another example is the categorization of glycine as haram, which is not factually correct, as glycine is an amino acid that may be found in a wide range of sources, not exclusively derived from pigs. In order to ensure precision, it is advisable for researchers to collaborate with professionals to acquire reputable references that may be utilised for the development of the flavouring ontology.

5. DISCUSSION

This study aims to construct a flavouring ontology that can recommend the halal status of flavours. This flavouring ontology was implemented into the Halal Status Flavouring Traceability System. This implementation aids halal management auditors in predicting the halal status of flavours to facilitate the processing of food producers' applications for halal certification. The methodology employed in this study for developing the flavouring ontology is based on the approach described in the publication "*101 Methods*" by Noy and McGuinness (2001). Several advantages of incorporating the Ontology Development 101 Method into the development of the flavouring ontology include:

1) It provides a structured approach to ontology development, which helps to ensure that the resulting ontology is well-organised, coherent, and easy to understand.
2) It promotes a comprehensive representation of the domain by starting a top-down view and emphasizing the use of reference sources.
3) It is reliance on multiple reference sources, and iterative refinement helps improve accuracy and reliability.
4) It supports the involvement of domain experts in the ontology development in order to enhance the ontology's quality and relevance.
5) It helps reduce bias by referring to multiple reference sources and consulting the domain experts, leading to a more balanced representation of the domain.

The definition of fundamental concepts during the specification phase is the most crucial work in the technique. The acquisition of knowledge during the specification phase serves as the foundation for conceptualisation. Consensus among domain experts is necessary for the establishment of this conceptualisation. An additional crucial factor to contemplate in the development of an ontology is the validation procedure employed to assess

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the precision and integrity of the information. The validation procedure involved experts assessing the flavouring ontology using a prototype that has been integrated with it. This is important because when domain experts are involved in the evaluation process, they are more likely to endorse the ontology, increasing its acceptance and adoption within the domain. This endorsement process can be done by identifying inconsistencies, inaccuracies, or missing elements within the ontology structure and content. Their validation also adds credibility and trustworthiness to the ontology (Howell et al., 2021).

The findings of the analysis pertaining to the assessment of the flavouring ontology revealed that a majority of the experts expressed satisfaction with the ontology-driven generated information by the prototype, particularly with regard to the inclusion of synonyms and the hierarchy of a flavour. Nevertheless, several experts have expressed the need for caution while constructing synonym metadata for flavouring to prevent the inclusion of inaccurate or misleading data. Most experts said there is room for enhancement in flavour metadata, aiming to achieve greater completeness and accuracy in the retrieved flavour metadata. Enhancement of flavour knowledge could be achieved through consultation with multiple references and by engaging in comprehensive discussions with domain experts. The acquisition of comprehensive and precise data pertaining to flavours holds significant importance in ascertaining the halal status of a certain flavour. Furthermore, experts have recommended that verifying the flavouring ontology should be repeated in consultation with domain experts, specifically regarding the synonyms, despite the fact that researchers have already consulted authoritative sources. According to the evaluation regarding the flavouring ontology, it revealed that the ontology can provide some advantages:

1) Ontologies ensure consistency and standardization of terms, concepts, and relationships within a domain (Azram et al., 2018). This advantage can resolve concerns pertaining to the inconsistent use of terms between food manufacturers and halal management auditors.
2) Ontologies enhance the integration of heterogeneous data sources by facilitating the integration of data from multiple sources, which are consolidated by offering a common lexicon and structure for arrangement of the data (Promthong et al., 2023). This advantage has already addressed the concerns highlighted about halal management auditors manually referring to multiple sources of flavouring to obtain precise information on them.
3) Ontologies enhance consistency in reasoning by supporting automated reasoning, which involves establishing explicit rules for deducing new information from existing knowledge (Promthong et al., 2023). This advantage enables the halal management auditors to predict a halal status of flavouring because most flavourings do not have halal certificates in the application of halal certification for food products. This automated prediction can expedite the process of the application for halal certification.

6. CONCLUSION

Constructing domain ontologies becomes challenging when domain experts are unfamiliar with knowledge engineering techniques and lack the ability to conceptualise the domain. This paper demonstrates the process of developing a domain ontology using the approach introduced by Noy and McGuinness (2001). This technique offered comprehensive guidance in delineating the scope and establishing the core concepts essential for specifying and conceptualising this new ontology. The evaluation results of the prototype by the experts revealed that they are satisfied with the information produced by the prototype's ontology in terms of synonyms and hierarchy of a flavour. Sharing the best practices on ontology development can benefit the whole community, especially domain experts in particular areas. The primary focus of this study was building the flavouring ontology, which involves the integration of multiple reference sources using the 101 Ontology development technique.

Soliciting comments from domain experts, specifically those involved in halal certification processes at the Department of Islamic Development Malaysia, allows us to align the ontology's functionalities with practical requirements for predicting the halal status of flavours in food manufacturing applications. Their insights were invaluable in gauging the compatibility of our ontology with industry practices and certification procedures. All of the concerns from the experts will be put forward in the direction of our future work. Besides this, our future works will also include using the improved version of the developed ontology designed to facilitate semantic document retrieval of flavouring documents. Here, the concepts within the flavouring ontology will be aligned with the textual content of scientific articles that relate to the flavourings. We expect to achieve a promising outcome

whereby the scientific articles regarding flavouring can be retrieved based on users' input queries.

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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Wikipedia as an Online Health Information Source: Consumers' Satisfaction with Information Quality

Boryung Ju
School of Information Studies, Louisiana State University, Baton Rouge, LA, USA
E-mail: bju1@lsu.edu

John Paul Bourgeois*
Webster Family Library, Cummings School of Veterinary Medicine at Tufts University, North Grafton, MA, USA
E-mail: john.bourgeois@tufts.edu

Yoonhyuk Jung
School of Media & Communication, Korea University, Seoul, Korea
E-mail: beyond@korea.ac.kr

ABSTRACT

For consumers making health decisions, Wikipedia is a popular source for health information. This study investigated major factors influencing consumer satisfaction with Wikipedia medical/health articles. Using a crowdsourcing method, data were collected from 322 adults who read/edit English Wikipedia medical/health articles and reside in the US. The results showed that the presentation of information was the most influential factor. Trustworthiness was the second most important factor for consumer satisfaction with the quality of information, followed by reliability, and topic coverage. Study participants did not consider other factors such as accuracy and currency to be crucial factors. Moderating effects of the control variables such as editing experience with Wikipedia articles, gender, and age were also examined to enhance the internal validity of the study. Implications for the Wikipedia editor community and researchers, and directions of future research are presented.

Keywords: Wikipedia, consumer health, information quality, consumer satisfaction, health information

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***Corresponding Author:** John Paul Bourgeois
https://orcid.org/0000-0001-5314-6466
E-mail: john.bourgeois@tufts.edu

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1. INTRODUCTION

The public seeks health information on the Internet with Wikipedia articles on medicine and health becoming a prominent information source for making health decisions. According to Fox and Duggan (2013), health information was sought by 72% of Internet users in the past year. Additionally, 77% of 'online health seekers' started searching on search engines, while another 13% used targeted sites such as WebMD. Even though a small portion (2%) start with a general site like Wikipedia, search engine results direct to websites regardless of trustworthiness and accuracy (Fox & Duggan, 2013). Recent studies show that Wikipedia is one of the most used medical and health information sources which could influence public health (Shafee et al., 2017), and its readership is higher than that of the US National Institutes of Health or WebMD (Heilman & West, 2015). Wikipedia health information is accessed and utilized as a health care information source by 50% to 70% of physicians (Heilman et al., 2011; Hughes et al., 2009) and is the single resource medical students use most (Allahwala et al., 2013).

There are around 20,000 health-related articles on English Wikipedia as of 2017 (Heilman et al., 2011). The strengths of Wikipedia health articles include topic coverage, reference materials, and collaborative updates. In their study Farič and Potts (2014) interviewed 32 "Wikipedians." These Wikipedia editors said their motivations for updating health-related Wiki content included: 'learning about subjects by editing articles,' 'wanting to improve and maintain Wikipedia [as] a professional responsibility,' 'providing good quality health information to readers,' 'editing Wikipedia as a fun, relaxing, engaging, and rewarding activity,' and 'belief in the value of Wikipedia.' Wikipedia health and medical content has been created/edited through collaboration from entities such as medical institutions and universities, academic journals, and groups of health professionals and researchers. A few examples of partnerships include WikiProject Medicine (https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Medicine), Gene Wiki (https://en.wikipedia.org/wiki/Gene_Wiki), and Cochrane (https://en.wikipedia.org/wiki/Cochrane [organization]), which have improved the quality and enhanced the availability of Wikipedia medical content for a broader readership. The information on these sites could impact an individual's decision to change health-seeking behaviors. While these collective efforts have updated, expanded, and improved Wikipedia's perceived accuracy among readers, Wikipedia medical content continually suffers from low readability, omission errors, and uneven coverage (Mesgari et al., 2015; Shafee et al., 2017).

In an information environment where more people seek and rely on online health information compared to traditional approaches of going to their physicians or healthcare providers (Fox, 2009; Renahy et al., 2010), the importance of the quality of online health information sources cannot be over-emphasized. Although healthcare providers/practitioners remain trusted sources of health information, in a study of 6,369 persons who searched for health information online, 48.6% did so without professional guidance (Hesse et al., 2005).

Despite its obvious benefits such as availability and accessibility, online health information is often poor quality, inaccurate, discordant, or misleading (Bernstam et al., 2008; Eysenbach et al., 2002; Price & Hersh, 1999; Rains, 2008). Medical and health information from certain sites is reliable and updated (Kitchens et al., 2014), although health information quality is inconsistent across various topics. As a public health information source, Wikipedia is useful and very highly ranked in terms of currency, but internally it also varies in article quality (WikiProject). There appears to be a dearth of studies that investigate the quality of Wikipedia health information from the perspective of readers' satisfaction. However, few studies have explored information quality and consumer satisfaction in the Wikipedia health-related contents. The development of trust and satisfaction with health information is especially relevant for Wikipedia given its unique standing as a non-governmental source of COVID information during the pandemic.

The current study addresses how health information quality in Wikipedia articles influences Wiki readers' satisfaction with Wikipedia. First, this study identified key factors influencing consumers' health information behaviors such as seeking, assessing, and using information. The study explored consumers' baseline perceptions of the quality of Wikipedia's health information. Second, the study explored key factors contributing to consumer satisfaction. By seeking online health information without subsequently discussing the information with a healthcare professional, consumers jeopardize their patient-health practitioner relationship and potentially their own health (Chen et al., 2018; Tan & Goonawardene, 2017). Consumers' perceptions of the quality of information and their satisfaction with the quality affects the information sources they select (Sbaffi & Zhao, 2020; Zhang, 2014) and is a crucial factor that leads to the continued use of particular information sources or services (Bhattacherjee & Premku-

mar, 2004; Venkatesh et al., 2011).

2. LITERATURE REVIEW

2.1. Quality of Wiki Health Information & Users' Satisfaction

Among both health professionals and the general public, Wikipedia health information is so popular that it could be developed as a unified, open platform for distributing health information (Heilman et al., 2011) and for promoting healthy lifestyles (Hickerson & Thompson, 2009). Along with specialized healthcare wikis, Wikipedia could be a valuable source for nurses seeking evidence-based information (Okoli et al., 2014; Younger, 2010).

Information quality is vital to all Wikipedia users – consumers and researchers. Since Wang and Strong (1996) provided a conceptual model with four major categories for understanding information quality, their framework has been applied to examine and evaluate personal Web portfolios (Katerattanakul & Siau, 2008), business Internet commerce (Katerattanakul & Siau, 2002; Lee et al., 2007), consumer goods and manufacturing companies (Pipino et al., 2002), and health information search results quality (Kitchens et al., 2014), as well as to model online consumer health information quality (Stvilia et al., 2009).

Past research has assessed Wikipedia health and medical information quality in various dimensions. However, the aspects of Wikipedia health topics examined in previous studies vary. Though Wikipedia contains an enormous number of high quality, well-referenced health and medical articles, its content coverage is insufficiently and unevenly representative of all topics (Mesgari et al., 2015; Shafee et al., 2017) and heavily favors English and other European languages (Heilman & West, 2015). Wiki article usefulness is examined in terms of access from search engines (Laurent & Vickers, 2009) and coverage of disease and disorders (Gilbertson et al., 2015). While these topics need improvement, the articles are useful and succinct. As a source of public health information, research has examined factual accuracy (Leithner et al., 2010; Okoli et al., 2014). When evaluated by three independent observers, the accuracy, completeness, and scope of Wikipedia articles on osteosarcoma were of a high quality generally but not as high as those of the National Cancer Institute (Leithner et al., 2010). Trustworthiness of online health information significantly influences its pursuit and utilization (Ye, 2010). Currency, reliability, and other information qualities such as readability and style have been examined for Wikipedia as a whole (Arazy & Kopak, 2011; Stvilia et al., 2007), but little research explores these attributes specifically for Wikipedia health and medicine articles.

In their systematic review of information quality, consumer satisfaction, and their moderating factors in online information environments, Ghasemaghaei and Hassanein (2015) found that website type (retail vs. e-health service) and information quality moderated the association between both perceived information quality and consumer satisfaction. Sample characteristics (general public vs. students; Eastern vs. Western countries) had no moderating effect. Similarly, information quality was directly proportional to consumers' satisfaction (Koo et al., 2011; Lim et al., 2009; Petter et al., 2013).

Based on previous studies' results, Bhattacherjee (2001, p. 364) proposed a post-acceptance model of information systems (IS) continuance based on an adapted expectation-confirmation theory (ECT) that manifests relationships among users' level of satisfaction with the initial IS use, their confirmation, perceived IS usefulness, and users' extent of confirmation. This model validates that satisfaction is the strongest predictor of users' intended continuation and that confirmation was a strong predictor of satisfaction. Though ECT postulates that the IS expectation and expectation confirmation are determinants of user satisfaction, our study's model did not explore expectation. Pre-acceptance attitude or belief is based mainly on cognitive perceptions such as advertisement or indirect information from other sources. On the other hand, post-acceptance satisfaction is based on direct, first-hand experience. Based on factors that have been commonly examined in prior research, we hypothesize as follows:

H1: The accuracy of health information on Wikipedia positively affects satisfaction.

H2: The trustworthiness of health information on Wikipedia positively affects satisfaction.

H3: The reliability of health information on Wikipedia positively affects satisfaction.

H4: The currency of health information on Wikipedia positively affects satisfaction.

H5: The topic coverage of health information on Wikipedia positively affects satisfaction.

H6: The information presentation of health information on Wikipedia positively affects satisfaction.

Other studies examined predictors of continuous use such as disconfirmation, perceived usefulness, and user satisfaction (Bhattacherjee & Premkumar, 2004). Addi-

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tional areas of research included how service quality and users' perceived values impacted short message service (SMS) usage in the post-SMS adoption phase (Lai, 2004), and user behaviors such as social influence and effort and performance expectancy (Venkatesh et al., 2011). Confirmation and satisfaction have been found to be vital to the continued use of IS. IS users' continuance decisions are similar to source selection in consumer health information decisions.

2.2. COVID-19 and Wikipedia

Of course, an examination of Wikipedia health information must discuss the recent COVID-19 pandemic. While a large research body exists regarding COVID-19 disinformation and misinformation online, that topic is too broad and too far beyond the scope of this study.

Throughout the pandemic, the public sought health information online, including Wikipedia. One method of assessing the impact of these information seeking behaviors was measuring digital health literacy. Dadaczynski et al. (2021) found that among German university students, those who used Wikipedia and other public websites had higher digital health literacy than those who relied more on social media. However, it was found across all respondents that assessing reliability and source purpose was a difficulty. On the other hand, Rosário et al. (2020) have found that among Portuguese university students, the reliance on Wikipedia for COVID-19 information was associated with lower digital health literacy when compared to those who used governmental information sources. Another finding was that as the pandemic wore on, respondents tended to have lower digital health literacy. Other studies noted that not only did digital health information literacy decline as the pandemic continued; the frequency of searches also declined. This phenomenon was observed not only on Wikipedia but across a wide range of media types and sites (Gozzi et al., 2020). Jarynowski et al. (2020) found that in Poland the generators of the information had an impact on the media consumption – governmental announcements created the highest consumption across all media types. However, the information lifecycle did vary by media: Traditional media responded more quickly, but online media has a longer information viability. This means that the public consumes online media longer after it is published than traditional media.

As COVID-19 enveloped the globe, the public turned to Wikipedia not only to consume information but to contribute to it. One study found that Wikipedia contributions increased 20% over expectations, with only a small fraction being reverted (Ruprechter et al., 2021). The Ruprechter et al. (2021) study did not stratify contribution by subject, so we do not know if these edits were made in the fields of health and medicine. Chrzanowski et al. (2021) did explore medical information accessed and contributed on Wikipedia, finding a significant increase in articles related to pandemic topics. Furthermore, their study observed a direct temporal-geographical correlation between COVID-19 mortality and editing/reading of COVID-19 articles on Wikipedia. Approaching the question of medical information consumption on Wikipedia from a different perspective, fewer Wikipedia articles on neurological disease were read during the pandemic, while total

Table 1. Demographics of study participants

Variable	Number
Age (yr)	322
18-19	13
20-29	61
30-39	77
40-49	65
50-59	57
60-65	49
Sex	322
Male	140
Female	181
Other	1
Racial background	322
American Indian/Native Alaskan	7
Asian/Pacific Islander	18
Black (non-Hispanic)	44
Hispanic	42
White (non-Hispanic)	199
Multiracial	8
Other	4
Online sites other than Wikipedia used for health information	322
WebMD	165
Medicine Plus	21
Health site (e.g., Mayo Clinic)	74
Centers for Disease Control and Prevention	50
Other	12

Wikipedia use increased (Rutovic et al., 2021). Although Wikipedia readership and contributions rose during the pandemic with low reversion rates to previous versions of the articles, these results do not on their own address the quality of information generated or consumed. Benjakob et al. (2022) found that Wikipedia COVID-19 articles often cited high quality information and remained robust against misinformation which was simultaneously spreading through other online sources, such as social media.

Based on the quality and quantity of information available on Wikipedia, other researchers have used the site as a source of data to track interventions for COVID-19 globally (Suryanarayanan et al., 2021). Although the information extracted from Wikipedia underwent processing, the processing manipulated the information into a machine-readable format, not to 'clean' the information itself. All this indicates that Wikipedia has proven to be a resilient, reliable source of information throughout the pandemic.

3. METHODOLOGY

3.1. Study Participants

We recruited a total of three hundred and twenty-two adults using Qualtrics Panel Services (www.qualtrics.com). This tool offers a comprehensive and versatile solution for seeking to conduct surveys, and thus has been widely used in academic research. It provides researchers with a robust set of features to design and distribute surveys, making it a popular choice for collecting data across various academic fields (Waddell et al., 2022). We specifically requested a profile of American residents who were readers and contributors of Wikipedia. The data was collected between April and May 2021. A purposive sampling approach was employed. In order to ensure the targeted population participated, we asked questions to establish respondent suitability. Study participants had a body mass index of 25 or higher, which is defined as being overweight or obese (https://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmicalc.htm) with the rationale that this population would be keener to access obesity-related health information. The participants were required to be between 18 and 65 years old; have experience of searching, using, or contributing to/editing the English edition of Wikipedia in the last two years; and reside in the US. Study participant demographics are in Table 1.

The current study has complied with all relevant national regulations and institutional policies and has been approved by the authors' institutional review board. Informed consent has been obtained from all individuals included in this study.

3.2. Data Collection

We identified key factors influencing information quality from previous studies on health information seeking and services (Koo et al., 2011; Stvilia et al., 2007; Wang & Strong, 1996) and adapted them for the present study. The survey was conducted online during the spring semester of 2021, capturing data on perceived Wikipedia quality factors (Table 2), including information presentation, reliability, trustworthiness, topic coverage, and accuracy. Additionally, demographic information about participants – such as age, gender, racial background, and their experience level in terms of readership and/or content con-

Table 2. Information quality factors

Information quality	Measurement question	Source
Accuracy	Do you agree that health information on Wikipedia is correct?	Modified questions from Koo et al. (2011), Stvilia et al. (2009), and Wang and Strong (1996)
Trustworthiness	Do you agree that health information on Wikipedia is credible?	
Reliability	Do you agree that health information on Wikipedia is objective?	
Currency	Do you agree that health information on Wikipedia is current and timely?	
Topic coverage	Do you agree that breadth of health topics on Wikipedia is comprehensive?	
Information presentation	Do you agree that health information presentation on Wikipedia is easy-to-read?	
Satisfaction	How do you feel about your overall experience of using health information of Wiki articles?	

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tribution to Wikipedia – was collected. Participants also provided their perceptions of the quality of other online health sources. The information quality questions were assessed on a 7-point Likert scale (1=strongly disagree, 7=strongly agree).

4. RESULTS

4.1. Seeking Online Health Information

Beyond Wikipedia, individuals predominantly sought health information from major online sources, with WebMD being the most visited (51.24%), followed by private health sites like Mayo Clinic (22.98%), the Centers for Disease Control and Prevention (CDC) (15.53%), Medline Plus (6.52%), and others such as Google or Bing (3.73%). Analyzing responses related to Wikipedia articles on weight and obesity, the most commonly sought-after information encompassed diet and nutrition (75.76%), healthy lifestyle advice (72.68%), and statistics and trends (61.49%). Additional areas of interest included complications of obesity (49.37%), treatments for obesity (44.72%), citations and references (43.96%), and symptoms of obesity (41.32%).

4.2. Multiple Regression Analysis

The data collected from the survey were analyzed with descriptive statistics and multiple regression to examine the effects of information quality factors on consumers' satisfaction with Wikipedia health information. In addition, the moderating effects of control variables were measured to assess statistically significant differences between regression coefficients of two groups for the three variables, respectively: age, gender, and editing experience (readers vs. readers/content contributors).

Table 3 presents the overall mean values of the seven information quality factors (grand mean=4.9462). All were greater than 4 (the median), which means respondents have positive perceptions of the health information quality in Wikipedia articles. *Information presentation* is the highest ranked factor (mean=5.4658; 82.92% rated positively for Somewhat Agree, Agree, or Strongly Agree), followed by *currency* (mean=5.0217; 66.15% rated positively for Somewhat Agree, Agree, or Strongly Agree), and *topic coverage* (mean=5.0093; 70.20% rated positively for Somewhat Agree, Agree, or Strongly Agree). These descriptive statistics reveal that the respondents were satisfied with health information in Wikipedia (mean=5.3696). The factor variances (standard deviation) are not disperse. Respondents favorably evaluated each category of information quality. Based on the Q-Q plots, the normality of independent variables was generally satisfied, as indicated in Fig. 1.

Table 3. Results of descriptive statistics (n=322)

Information quality factors	Mean	Standard deviation
Accuracy	4.6398	1.47483
Trustworthiness	4.8385	1.37581
Reliability	4.7019	1.44621
Currency	5.0217	1.27136
Topic coverage	5.0093	1.37736
Information presentation	5.4658	1.28752
Satisfaction	5.3696	1.25430
Grand mean	4.9462	1.35530

Results of multiple regression analysis (Table 4) show the associations between six independent variables (information quality) and respondents' satisfaction. A goodness-for-fit measure, R square (R^2), is 58.5%, and the regression model in this study is proved to be valid (F=73.949, $p<0.01$). Collinearity factors, Tolerance, and variance inflation factor (VIF) diagnose whether independent variables are too closely related. Table 4 shows that tolerance statistics for each are all above 0.40 and VIFs for each are all lower than 3, which ensure multicollinearity (Allison, 1999).

Trustworthiness, *reliability*, *topic coverage*, and *information presentation* significantly affected user' satisfaction with Wikipedia health information; *accuracy* and *currency* had no significant effect on satisfaction. Among the factors, *information presentation* (t=6.644, $p<0.001$) and *trustworthiness* (t=4.727, $p<0.001$) were most influential on users' satisfaction, followed by *reliability* (t=3.418, $p<0.01$) and *topic coverage* (t=3.108, $p<0.01$).

In addition, prior studies reveal that individual factors have significant impact on users' adoption of health information (e.g., Ghasemaghaei & Hassanein, 2015; Miller & Bell, 2012). We thus examined moderating effects of gender, age, and editing experiences. Respondents were divided into two groups for each variable: male vs. female, 40 or older vs. younger than 40, and only a reader vs. editor. We examined whether there is significant difference between regression coefficients of the two groups for these three variables. Table 5 shows the results of moderating effects. The effect of *information presentation* on satisfaction was significantly increased in female respondents, and the effect of *topic coverage* was enhanced in younger

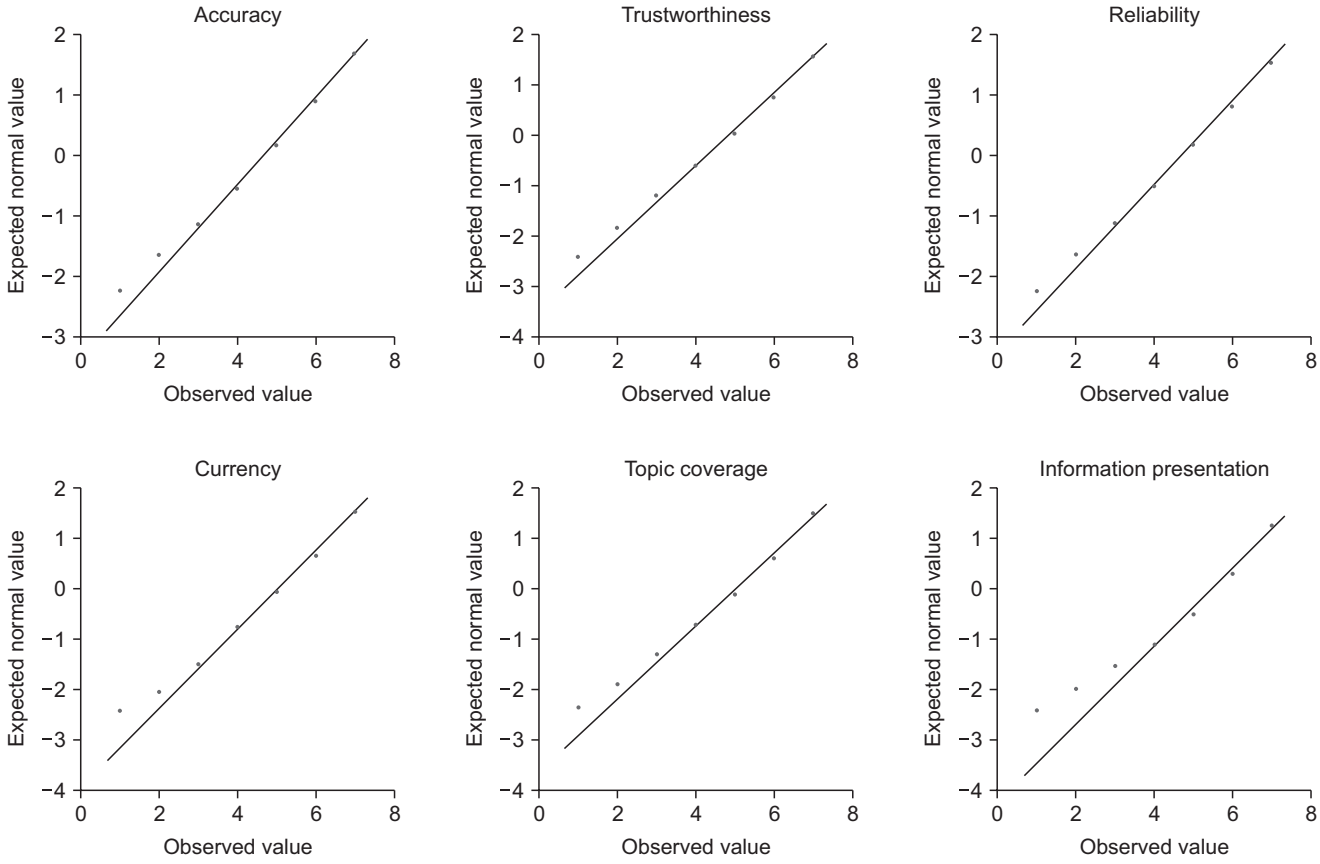


Fig. 1. Q-Q plots (normality of independent variables).

Table 4. Results of multiple regression analysis: information quality

	Unstandardization coefficient		Standardization coefficient	t	Significance level	Collinearity statistics	
	B	Standard error	Beta			Tolerance	VIF
Independent variable							
Constant	0.926	0.229	-	4.040	<0.001	-	-
Accuracy	0.050	0.046	0.058	1.074	0.284	0.445	2.248
Trustworthiness	0.270	0.057	0.297	4.727*	<0.001	0.335	2.985
Reliability	0.145	0.042	0.167	3.418*	0.001	0.549	1.821
Currency	-0.005	0.051	-0.005	-0.098	0.922	0.503	1.989
Topic coverage	0.142	0.046	0.156	3.108*	0.002	0.523	1.913
Information presentation	0.281	0.042	0.288	6.644*	<0.001	0.700	1.428
Dependent variable							
Satisfaction R^2=0.585, *Adjusted* R^2=0.577, F=73.949							

VIF, variance inflation factor.
*p<0.01.

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Table 5. Results of multiple regression analysis: sex, age, and experience (control variables)

Control variable	Accuracy				Currency			
	Trustworthiness		Reliability		Topic coverage		Information presentation	
	Reg. coef.	Sig. diff.	Reg. coef.	Sig. diff.	Reg. coef.	Sig. diff.	Reg. coef.	Sig. diff.
Sex								
Male	0.330	t=-0.198 (p=0.843)	0.213	t=1.613 (p=0.108)	0.179	t=-0.045 (p=0.964)	0.168	t=-2.975[a] (p=0.003)
Female	0.343		0.114		0.182		0.374	
Age (yr)								
>40	0.355	t=-0.322 (p=0.748)	0.200	t=0.580 (p=0.562)	0.089	t=-2.835[a] (p=0.005)	0.343	t=1.740 (p=0.083)
<40	0.376		0.164		0.274		0.220	
Editing experience								
Reader only	0.499	t=3.481[a] (p=0.001)	0.134	t=-1.559 (p=0.120)	0.204	t=1.338 (p=0.182)	0.234	t=-1.728 (p=0.085)
Editor	0.269		0.233		0.116		0.355	

Reg. coef., regression coefficient; Sig. diff., significant difference.
[a]This value is statistically significant.

generations. Respondents who had no experience of editing/contributing Wiki content were more influenced by *trustworthiness.*

5. DISCUSSION

Regarding Wikipedia health information, users have a mostly positive evaluation based on our results. We furthermore demonstrated that perceived quality of information influences Wikipedia user satisfaction, while accuracy and currency are far less relevant.

Presentation of the information was the most influential factor affecting user satisfaction. Participants recognized and chose Wikipedia as a source of health information due to the well-presented health information. This finding aligns with previous studies identifying information quality in health systems as a crucial factor and showing that effective presentation of information helps readers understand and interpret health information (Koo et al., 2011). Comparatively, research has also mentioned the usefulness of hospital websites, and that they serve as a natural extension of services to patients and health information consumers (Fulda & Kwasik, 2004; Gallant et al., 2007). Similarly, previous studies have discussed information quality markers on health websites, including clarity of written online health information on health Q&A sites (Chu et al., 2018) and readability (Bates et al., 2006; Stvilia et al., 2007). Interestingly, the readability of articles in the hard sciences has been found to be higher than for articles in the humanities and soft sciences using an objective measurement of readability (Ehmann et al., 2008). In contrast, medical content on Wikipedia has been perceived as having low readability due to errors, even when the articles are well referenced and have comparatively good quality (Mesgari et al., 2015).

Trustworthiness: Trustworthiness was the second-most mentioned factor affecting user satisfaction. Trustworthiness is a quality of information that is deserving of trust or confidence, which may be related to other attributes of information quality as well. In this study, we conceptualized trustworthiness as credibility. Choi (2019) conceptualized the trustworthiness of health information on the Internet as having three dimensions: the operator (the agent(s) who develop and manage the sites), content (valid and updated information), and design (structural, technical, aesthetic, and interactive features on the site). This finding also aligns with the measure of online health information for information seeking in Kitchens et al. (2014)'s study. They conceptualized two factors for quality of information on a website: accuracy and trustworthiness. Trust-

worthiness in their study entails the "websites' authoritativeness, use of source attribution, justifiability of claims, distinction between advertising and actual health content, and transparency" (Kitchens et al., 2014; p. 456). They also found a positive association between website quality and website importance.

Reliability: In this present study, reliability is conceptualized as objective information which positively influenced consumer satisfaction. In other studies, reliability refers to having many citations and related sources, or notable and verifiable information, with the number of references as a proxy for reliability (Heilman & West, 2015). Wikipedia articles are regarded as relatively well referenced and providing high quality (Heilman & West, 2015; Mesgari et al., 2015).

Topic coverage: Health topic coverage on Wikipedia had a positive influence on consumer satisfaction in this study. Considering that medical/health topics are complicated and vast in the coverage, it is not surprising that the topic coverage of Wikipedia was perceived differently. Studies have found that Wikipedia fails to provide an answer to clinical questions compared to large search engines (Okoli et al., 2014); it unevenly covers various topics due to the small number of volunteer contributors (Shafee et al., 2017); and content has improved only gradually (Zhao et al., 2020). Nevertheless, Wikipedia could serve as a great starting point for consumer health information and can be a popular platform as a source of public health information.

Accuracy: Wikipedia's accuracy had an insignificant impact on satisfaction and was rated relatively low compared to the other factors in this study. This finding implies that readers may not expect highly accurate health information on Wikipedia. Empirical research has found that there is conflicting health information between Wikipedia and peer-reviewed medical literature (O'Mathúna, 2018). However, the respondents in our study were overweight or obese and more aware of their health, so they may want highly accurate health information from expert sites (e.g., WebMD) rather than Wikipedia. We can infer that users utilize Wikipedia to find general health information but have different digital sources for highly specific health information.

Currency: The respondents assessed how current the health information is on Wikipedia and rated it relatively highly, but there was no significant impact on satisfaction. This result suggests that respondents thought that health information is up-to-date anywhere else (information sources or websites), but that currency was not an important attribute of Wikipedia health information. The majority of respondents chose WebMD as their most frequently used digital health information source. In addition, 16% of respondents relied on the CDC website, indicating that users' contingent information-seeking behavior was based on information quality.

Analyses of control variables show that female participants showed higher satisfaction from information presentation, younger respondents from topic coverage, and those inexperienced with Wiki editing were most influenced by trustworthiness. Women frequently demonstrate strong abilities in verbal and linguistic skills, potentially making them more attuned to the subtleties of how information is presented (Halpern et al., 2007). As far as the impact of age is concerned, growing up immersed in the Internet and digital technology, younger people, known as digital natives, are generally more at ease and acquainted with various online platforms. This familiarity makes them particularly attuned to the range and comprehensiveness of topics available online. People who have not contributed to Wikipedia may feel that their expertise falls short compared to active editors and contributors. This feeling of a knowledge gap may cause them to rely more heavily on the trustworthiness of the presented information, as they might believe they are not as equipped to critically assess the content.

Our research findings indicate that factors such as information presentation, trustworthiness, reliability, and topic coverage significantly influence the quality of content contributed by Wikipedia content contributors. For instance, contributors should prioritize using credible and authoritative sources with proper references to enhance trustworthiness. Ensuring content is fact-based, verifiable, and presented objectively contributes to reliability. Additionally, content should be logically presented, readable, and clearly organized for effective information presentation. Regarding topic coverage, greater participation from individuals with qualified content knowledge is needed, especially in health topics, to diversify and enrich the content across a variety of health-related subjects.

Nevertheless, Wikipedia functions as a collaborative and open editing platform, where contributors (editors) voluntarily create or edit content to the best of their abilities. Consequently, we aim to present our findings as guidance for their contributions, offering collective insights and considerations to enhance the quality of their input.

This study has limitations. First, we used purposive sampling for this study. The respondents were individuals who might have health concerns related to being over-

weight/obese and who were reading and/or editing health information in Wikipedia articles. Thus, this study sample was limited to a specific group in both the topics and their source selection. Even though our purposive sample of participants included crucial informants for the study, it could affect the generalizability of the findings. Second, our study participants resided in the US and could read/edit the English edition of Wikipedia. There are Wikipedia editions in other languages (e.g., Spanish or Chinese) that are read by significantly larger populations compared to the US population. Lastly, each construct of information quality entails multiple sub-dimensions such as trustworthiness and information presentation. Hence, more nuanced construct development in future studies would enhance the breadth of the study findings and provide more detailed insights.

6. CONCLUSION

This study examined several influential attributes related to consumers' satisfaction with health information on Wikipedia. Our findings indicated that people select Wikipedia to find trustworthy, reliable, variety-rich, and well-presented health information. These perceptions and seeking behaviors are confirmed by prior research postulating that the selection of information sources depends on specific characteristics of the sources (Zhang, 2014). Health information on Wikipedia could have real-world impacts as it becomes more popular that are both positive and negative. For consumers of health information, decisions based on inaccurate or untrustworthy health information can be fatal; therefore, consumers must be able to assess the quality of online health information.

Our findings have several implications. The findings can inform both the medical and Wikipedia-editorial community about how consumers perceive and evaluate health information on Wikipedia. Focusing on the findings of this study can help improve the quality and broaden the readership of health information on Wikipedia. Considering that there is a vast amount of available health information on Wikipedia and that consumers depend on the information for their health decisions, it is enormously important to focus on improved quality. Increasing providers' and developers' awareness about the information quality on Wikipedia could impact consumer satisfaction and health information selection. Future research should explore the associations among consumers' expectations, satisfaction, and selection of health information sources. Additionally, as indicated by the control variables in this study, researchers could focus on gender, experience editing Wikipedia articles, and perceptions of various age groups related to health information quality attributes. There is especially a gender imbalance in Wikipedia contributors providing health information on Wikipedia. Future research should provide recommendations on how this gender gap can be mitigated.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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Health Information Behavior of Indonesians During the COVID-19 Pandemic: A Sensemaking Perspective

Rusdan Kamil*
Department of Library and Information Science, Faculty of Humanities, Universitas Indonesia, Kota Depok, Indonesia
E-mail: rusdan.kamil@ui.ac.id

Laksmi Laksmi
Department of Library and Information Science, Faculty of Humanities, Universitas Indonesia, Kota Depok, Indonesia
E-mail: laksmi@ui.ac.id

ABSTRACT

Information behavior played a significant role in minimizing the risks of the COVID-19 pandemic. When faced with such a situation, an individual needs information for decision-making and in order to determine the best course of action relating to their health. This study aims to explore information behavior during each phase of the COVID-19 pandemic in Indonesia, which is known for its close-knit collective culture. A sensemaking approach is used, which emphasizes the process individuals go through to understand their situation and give meaning to the information they are getting from their environment. Data was collected through in-depth interviews with 10 participants to obtain a description of their information behaviors during the pandemic. Data analysis was carried out using open, axial, and selective coding. We propose a sensemaking-based information behavior strategy framework for mitigating risk and reducing ongoing health crises. Changes in information behavior strategies, including search, prevention, and restriction of information exposure, were random at the beginning of the pandemic, but became more regular in later phases. This was influenced by the "knowledge gap fulfillment" and "use of local knowledge" among the participants throughout the pandemic. In conclusion, the participants developed a sensemaking process including an understanding of the pandemic situation and the risks that they faced. They used a number of information behavior strategies to prevent transmission, and their perception of the risks changed across the course of the pandemic, up til the situation began to be considered back to normal again in Indonesia.

Keywords: COVID-19 pandemic, health information behavior, local knowledge, risk, sensemaking

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***Corresponding Author:** Rusdan Kamil
https://orcid.org/0009-0005-0895-3433
E-mail: rusdan.kamil@ui.ac.id

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1. INTRODUCTION

There has already been plenty of research into changes in students' information behaviors in relation to learning activities in the context of the COVID-19 pandemic in Indonesia (Hajar & Rachman, 2020; Nurfadillah & Ardiansah, 2021; Safri et al., 2022). The situation also encouraged every individual to acquire more health information, especially information about the COVID-19 disease and the events that were occurring. This is a part of health literacy, which can be defined as "the degree to which individuals can obtain, process, understand, and communicate about health-related information needed to make informed health decisions" (Berkman et al., 2010, p.16). In the context of healthiness, information-seeking behavior refers to the various ways individuals seek information about health, risks, disease, and health protection (Lambert & Loiselle, 2007).

Sensemaking in relation to health information behavior involves the active effort by individuals to address their health information needs by balancing their information behavior appropriately (Mamykina et al., 2015b; Westbrook & Fourie, 2015). This can be done through coordinated information behavior, avoidance, and restrictions to information exposure, so that individuals can overcome their knowledge gap and maintain their emotional balance. During the pandemic, people were introduced to various new behaviors and habits suggested by health authorities in order to prevent infection from the SARSCoV-2 virus.

To understand and address the pandemic, scientists from the relevant fields collaborated to create the best health management strategies, using a multidisciplinary approach (Chams et al., 2020; Holmes et al., 2020; World Health Organization, 2020). Xie et al. (2020) have argued that the scientific community needs to look into the pandemic phenomenon from an information science perspective, to test the theories and assumptions that prevailed during the crisis in terms of the various models of information behavior. The field of information behavior itself has studied human behavior and interactions with information in relation to a number of crises, be it pre-crisis, during the crisis, or post-crisis (Krakowska, 2020). Conducting a study of information behavior during a crisis allows our field to contribute to and resolve current societal issues (Montesi, 2021).

A previous study by Andalibi and Garcia (2021) identified the importance of achieving a balance between information-seeking behavior and limiting information among women who had a miscarriage in the United States. By utilizing the sensemaking perspective, they found that the process of building emotional validation for these women required strategies of both information-seeking behavior and information avoidance on pregnancy topics. Another study by Jensen et al. (2022) in Denmark found that a combination of information avoidance, information-seeking behavior, and refraining from seeking too much information was most effective for fulfilling the information needs of people with cancer. It also helped keep patients free from the stress of information overload.

The COVID-19 pandemic stands as the main global health crisis of the twenty-first century so far. A cultural sociology perspective shows that while crises can obviously traumatize people, they can also help form long-term collective memories that can help people overcome problems during the next crisis period (Xu & Lo, 2022). Therefore, the understanding of information behavior during the COVID-19 pandemic is essential as a way of building knowledge and educating people for any possible global health crises in the future. This study aims to contribute to various studies regarding information behavior generally during a crisis, and health information behavior in particular.

2. RESEARCH QUESTIONS AND OBJECTIVES

This study aims to understand the information behavior strategies of Indonesians during the six phases of the COVID-19 pandemic. It also seeks to explore the way local knowledge possessed by the community was utilized in order to improve individual knowledge of the ongoing situation and the risks of the COVID-19 pandemic. This approach could be developed to produce information behavior strategies that could be used by individuals in the future in making health decisions and adapting to the ever-changing nature of a pandemic situation. Specifically, this research aims to answer the following questions:

RQ1. What are the individual health information behavior strategies of people during a pandemic situation such as COVID-19?

RQ2. What was the process of sensemaking adopted by individuals in their health information behavior regarding the situation and risks of the COVID-19 pandemic?

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3. LITERATURE REVIEW

3.1. Health Information Behavior

Information behavior, also known as human information behavior, is the field that studies the way humans interact with information. Broadly speaking, it is an area that explores human interactions with information in terms of the fulfillment of needs, searching, and using information in specific contexts and situations. Information behavior in the health field covers two areas: (1) professional information behavior, which relates to the way doctors, nurses, nutritionists, or any other medical professionals acquire information and fulfil their need for knowledge and competency to improve medical measures for patient care; and (2) personal information behavior, which is undertaken by individuals seeking information to meet their own information needs in relation to preventive action and healthcare (Case & Given, 2016; Robinson, 2010). Information behavior models that have been used to examine health information behavior include the Wilson Model, the Kuhlthau Model, and the Sensemaking Model (Andalibi & Garcia, 2021; Das & Sarkar, 2014; Warner & Procaccino, 2004).

Health information behavior, according to Lambert and Loiselle (2007), includes health-related knowledge searching with regard to risks, diseases, and health protection activities. In terms of scope, the study of health information behavior takes in the strategies used by people in tackling their health concerns, individuals' active involvement in their own medical decision-making, and changes in behavior and preventive health techniques. These are all investigated, moreover, as factors that influence the purpose of individual information seeking (Lambert & Loiselle, 2007; Zimmerman & Shaw, 2020). The development of information technology such as smartphones and social media has expanded the focus of research into current health information behavior, which has been facilitated by digital technology (Percheski & Hargittai, 2011; Wang et al., 2021). In addition to the health information behavior of information seeking, some individuals actively avoid health information because of uncertainty, confusion over how to manage the information, or the possibility of the available sources causing them emotional distress (Barbour et al., 2012).

According to Weaver et al. (2010), there are three main motives behind why people look for health information. These can be described in the following terms: (1) curative health information seeking: This involves any kind of looking for information about how to control or treat diseases or health problems; (2) preventive health information seeking: This includes looking for information on such topics as individual and public hygiene, environmental health, appropriate diet, or exercise; and (3) a combination of curative and preventive health information seeking, which involves looking for information about both preventive and curative health measures; survivors of serious illnesses often undertake this kind of information seeking.

Wilson (2020) developed a multiple decision model to describe individuals' decision-making in their information behavior. This model sets out the process of decision-making performed by individuals who have already understood their own information needs. Factors influencing this model include the principle of minimum effort by individuals, and patterns of information behavior that are designed to reduce stress. Ultimately, individuals may choose to seek information, avoid information, or even exhibit non-seeking behavior by limiting their own information exposure.

3.2. Sensemaking Perspective

Sensemaking is a metatheory that describes the processes used by individuals in understanding their surrounding environment through meaning-making. Sensemaking takes in the individual's active efforts to identify, interpret, internalize, and respond to information to fill in their own knowledge gap (Case & Given, 2016). This concept has been applied in a number of studies relating to health information as a way of understanding and addressing the various challenges involved. The sensemaking process aims to build a sense of identity and help individuals overcome any life disruptions (Naveh & Bronstein, 2019; Ruthven, 2019). Sensemaking can be viewed as a holistic approach to problem solving.

Sensemaking in health information behavior can be based upon individual or social understanding in relation to personal health. Westbrook and Fourie (2015) showed that factors such as environment, body condition, and lifestyle can become information sources for medical decision-making in the individual sensemaking process. Mamykina et al. (2015a) made the point that building understanding via sensemaking is not only done individually, but also takes place socially, through discussion, negotiation, and conflict resolution, as in the diverse opinions and information found in online forums.

In the framework for chronic disease management developed by Mamykina et al. (2015b), the sensemaking process consists of classification activities, information

monitoring, dealing with new experiences relating to personal health and wellness, developing and utilizing internal representations that can serve as a basis for choosing appropriate health actions, and the habitual performing of daily activities that respond to the newly received health information. According to Dervin (1983; 2015) the sensemaking process can consist of four components, namely:

- Situation and Context: In sensemaking, this component can be defined as the situation that motivates individuals to carry out information-seeking behavior, in terms of both internal and external factors.
- Gap of Knowledge: Before starting the information-seeking process, individuals analyze the knowledge they already have and identify the information they require. This process will result in a description of the knowledge gap. Acquiring the required information reflects the individual's active effort to clarify the situation and context.
- Bridge: Individual information seeking provides a bridge between the knowledge gap and the current situation perceived by the individual. In information seeking, there are sub-components that individuals need to be aware of, specifically, information sources, information relevance, information-seeking strategies, and the quality of the information available.
- Outcome: After the information search, individuals utilize the search results to bridge the knowledge gap they encounter when dealing with new situations. Once the situation has been understood, individuals switch from a sensemaking mode to a habitual mode, where the knowledge gap has now been filled, and no further effort is required to comprehend the existing situation.

3.3. COVID Societies and Local Knowledge

The COVID-19 pandemic changed every aspect of society. Social distancing, mask usage, and the need to get COVID-19 vaccination were new situations that people had to deal with, in order to prevent infection and avoid the adverse effects of catching COVID-19. Lupton (2022) refers to such a society, faced with the threat of a long-term global health crisis and the risk factors posed by a mysterious viral infection in relation to social life, economics, inequality, possible stigma, and mortality, as a COVID society. In order to understand the changes that occurred at this time, Lupton and Willis (2021) conducted an analysis from a socio-material perspective of political responses, health systems, and pandemic policies in different parts of the world, highlighting the differences in representations and in the experiences of different social communities during the pandemic.

Indonesia is known as a society with a close-knit collective culture, factors which were all beneficial for social resilience during the pandemic (Putra, 2022). Suwignyo (2020) argued that Indonesian collective culture, with its love of gatherings and daily sharing of information and knowledge, was challenged during the pandemic due to social distancing, which hindered any large gatherings between groups for local knowledge exchange. Montesi (2021) suggested that information researchers should investigate the role of the information shared by family, neighbors, and co-workers, which is a form of "implicit knowledge" — knowledge accumulated over time and shared by community members within a particular place. This is also in line with research that has been conducted into the adaptations in information behavior in families and local knowledge during the health crisis (Montesi, 2023; Pan et al., 2020).

Local knowledge itself is unique knowledge accumulated by a community in a specific location over generations, which is utilized by the community in decision-making, and in forming strategies for coping or adapting to situations that are constantly changing. Local knowledge is made up of knowledge, practices, and beliefs. Other terms for local knowledge found in the literature are "traditional knowledge" and "indigenous knowledge" (Naess, 2013, p.100). This, including religious information with cultural and local dimensions, is part of the "information environment" as considered by Caidi (2019). In this research, "local knowledge" refers to a set of information limited to a specific geographical area and time, obtained through social and cultural practices within the local community. The local knowledge encompasses information gained from interactions with the surrounding environment, information from friends or family, and information derived from local cultural traditions, especially regarding self-care and situations of health crises.

The COVID-19 pandemic led to a fear of infection, to feelings of loneliness as it became increasingly difficult for people to meet physically, and to various other negative emotions as people's lives ground to a halt (Gan & Fu, 2022; Luchetti et al., 2020; Luo et al., 2021). To understand COVID society, Lupton (2021) identified six different phases of the pandemic, viewed from a risk perspective, as set out below:

- Distant Threat Phase: In this phase, world society

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received the news about the outbreak of a mysterious acute respiratory syndrome in Wuhan City, China, in December 2019. The media referred to the disease as a type of SARS or MERS, which are both caused by coronaviruses. However, it was not at this time regarded as a direct threat to people outside the outbreak zone.

- National Lockdown Phase: In this phase, most social activities stopped, schools were closed, international flights were cancelled, and nationwide lockdowns began to be implemented to prevent mass transmission of COVID-19. Information was circulating about the risk of infection caused by physical contact with objects contaminated with the virus. Practices such as spraying disinfectants, maintaining social distance, and washing hands frequently were the focus of health campaigns.
- COVID Zero Phase: In this phase, the transmission rate was reduced by suppressing community mobility as much as possible, and restrictions were made at the regional level in line with daily COVID reports. The risk of infection was now understood to depend on inhaling virus particles in the air, through an aerosol mechanism. Thus in this phase, the mandatory use of masks for daily activities began to be introduced, to flatten the curve of COVID-19 positive cases.
- Vaccine Dilemma Phase: In this phase, the risk that developed was that people became more susceptible to contracting COVID-19 if they had not been vaccinated. The focus in this phase was on a mass vaccination campaign for everyone, in order to end the pandemic. This phase also saw many people who were hesitant about taking the COVID-19 vaccination, due to the disinformation and misinformation that was circulating.
- Delta Response Phase: In this phase, the main risks were the threat of a renewed growth in the daily infection rate and increased mortality in communities. This was caused by the spread of the Delta variant of SARS-CoV-2, especially among people who had not received the vaccine. In this phase, the vaccination campaign was intensified, amidst many confirmed cases and deaths.
- Living with COVID Phase: In this phase, people have become accustomed to living alongside COVID-19, accepting it as a daily risk, and self-isolating when infected. People are also expected to accept the idea that the COVID-19 virus will not die out; and will continue to mutate, with the reality that positive confirmation rates and deaths will continue to occur.

4. METHOD

This research uses a qualitative approach to study health information behavior during the COVID-19 pandemic. More specifically, it follows the Grounded Theory method. Grounded Theory offers a methodology for developing theories that is based on the collection and systematic analysis of data, using a pragmatic, inductive approach that is underpinned by a theory of symbolic interaction (Birks & Mills, 2015; Corbin & Strauss, 2014). It is a method that has been widely used in information behavior research (González-Teruel & Abad-García, 2012; Hicks, 2018; Mansourian, 2006).

Participants were recruited via the social media forums of Instagram, X (formerly Twitter), and Facebook, using a purposive sampling technique. The criteria for inclusion were that participants had been living in Indonesia during the pandemic, were at least 18 years old, had been infected by the COVID-19 disease, had experienced negative emotions during the pandemic, had received the COVID-19 vaccine, and that they used the Internet and social media. Recruitment was conducted from June to August 2023. Participant screening successfully collected 20 potential respondents who filled out the questionnaire. After analysis, five people were eliminated because they claimed not to feel any negative emotions during the pandemic, four people were not willing to participate in follow-up interviews, and one person was ignored because they had lived abroad during the pandemic. In the end, 10 participants in total were interviewed in this study.

After conducting in-depth interviews with 10 people, the decision was taken to stop recruiting new participants, as no new codes were emerging from the data. The participants ranged from 24 to 36 years of age, and all lived in major cities on Java Island, which was the epicenter of COVID-19 in Indonesia. The participants consisted of four male and six female. The average length of the interviews was 49 minutes (with a range of 35 to 107 minutes). The interview consisted of two parts. In the first part, participants were asked to describe their demographics and general health information behavior. In the second part, participants were queried about how they depicted the pandemic situation in each phase, the obstacles they encountered, how they overcame them, the information behaviors they engaged in during each phase, and the health decisions they made after obtaining information. In total,

there were 32 questions. The interviews were held online via Zoom meetings. Table 1 shows the demographic data for the participants.

The interviews were recorded via audio and video and were transcribed later. The process used for analyzing and coding the data was based on the stages of coding developed for Grounded Theory by Corbin and Strauss (2014), which consist of three phases. Inductive analysis and open coding were used to generate appropriate codes, from an examination of the data context and the research questions. Using ATLAS.ti 9.0 (ATLAS.ti Scientific Software Development GmbH, Berlin, Germany), we applied code labeling to each response to our questions as part of the open coding process, generating 72 codes. Axial coding analysis was then conducted to find the relationship between the codes and to generate broader categories and themes. We then discussed and refined the themes and reviewed any similarities and differences in data interpretation, before uniting to reach an agreement on the interpretation of the theme. We then wrote up the results of the analysis. Using the assistance of ATLAS.ti 9.0, we linked themes and codes in the axial coding stage and identified four relevant core categories to develop the framework resulting from the selective coding analysis in this research. In this study, the themes and categories were developed to answer research questions that focused, from a sensemaking perspective, on information behavior strategies in relation to the situation and risks of the COVID-19 pandemic.

5. FINDINGS

The detailed findings for the different phases will be written and organized as follows: (1) a description of the situation and the risks that emerged in each phase of the COVID-19 pandemic, from the start of the Distant Threat Phase at the end of December 2019, through to the beginning of the Living with COVID-19 Phase at the end of December 2022; (2) the identification of the information needs expressed by the participants in their interviews in relation to each phase of COVID-19; and (3) an explanation of the participants' information strategy and sensemaking process in their health information, in relation to the changes in risk perception and their understanding of the health protocols in each of the different phases as part of the sensemaking process.

5.1. Distant Threat Phase

The initial phase commenced in late December 2019, marking the onset of the discovery of mysterious pneumonia cases in Wuhan City, China, until the end of February 2020, characterized by the identification of COVID-19 pandemic cases outside of China. The information then spread quickly to the rest of the world. During this phase, the risk posed by the virus was still confined to a local level. Almost all the participants (eight people) knew about the beginning of the COVID-19 pandemic in January 2020, while Budi (36, male [M]) and Indah (25, female [F]) had started following this news at the end of December 2019. Budi (36, M) commented:

"The first time I heard the news was from social media and websites; these are my primary information sources. To be precise, it was right at the beginning, around November to December 2019, when the first case appeared."

Table 1. Participant demographics

Pseudonym	Age (yr)	Sex	City of origin	Education
Hasan	24	Male	Jakarta	Bachelor's
Dewi	26	Female	Bandung	Bachelor's
Budi	36	Male	Bogor	Postgraduate
Susi	26	Female	Jakarta	Associate degree
Ulfah	25	Female	Bandung	Bachelor's
Guntur	25	Male	Bandung	Bachelor's
Rini	31	Female	Jakarta	Postgraduate
Indah	25	Female	Tangerang	Bachelor's
Ayu	25	Female	Semarang	Bachelor's
Butet	29	Male	Bandung	Bachelor's

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Meanwhile, Indah (25, F) remarked:

"The first time I know about it was at the end of December. If I'm not wrong, it was December 2019. It was early on, and it was buzzed on Twitter."

The participants received the news from various information sources, including social media, online news portals, and in some cases, television (four people). This shows how important digital information sources are, especially social media, in spreading information. In the distant threat phase, the participants felt that the risk of infection was low in Indonesia, and doubted the possibility of the virus entering the country, while still keeping an eye on the situation.

The participants felt some negative emotions, such as fear, due to the spread of "panic" videos relating to the virus, which they found on social media, especially Twitter, Instagram, and TikTok, or as shared videos in WhatsApp groups. According to Ayu (25, F), she felt "Lowkey panic when I received the news, the spread was fast, and I was worried if it would become widespread. But at that time I was not as panicked as when it entered Indonesia, it was still in China." Some participants avoided information during this phase, especially in view of the surge in false news and hoaxes; this was the approach taken by Dewi (26, F), Budi (36, M), Rini (31, F), and Butet (29, M) to the ongoing situation. The educational background of the participants, who had all reached university level, helped them to search for more information to discover what was actually going on, fill in their knowledge gaps, and validate the various sources of information they obtained. In the words of Dewi (26, F):

"When the news reported that the virus was only in Wuhan, it didn't seem like there was much risk, but when the virus spread to another nation, it began to raise concerns that it would reach Indonesia as well. [... I was] reading articles about the virus, and doing as much as possible to find articles or research about the COVID virus, which turned out to be what was previously known as SARS-CoV, but unfortunately at that time there was not much research on COVID-19."

5.2. National Lockdown Phase

When the Indonesian government officially announced the first case of COVID-19 in Indonesia, this highlighted in the minds of the public the increased risk, and there was a particular focus on the risk of infection through physical contact with contaminated objects. This phase spanned from March 2020 until the end of April 2020. The participants received the news about the first positive case in Indonesia via social media. This also aligns with Rini's (31, F) statement: "I think I heard the information from social media, to begin with, and then browsing through the news on TV or online."

In this phase, the participants had to adapt to overcome the new challenges and deal with the restrictions on daily activities. They began to switch to using various forms of digital media to interact. This change in their usual habits initially felt quite tricky. However, after a little time, they began to get used to the different technology. In the words of the participant Butet (29, M): "Actually it was hard at first, because I am not from an era where I frequently use various social media platforms to interact, such as Zoom." Sunbathing in the morning also became a new habit for some participants during the lockdown. Guntur (25, M) described Indonesians' indifference to the initial spread of COVID-19, up to a thousand confirmed cases. He began wearing a mask due to public warnings and faced difficulty visiting certain areas.

Indah (25, F) experienced a similar situation:

"It was difficult at the beginning, due to some devices not being able to support online activities […] to be able to communicate more effectively, as we were faced with a situation that didn't allow it. So maybe adaptation was more about familiarization."

During this phase, the participants searched for information on how to prevent transmission and how to boost immunity through nutrition and vitamins, including the consumption of "jamu," which is a traditional Indonesian herbal beverage known for its efficacy in boosting the immune system to prevent diseases. They followed tips for maintaining health taken from social media or appeals from the health authorities, as well as guidance on religious worship during the lockdown period. Rini (31, F) described the information she received in these terms:

"At that time, it was all about masks, from the introduction of the masks, the problems involved and which types were effective, to the point that we needed to wear double masks, like that. Then getting familiar with washing your hands with soap, social distancing, and so on."

5.3. COVID Zero Phase

The COVID Zero phase in Indonesia was known as Large-Scale Social Restrictions, or *Pembatasan Sosial Berskala Besar* (PSBB), and the Enforcement of Restrictions on Community Activities, or *Pemberlakukan Pembatasan Kegiatan Masyarakat* (PPKM), spanning June 2020 to January 2021. With the risk of infection from inhaling virus particles in the air (aerosol transmission) now recognized, this phase introduced the mandatory wearing of masks for daily activities, and the avoidance of any activities that would involve a crowd. During this phase, there were numerous Indonesians who were not yet familiar with the use of health protocols. In relation to this, Budi (36, M) remarked: "From the beginning of the pandemic, yes, our people have shown a low level of obedience in following the rules, socializing and such like; at least, that is how I see it, around me."

The collective nature of Indonesians contributes to non-compliance, possibly due to their inclination towards gathering and socializing.

The participants' strategies to meet their information needs included searching for information about symptoms, how to prevent transmission, restrictions on people's mobility, mortality trends, and self-isolation. Indah (25, F) described the way she fulfilled her own information needs at this time in these terms: "During the activity restrictions, the number one thing was to search about how to manage COVID, what to do if infected, the medicines that could be used, other than the standard drugs, and vitamin supplements, any supplement that could suppress the virus." Ulfah (25, F) and Rini (31, F) also searched for information about foods and vitamins that could boost immunity and prevent transmission. Dewi (26, F) noted that her information browsing took in various information sources, including Google searches, online news sites, telemedicine, and fact-checking or information evaluation sources for paramedics. Susi (26, F) described the trust she placed in the information provided by the health authorities when browsing for information:

"For me, I was looking a lot for information, is it happening or not, the truth, and what I probably believed the most was the information from the authorities, specifically the Health Ministry; the information they relayed about the current condition, that is what I believed. Even though in reality, I didn't know."

A similar situation was described by Budi (36, M), who referred to all the information he found about conspiracy theories, the need he felt to verify it, and how he eventually sought to avoid such information:

"I tried looking for as much information as possible to prepare for the worst. However, when I was reading on social media or websites, at that time, there were a lot of people who did not believe in COVID — conspiracies and such. […] It was like, I tried to verify the statements from groups opposed to the pandemic, but it confused me as to which statements were true. I didn't find the correct statement. So, instead of making myself confused by other people's statements, like Mr. X or Mr. Y and people who probably didn't believe the pandemic, I purposely didn't read the information when the names of such people popped up. Anyway, I just skipped those kinds of conspiracy theories, other than to know that there were still people out there who didn't believe it."

5.4. Vaccine Dilemma Phase

This phase was distinguished by the faster virus transmission caused by the new variant of COVID-19 and by the beginning of a mass vaccination campaign for the population as a means to end the pandemic, which took place from February 2021 to May 2021. The information needs of the community had changed, as the COVID-19 vaccination policy was implemented to reduce transmission and the number of cases. Apart from the potential side effects, the halal status of the vaccine was a specific concern for the majority of participants. This reflects apprehensions related to the religious aspects or beliefs regarding the vaccine's usage. This phase was also characterized by the spread of various hoaxes and misinformation about vaccines that were introduced into the community. Hasan (24, M) looked for information relating to the vaccines, from the different types to the side effects: "I looked for the side effects of the vaccine on the receivers, using trusted sites, the indication of the vaccines, and also information about which type of vaccine had been sent to different countries. That's what I looked at."

Indah (25, F) also wanted as much information as possible about the vaccine before receiving one: "I needed a lot of information to understand about the vaccine." Ayu (25, F) said that in order to remove her doubts about vaccination, she looked for additional information to make sure the vaccine was safe: "At that time, I was still hesitant about vaccines. We know that vaccines are a weakened virus injected into our body. The virus enters our body, so it makes us immune automatically. However, what if we're not immune? I started overthinking like this at this time."

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The participants agreed that the vaccines were one of the things that made it possible to live a normal life again. Dewi (26, F) stated that her reason for getting vaccinated was so she would be able to restart normal activities:

"That was my initial reason, mainly for the freedom of doing normal activities again. At that moment, I thought, in the future there is no guarantee that we won't get infected if we don't receive a vaccine. What are the consequences for us? So, following some articles and information from health workers, we need to understand that receiving the vaccine will at least minimize the side effects if we get infected by COVID; so, from that, I concluded, oh, it's better for me to be vaccinated now rather than not, because if I don't and I get infected, the effects will be worse."

In similar terms, Butet (29, M) commented:

"My reason first and foremost was because I assumed there was definite information that vaccination was the primary way out to get out of this pandemic […], so I ought to get vaccinated."

When the campaign started, there was some misinformation encountered by the participants. For example, Dewi (26, F) commented: "Probably the most intense ones I avoided were what people call the anti-vaccine groups." Hasan (24, M) also avoided information that suggested people should not get vaccinated: "I avoided information relating to vaccine denial. For example, things that said that vaccines are dangerous, vaccines cause death, and vaccines have a microchip in them. I immediately avoided this. I don't believe it anyway." Guntur (25, M) described his strategies for limiting his exposure to vaccine misinformation before getting vaccinated: "I largely avoided this information before getting vaccinated, because such information could make me reluctant. But in the end, I couldn't help but look for vaccine information, because I didn't want to spread the disease either."

5.5. Delta Response Phase

In this phase, the risks that were current related to the surge in daily infection numbers and deaths in the community brought about by the Delta variant of COVID-19. This phase took place from June 2021 and subsided by September 2021. This mainly infected people who had not been vaccinated. Thus, the vaccination campaign was intensified at this time, in response to the increasing number of confirmed cases and deaths. The kinds of health information the participants encountered during this phase differed greatly from the previous phase, especially with regard to appeals to follow health protocols, and the obligation to participate in the vaccination program.

During this phase, even though they had received the vaccine, the participants were concerned about being infected by the Delta variant because it had more severe symptoms than the previous variant. The most dangerous risk was infecting family members and causing their death. Rini (31, F) voiced her experience of losing her friends: "I was worried at this time, there were a lot of victims, and many of my friends from the same year, my close friends, passed away." Guntur (25, M) noted that the information he avoided was the rise in the mortality rate after the arrival of the Delta variant. Speaking about the situation with the Delta variant, Dewi (26, F) remarked:

"At that point, fear of this Delta variant increased. Moreover, there were also symptoms like difficulty breathing, and there were a lot of people who hoarded portable oxygen tanks and the like. So, in my opinion, this was a serious disease that's not to be joked about, and the pandemic set back the whole world. […] I was clearly afraid that I was going to get infected, and spread it to those around me. That was what I was most afraid of."

The participants also explained that they avoided information during this phase in order to keep their emotional stability. They also recognized the severe risks in ignoring the appeal to implement health protocols. This is what Hasan (24, M) had to say:

"At the time, I always avoided such information. So I didn't panic; I didn't fear the disease. I kept myself healthy by doing this during the Delta phase; I kept my quality of life, preventing infection by frequently washing my hands, wearing a mask, and keeping my distance."

5.6. Living with COVID Phase

In this phase, people started going back to their normal activities; they were not looking for all the latest information as intensely as before, and were no longer avoiding information. This phase extended from October 2021 until December 2022, characterized by the relaxation of health protocols and the spread of the Omicron variant, which resulted in mild symptoms for COVID-19 patients. The participants only focused on what guidance needed to be followed when the situation got back to normal with the return of crowd activity in the community. Ulfah (25,

F) referred to the moment she realized normal activity had returned by commenting, "I could do my activities normally again, yeah, in the middle of 2022." On the other hand, Dewi (26, F) felt that the normal situation where people were gathering on the streets or in markets only returned at the end of 2022:

"For example, people started to crowd again in the streets afterwards. From 2020 till the end of 2021, the streets were empty. The streets began bustling again around the middle of 2022, the streets were crowded again with people, and there were a lot of street vendors back. I concluded from this that the situation was back to normal."

Butet (29, M) compared the new normal situation with the return of crowds and added the changes in people's behavior of using masks to the time before the pandemic occurred: "I think life is back to normal, because some activities that were prohibited before are now allowed, and we can also finally do stuff directly face-to-face; and the use of masks has loosened, we don't always have to wear a mask." The changes in behavior in this phase of living with COVID-19 were described as a normal situation, because people had adapted to the various new habits. This was commented on by Guntur (25, M) and Susi (26, F). According to Guntur (25, M):

"Also like, everywhere you go, you still have to maintain health protocols, such as wearing a mask and social distancing. I started implementing these even before Jokowi's President announced that we're free from COVID. But living with COVID still has me worried; I'm worried I'll get infected again, and that I get infected by the delta version."

Similarly, Susi (26, F) commented:

"At peace with it, I won't say we're at peace. I'm already used to wearing masks when there is a crowd. Although now the information is that we can remove our mask for outdoor activities, even if it's crowded, it's impossible and uncomfortable, because I'm just used to wearing a mask. So I keep that in mind."

In this phase, the participants were not as engaged in searching for or avoiding information, because their information needs were changing due to the pandemic situation. They preferred to utilize the information they had already gathered, mainly about the health protocols that were still applicable. Ayu (25, F) indicated that the pandemic had taught her to familiarize herself with a new set of habits, such as utilizing digital media, like Zoom meetings: "We're used to Zoom meetings, and work from home, nowadays doing activities this way just feels normal." Finally, the participants referred to the way different risks had occurred at different times during the pandemic. In the words of Rini (31, F), "Looking back to the beginning of COVID, this was really a period of uncertainty, because we still didn't know, the world didn't understand how to deal with it."

6. DISCUSSION

6.1. Information Behavior When Faced with COVID-19

The information behavior strategy of the participants changed significantly as the pandemic situation and the level of risk they faced also changed. Initially, people were looking for information to understand this new and uncertain situation. The participants relied on primary information sources such as health authorities (specifically, the Ministry of Health and the World Health Organization) and news outlets to get guidelines and all the latest information. This aligns with the findings of Andalibi and Garcia (2021) about information needs mainly being fulfilled by health authorities.

Information needs significantly influenced the participants' information behavior strategies during each phase of the pandemic, and these were also influenced by changes in the health protocols and recommended preventive actions. Individuals started to look into information about vaccines, dosage, side effects, and availability the moment they entered the Vaccine Dilemma phase. The spread of the Delta variant also triggered an increased need for information on threats relating to this variant. During this phase, individuals also avoided some information and limited their information exposure, which served as a practical approach for protecting themselves from information they could not handle, as has also been seen among cancer patients (Jensen et al., 2022).

Throughout the pandemic, the participants continued to adapt their information behavior strategies. They needed accurate and reliable information to be able to make informed health decisions. This strategy reflected people's need to keep up-to-date with the development of the pandemic. The change in information behavior strategy, which was random at the beginning of the pandemic but later became increasingly organized, was due to the way the knowledge gap of the participants was filled as the

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pandemic went on. This is reflected in a comment by one of the participants that the uncertainty of the situation gradually became clearer as events progressed.

The participants made use of considerable information from the Internet and social media. This evoked the principle of carefulness in choosing information validity, with the need to take into account the authority of the writer, quality, relevance, and objectivity influencing the participants in their search for and use of information during the pandemic. This finding is in line with Sbaffi and Rowley (2017)'s research regarding web-based information seeking, and the way the credibility level and trustworthiness of the information available on a website page influence this interaction of participants. This also applies to information seeking on social media, where the information behavior strategy needs to consider the credibility factor of the information sources themselves (Osatuyi, 2013; Soroya et al., 2021).

Based on further analysis, we found that participants developed various information behavior strategies, which we categorized into two core categories during the COVID-19 pandemic. There are two frameworks of information behavior strategies: (1) *Pandemic Crisis Understanding*: This framework provides an overview of the recurring information behavior strategy cycle of participants, starting with understanding the evolving situation and risks before the crisis occurs (phase 1), during the crisis (phases 2 to 5), and after the crisis (phase 6) until the situation returns to normal; and (2) *Information Behavior Needs and Strategies*: Individual understanding ultimately creates an information need, which is part of the process of identifying individual knowledge gaps caused by changes in threats and health protocols during the ongoing health crisis.

6.2. Local Knowledge and Sensemaking Process Amid the COVID-19 Pandemic

The sensemaking process in relation to the COVID-19 pandemic involves an individual's active behavior in understanding, identifying, interpreting, internalizing, and responding to information to resolve their knowledge gap during this period. The participants utilized information from various channels to understand the situation that was occurring. The right information behavior strategy helped individuals to understand the ever-changing nature of the pandemic quickly. In each phase, all of the participants recognized the situation and their relevant information needs, such as information about virus transmission, nutrition, health protocols, or vaccination. Interpreting new information alongside their existing knowledge base helped them to respond to the changes that occurred throughout the six phases of the pandemic, whether in terms of preventive measures, persuasive measures, or both. Moreover, they internalized and responded to the information in order to make the best health decisions for themselves.

Paying attention to their own knowledge gap, the participants moved as the situation changed from an active sensemaking process when their knowledge base was not met, to a habitual mode when their information needs had been met, and less effort was required in relation to any health actions. This again reflects work by Mamykina et al. (2015b). This is also in line with Wilson (2020)'s position that individuals choose to make the minimum effort and consider emotional factors in deciding their information behavior strategy. In addition, the sensemaking process undertaken by the participants was one of information seeking and avoidance, which ensure a sense of normality in a situation full of uncertainty. The participants were faced with events that shook their beliefs about when they could return to normal activities, and involved various health-related decisions, such as wearing masks, getting vaccinated, or avoiding the news about deaths.

The participants utilized local knowledge as their information source to help them recognize the dangers and improve their understanding of the situation and security risks during the pandemic. This included information on the mortality rate and the number of positive cases at the time, the crowd situation in the streets or markets, or the level of mask usage in the geographical neighborhood where they lived. In addition, they also shared information about herbal remedies, especially traditional herbal concoctions or "jamu," to strengthen the body's immunity during the pandemic. The participants received this local knowledge not only through direct observation, but also from family, friends, and coworkers, which is a standard information-sharing practice among Indonesians. This is also in line with the findings of Montesi (2023)'s study in Madrid of the "new normal" situation of the pandemic, which examined changes in perceptions of the situation and the risks of the pandemic in terms of people's responses to their local environment and their use of information exchange.

In interviews, participants depicted a high level of solidarity in the community, where mutual assistance is a common experience. Participants undergoing self-isolation at home often received support in the form of food, vitamins, and daily necessities from neighbors, creating

an atmosphere of mutual care. This practice supports the care of those who are unable to leave their homes freely during the pandemic.

As the population with the largest Muslim population in the world, during the pandemic, Indonesian society paid significant attention to religious information related to the ongoing pandemic situation. Muhtadi and Soderborg (2023) indicate that the level of fear and behavior during the pandemic was closely associated with religious factors among Indonesians. As described by the participants, in addition to following health authorities, they underscored the importance of religious information from the Indonesian Ulema Council (*Majelis Ulama Indonesia* or MUI) or local religious organizations in making health decisions. This includes considerations regarding the permissibility (halal status) of vaccines, procedures for burial during pandemic situations that are different from normal conditions, and directives against gathering and the use of masks during worship, as responses to the prevailing health protocol guidelines.

Based on further analysis in the sensemaking process, we developed two core categories that explain how participants engaged in the sensemaking process: (1) *Crisis Knowledge Sources*: In meeting these needs, individuals are prompted to address existing knowledge gaps using various strategies of search, avoidance, limitation, use, and evaluation of information by exploring available information resources, supported by processes of interpretation, internalization, and response to available local knowledge throughout the ongoing pandemic; and (2) *Outcomes for Deciding Health Actions*: Consequently, this results in outcomes to fill knowledge gaps as a stage of internalization, and continued alternating processes of sensemaking and habitual modes to make appropriate health decisions. These were random at the beginning of the pandemic but became more regular in later phases. This was influenced by the "knowledge gap fulfillment" and "use of local knowledge."

7. RESEARCH LIMITATIONS

This study has described the information behavior strategies and sensemaking process used by Indonesians during the COVID-19 pandemic. Qualitative research utilizing interviews with a limited sample supports the interpretation of the findings precisely and in detail. We are aware that the small sample size of 10 participants is a limitation of this study. However, the developed research design has provided us with rich and in-depth data. This study does not aim to generalize to the wider population, but to provide an early depiction of information-seeking strategies and sensemaking processes during this global crisis. The study suggests the transferability of these findings to other similar cases and crises (Maxwell, 2005). Another limitation of this study is the fact that the participants were all from Indonesia, and living in various cities on Java Island. We recognize that the lack of diversity in domicile and other cultural characteristics of the participants may influence the results. However, we have produced the analysis and findings from a number of themes and categories that repeatedly emerged in the interview data with the participants. Future research may address this issue by using more significant and more diverse samples.

8. CONCLUSION

The conclusion of this study states that the participants' health information behavior in the six phases of the COVID-19 pandemic underwent changes and adjustments in strategy. Their approach was random at the beginning but became increasingly organized as the situation moved towards normalcy. This is influenced by the factors of "knowledge gap fulfillment" and the "utilization of local knowledge" that communities have been following during the COVID-19 pandemic, as outlined in the framework we have developed. Furthermore, the changing risks and situations in each phase of the pandemic gradually influenced the communities' process of sensemaking, decision-making, and building their understanding regarding this protracted health crisis.

Based on the findings of our further analysis, we attempt to connect core categories and propose a framework for behavior-based information strategy understanding aimed at mitigating risks and reducing ongoing health crises. This framework comprises four components: Pandemic Crisis Understanding, Information Behavior Needs and Strategies, Crisis Knowledge Sources, and Health Action Decision Outcomes. The framework aims to enhance the individual's health decision-making processes during the crisis. The framework commences with comprehending the situation and context during the COVID-19 pandemic crisis to identify information needs, followed by identifying relevant crisis knowledge channels and sources, such as social media, television, or direct communication from family or colleagues, receiving pandemic-related information from health authorities, along with utilizing local knowledge related to self-care

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during the crisis. Furthermore, active efforts to identify, interpret, internalize, and respond to required available crisis information throughout the ongoing pandemic were undertaken to make appropriate health decisions at each phase based on the risk level. This process was carried out through alternating sensemaking and habitual modes throughout the COVID-19 pandemic crisis phases. Amid a community often neglectful of health protocols, and the spread of misinformation and conspiracy theories which was widespread during the crisis, this framework was crucial in integrating individual sensemaking understanding with social processes such as dialogue with others. This aimed to enhance individual's understanding of the crisis risk situation they faced and the necessary health decisions to be made.

This study provides empirical evidence of the utilization of a knowledge base derived from the participants' experiences in health information behavior during the health crisis, as their understanding of the situation, risks, and the management of health protocols changed. This shows the value of Montesi (2021)'s proposal for further study into the COVID-19 pandemic. Furthermore, this study also answers the challenges raised by Krakowska (2020) regarding the lack of research on information behavior in crises, especially on the changes in people's individual information behaviors when faced with a health crisis, which are not commonly covered in the literature. These preliminary findings can be used for future research to study how the described changes in the information behavior strategies of individuals may be relevant to other crises, such as natural disasters, economic crises, or sociopolitical crises in particular regions.

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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Point of Interest Recommendation System Using Sentiment Analysis

Gaurav Meena*
Department of Computer Science, Central University of Rajasthan, Ajmer, India
E-mail: gaurav.meena@curaj.ac.in

Ajay Indian
Department of Computer Science, Central University of Rajasthan, Ajmer, India
E-mail: ajay.indian@curaj.ac.in

Krishna Kumar Mohbey
Department of Computer Science, Central University of Rajasthan, Ajmer, India
E-mail: kmohbey@gmail.com

Kunal Jangid
Department of Computer Science, Central University of Rajasthan, Ajmer, India
E-mail: jangidkunal1999@gmail.com

ABSTRACT

Sentiment analysis is one of the promising approaches for developing a point of interest (POI) recommendation system. It uses natural language processing techniques that deploy expert insights from user-generated content such as reviews and feedback. By applying sentiment polarities (positive, negative, or neutral) associated with each POI, the recommendation system can suggest the most suitable POIs for specific users. The proposed study combines two models for POI recommendation. The first model uses bidirectional long short-term memory (BiLSTM) to predict sentiments and is trained on an election dataset. It is observed that the proposed model outperforms existing models in terms of accuracy (99.52%), precision (99.53%), recall (99.51%), and F1-score (99.52%). Then, this model is used on the Foursquare dataset to predict the class labels. Following this, user and POI embeddings are generated. The next model recommends the top POIs and corresponding coordinates to the user using the LSTM model. Filtered user interest and locations are used to recommend POIs from the Foursquare dataset. The results of our proposed model for the POI recommendation system using sentiment analysis are compared to several state-of-the-art approaches and are found quite affirmative regarding recall (48.5%) and precision (85%). The proposed system can be used for trip advice, group recommendations, and interesting place recommendations to specific users.

Keywords: recommendation system, point of interest, sentiment analysis, neural networks, BiLSTM

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***Corresponding Author:** Gaurav Meena
https://orcid.org/0000-0001-5528-2437
E-mail: gaurav.meena@curaj.ac.in

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1. INTRODUCTION

Individualized suggestions for goods, services, and locations are provided by recommendation systems, which have become an indispensable part of our day-to-day lives. These suggestions are derived from our preferences and actions. One such system is a point of interest (POI) recommendation system, which recommends popular and relevant places based on user interests and location (Acharya et al., 2024). The POI recommendation system using sentiment analysis (SA) has potential applications in various domains, including tourism, hospitality, and marketing. By providing personalized recommendations for the user and emotional preferences, the recommendation system can enhance user engagement, increasing user loyalty and revenue for the business using SA. In conclusion, POI recommendation analysis is a promising approach to providing users with tailored and enhanced travel experiences (Xu et al., 2019). One approach to improving the accuracy of POI recommendation systems is through a method for determining the emotional tone of a passage of text, known as SA. SA can be applied in the context of POI recommendation systems to analyze the sentiments indicated in user reviews of various places like restaurants, hotels, tourist attractions, and more. By using SA, the system can gain insights into the overall satisfaction of users with a particular place and make better recommendations to users based on their preferences. Integration of SA into POI recommendation systems is being done to provide consumers with suggestions that are more accurate and more tailored to their specific needs. By analyzing the sentiments expressed in user reviews, the system can identify highly recommended users and recommend them to users with similar preferences. It can increase user satisfaction and engagement with the recommendation system. In addition, using SA for POI recommendation systems can help businesses improve their products and services based on user feedback. Utilizing user SA, businesses can identify areas for improvement and make adjustments to their products and services to better meet the requirements and expectations of their clientele. According to Mishra et al. (2020), using SA in POI recommendation systems can enhance the accuracy of suggestions, boost user happiness, and offer meaningful feedback to different enterprises.

This study aims to develop a recommendation system for POIs that considers the sentiment of user reviews. The challenge is to provide accurate and relevant recommendations despite the large number of POIs available and the diverse interests of users. To handle this challenge is our research problem, and so this study proposes using SA to determine the sentiment of user reviews about a particular POI to address this challenge. The proposed system will recommend POIs that have positive, negative, or neutral sentiments based on user reviews. The proposed solution uses a bidirectional long short-term memory (BiLSTM) model for SA and an LSTM model for POI recommendation. The proposed POI recommendation system will take input such as the user's ID, location, and interests, and recommend POIs within a radius of 5 km from the user's location that matches the user's interests and has a positive or neutral sentiment. The goal is to develop a personalized POI recommendation system that incorporates the sentiment of user reviews. Based on user choices and reviews, the POI recommendation system employs SA to give POIs tailored to their specific needs. The study aims to contribute the following objectives:

- Enhance User Experience: Through the provision of more tailored suggestions that are derived from the user's preferences and the SA of their evaluations, the model that has been developed intends to enhance the user experience significantly. It will make it easier for users to find the most suitable POIs.
- Increase User Engagement: By providing personalized recommendations, the proposed model aims to increase user engagement and encourage users to use the system more frequently.
- Improve POI Selection: The proposed model aims to improve the selection of POIs by considering the users' preferences and analyzing their reviews' sentiments. It will help users find the most suitable POIs that match their interests and preferences.
- Increase User Satisfaction: The proposed model aims to increase user satisfaction by providing personalized recommendations that match their preferences and interests. This will make users more likely to recommend the system to others.
- Improve Business Outcomes: The proposed model aims to improve business outcomes by increasing user engagement and satisfaction, which can lead to increased revenue and customer loyalty for businesses the system recommends.

The proposed study is subsequently organized into five sections. Specific significant studies on SA and POI recommendation systems are reviewed in Section 2. Section 3 explains the proposed approach, covering a summary of the datasets utilized in the study, the proposed SA model,

and the POI recommendation model using SA. In Section 4, the results of the suggested models are discussed. Finally, Section 5 concludes the present study by discussing findings and giving some future scope of study.

2. LITERATURE REVIEW

A good recommendation system should have as its primary objective the provision of consumers with a collection of suggested destinations that are a great match for their preferences. People who use location-based social networks (LBSN), often known as LBSNs, might benefit from user recommendations of their favorite local attractions, such as shopping centers and restaurants (Zhang & Chow, 2015). Users can post their positions and share their ideas on interesting regions to visit via LBSNs. The conclusions drawn from these discussions may then be applied to making suggestions to other users. According to Yu et al. (2019), the objective of a recommendation system is to provide consumers with a list of locations and items most closely aligned with their preferences.

According to Ding and Chen (2018), local business social networks are online communities where members can search for particular areas of interest and broadcast their geographical whereabouts through check-ins. LBSNs like Foursquare and Yelp attract attention since they allow finding new locations to add to favorites lists. Therefore, individualized suggestions for POI recommendation are important. It is possible to model people's unique choices using the wealth of user and POI data found, including check-in data, POI locations, and classifications. The algorithmic procedure for recommending POIs has been through a relatively protracted development period. It starts with collaborative filtering methods and tensor decomposition algorithms and then moves on to using deep learning algorithms to mine the geographical preferences of users. Because of the inherent graph structure of POI data, the development of graph neural networks has led to a change in the focus of a substantial amount of research toward applying graph neural network algorithms for POI recommendations (Ma et al., 2018). Liu et al. (2018) proposed a modified Feature-Scaled Unifying Algorithm system to obtain important POIs from temporal features using non-negative matrix factorization. The results suggested the importance of time in physical space.

An Adversarial Point-of-Interest Recommendation (APOIR) model for examining the distribution of latent user preference for POI recommendation is proposed by Zhou et al. (2019); the recommender (R) and the discriminator (D) are the two main components of APOIR. By maximizing the likelihood that these POIs are expected to be unvisited and possibly fascinating, the recommender makes recommendations based on the distribution learned. The discriminator is responsible for distinguishing between recommended and actual check-ins and providing gradients to provide direction for improving R within a rewarding framework. The two components are co-trained using the same method by playing a minimax game, in which one of the components wants to develop while pushing the other to the maximum. APOIR incorporates geographical and social relationships between POIs into the reward function and optimizes R through reinforcement learning. Compared to state-of-the-art approaches, the suggested strategy achieves considerable performance improvements in four standard criteria. Zhou et al. (2019) contribute to a better understanding of the critical user check-in behavior in POI recommendations. They introduce a novel method for productively learning latent user preferences.

Wang et al. (2019) proposed mine trust-based POIs using modified collaborative filtering — the model of a fusion of temporal and spatial features based on the user's physical space. Most POI location recommendations made by recent studies employ conventional collaborative filtering recommendation techniques. For instance, a 3-layer network framework POI recommendation approach using LBSN was proposed (Zhang et al., 2019). Additional tags, social and geographic data, and other data are modeled individually and incorporated into a matrix factorization framework. Although this technique is more accurate than previous methods, the performance of recommendations as a whole still needs to be enhanced. According to Yu et al. (2019), a POI recommendation system supported by the semantics of the user's contextual behavior is proposed.

A continuous POI recommendation approach utilizing latent variables with recurrent neural network was proposed by Lu et al. (2019). Recommending POIs combines the preferences of users and sequential access to POIs. There is still scope for enhancement of the extraction of prospective knowledge despite the method's better precision than continuous POI. Zhao et al. (2021) proposed mine sentiment-based POIs from the users' rated data. The approach showed enhanced results. Sun et al. (2020) proposed the long- and short-term preference modeling model to extract users' long- and short-term preferences for personalized POI recommendations. Dang et al. (2020) presented a detailed study on the SA models using various

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algorithms like deep neural networks, convolutional neural network, recurrent neural network, term frequency-inverse document frequency or word embedding on the series of datasets. Dai et al. (2019) introduced a new neural network approach to context-aware citation recommendations by combining stacked denoising autoencoders and BiLSTM.

The use of SA in POI recommender systems was examined by Mishra et al. (2020). They pointed out that with the rise of the tourism sector and the Internet, data is available about various POI locations, making it difficult for users to make informed selections. The authors proposed a model that uses review data to select POIs that fit their interests. They use the Sentiment Intensity Analyzer to calculate the mean value of sentiment weightage in the reviews and suggest top places based on the score. User preferences were derived through semantic clustering and the SA of their comments and reviews (Abbasi-Moud et al., 2021). The features of tourist attractions were extracted. The proposed recommendation system was based on contextual information such as weather, time, location, user preferences, and the similarity of tourist preferences to nearby attraction elements.

A deep learning-based POI recommendation strategy in LBSNs is also proposed (Liu & Wu, 2021) to address the challenges of data sparsity and a lack of negative samples that affect many POI recommendation systems. A BiLSTM attention mechanism assigns weights to different parts of the current sequence following the user's long-term and short-term preferences. Using the user's past and the current POI sign-in sequence, the suggested method records the whole sequence.

The encoder data is then given into the BiLSTM-Attention algorithm, representing the current POI sign-in sequence based on attention. The decoder then goes over it to provide a Top-N recommendation list. Previous approaches illustrated in Sachin et al. (2020), Murthy et al. (2020), Aman et al. (2020), and Das et al. (2021) have used SA in different perspectives for mining content from text. Dang et al. (2021) proposed an integrated SA and recommender system combination. The results were quite efficient. As explained, SA has varied applications in online advertising (Zhao et al., 2021). Naresh and Krishna (2021) deployed machine learning models for SA, demonstrating the potential of machine learning models.

An LSTM-LSA-based model was presented by Wang et al. (2023) to create a more secure recommendation system for POIs, with privacy serving as the determining criterion. The Stan model, defined by Luo et al. (2021), proposed a POI recommendation model based on a self-attention layer from mining spatiotemporal features-based POIs. It is a key feature for travelers to be able to visit, in the order of their preferred destinations, beginning from the network site, which provides them with advantages such as access to shopping malls and restaurants, among other options. Several factors determine the collection of locations and the choice of those locations, the most important of which are the orders given by consumers to locations, the distance between them, and the total amount of time spent on the trip. A prototype is developed for a system that may be used to fulfill consumers' visitation requirements and can deliver packages in sequences determined by their locations (Mohbey et al., 2021).

In order to mine user-interested POIs, Hossain et al. (2022) presented the context-aware recency-based attention network model, which used contextual information. In order to examine the connections between social media and its impact on community-based tourism, Khruahong et al. (2022) suggested a BiLSTM model incorporating a Social Media Sensing framework as SA. Effectively illustrating nonlinear and linear relationships between the user and the object is the strength of deep learning (El Alaoui et al., 2022). Data sources like images and texts are mined for their underlying relationships, which are extracted. Learning and training are predicated on refining a process to reduce reconstruction error. Deep learning can take data from any source and transmit it to the output using categorization. This exemplifies deep learning's primary benefit. Alemayehu et al. (2023) proposed a SA system for the Amharic language.

Based on the literature review, it is clear that the POI suggestion system could use some work because the current systems are not very good at recalling points and being accurate. It is also evident from the review that this improvement can be achieved using SA to develop the POI recommendation model.

3. POI RECOMMENDATION SYSTEM USING SA

The proposed model aims to address the limitations of the existing models by incorporating SA to provide more personalized and relevant recommendations. Fig. 1 depicts the detailed procedures involved in the proposed POI recommendation model, such as data loading, preprocessing, model training, and user input processing, which leads to the final recommendations. Overall, the proposed model can improve the user experience by pro-

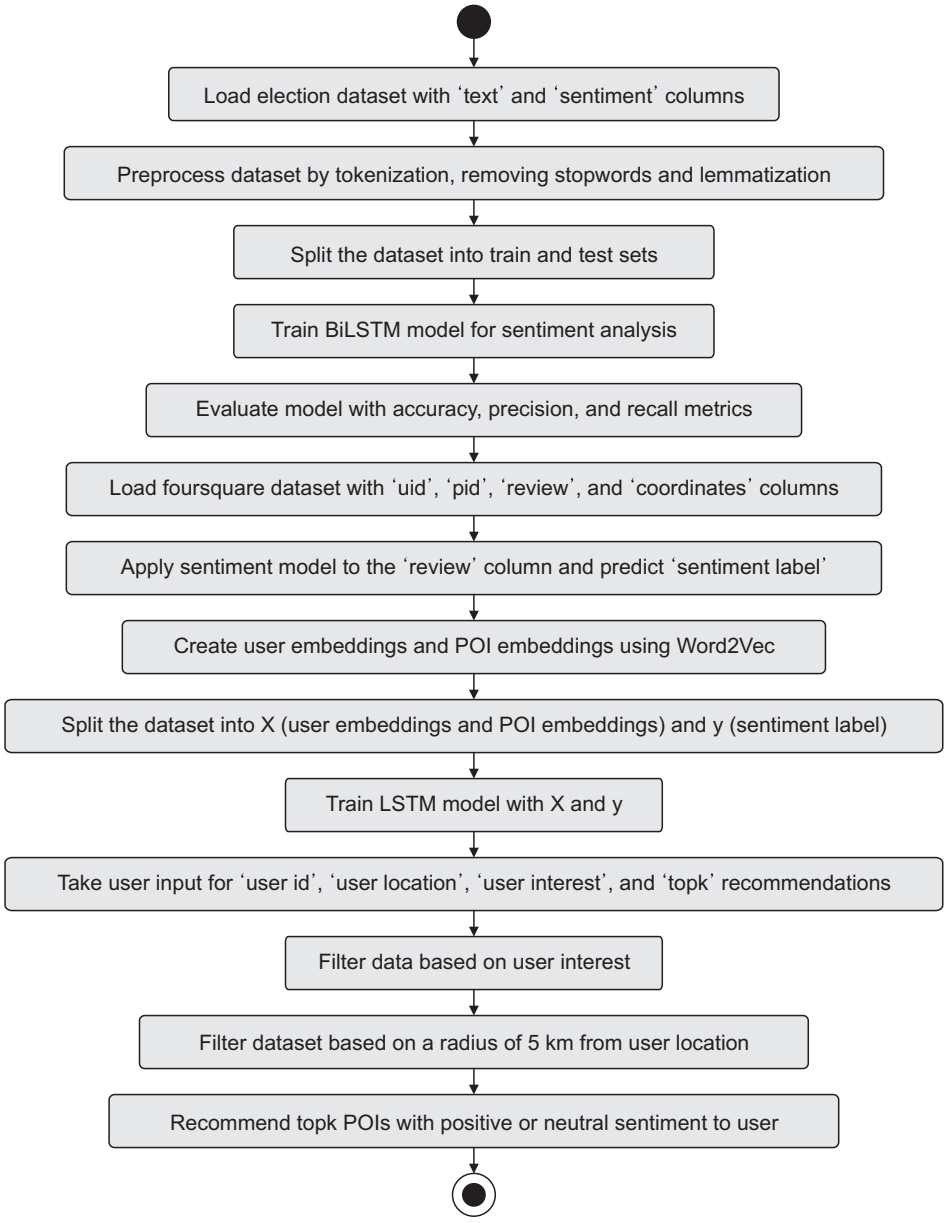


Fig. 1. Procedure involved in proposed POI recommendation system using sentiment analysis. POI, point of interest; BiLSTM, bidirectional long short-term memory.

viding tailored recommendations, which are more likely to be of interest to the user.

3.1. Dataset and Data Preprocessing

Two datasets are used in the proposed POI recommendation system using SA: the election dataset for SA and the Foursquare dataset for POI recommendation.

3.1.1. Election Dataset

The election dataset is a labeled dataset that contains a collection of tweets related to *General Elections Held in India – 2019*.[1] The dataset was obtained from Kaggle, and the dataset has two columns: 'text' and 'sentiment,' and 162,980 rows. The 'text' column includes the tweet text, while the 'sentiment' column indicates the sentiment polarity of the tweet. The sentiment polarity can be either positive, negative, or neutral. The election dataset is used for training and testing the SA model.

3.1.2. Foursquare Dataset

The Foursquare dataset includes user reviews of different POIs, such as restaurants, cafes, and museums. The

[1]https://www.kaggle.com/datasets/cosmos98/twitter-and-reddit-sentimental-analysis-dataset

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dataset was obtained from Git Hub and collected from the Foursquare API. The dataset contains four columns: 'uid,' 'pid,' 'review,' and 'coordinates.' The 'uid' column represents the user ID who wrote the review; the 'pid' column represents the POI ID; the 'review' column includes the text of the user review of the 'pid'; and the 'coordinates' column includes the latitude and longitude coordinates of the POI.

The SA model trained on the election dataset is applied to the 'review' column to predict the sentiment of each review, and a new column, 'score,' is added to the dataset to represent the predicted sentiment. Table 1 shows the unique numbers of users, POIs, check-ins, and reviews of the Foursquare dataset.

3.1.3. Evaluation Metrics

Evaluation metrics are essential for evaluating the effectiveness and performance of a recommendation model in the context of POI recommendation incorporating SA (Meena et al., 2022). These metrics help evaluate the model's accuracy, relevance, and quality of recommendations.

$$Accuracy=\frac{(TP+TN)}{(TP+TN+FP+FN)} \quad (1)$$

$$Precision=\frac{(TP)}{(TP+FP)} \quad (2)$$

Table 1. Foursquare dataset info

Column	Numbers
Number of users	9,728
Number of point of interests	12,449
Number of check-ins	177,142
Number of reviews	234,793

$$Recall=\frac{(TP)}{(TP+FN)} \quad (3)$$

$$F1\text{-}Score=2\times\frac{Precision\times Recall}{(Precision+Recall)} \quad (4)$$

By analyzing these metrics, we can determine the effectiveness and accuracy of the models. From the metrics, we can compare different recommendation models. These metrics help understand the model's strengths and weaknesses and provide insights into areas for improvement and future research.

3.2. Sentiment Analysis Model

Fig. 2 presents the complete data preprocessing and model-building pipeline for a SA model using the Bag of Words (BOW) approach. The steps involved in the design and implementation of the proposed SA model are as follows.

Loading and Cleaning the Election Dataset: The first step is to import all necessary libraries, such as pandas, NumPy, Keras, sci-kit-learn, matplotlib, nltk, etc., and load the election dataset, which contains text and sentiment columns. Any null or missing numbers, duplicate data, and fields that are not needed are taken out of the data to clean it up.

Preprocessing: Some classes of sentiment columns have significantly fewer samples than others. Equalizing the class distribution of the sentiment score column ensures that the model is not biased toward any particular class. It under-samples each sentiment label to the specified number of samples using the resample method of sklearn.utils library. The next step is to tokenize the text data, which involves breaking down the text into a list of individual

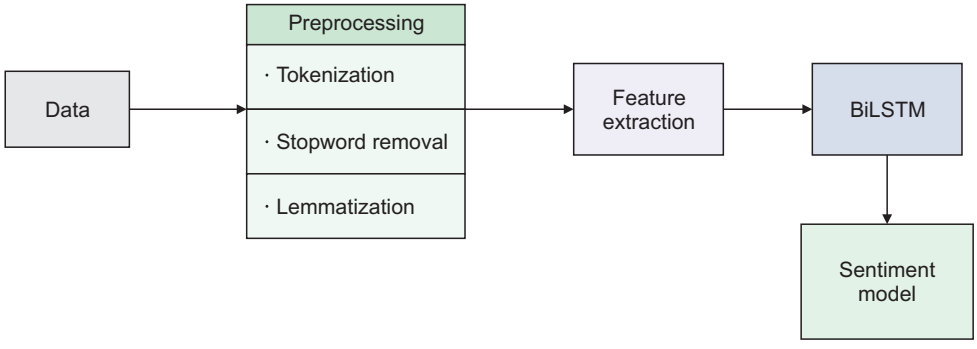


Fig. 2. Schematic diagram of sentiment analysis model. BiLSTM, bidirectional long short-term memory.

words or tokens. This process also involves removing special characters, numbers, punctuation, and non-letter characters using regular expressions, and then removing the stop words using the nltk library, which involves eliminating common terms with little or no meaning, such as 'a,' 'the,' 'and,' and so on, and in the last step lemmatization to convert words to their base form is performed.

Feature Extraction: Feature extraction is performed using the BOW approach in the proposed model. It transforms the text data into a token count matrix. The CountVectorizer method of the sklearn.feature_extraction.text library is used to perform the BOW feature extraction.

Splitting the Dataset: The cleaned and preprocessed dataset is divided into 70% train and 30% test sets. The training set is used to train the BiLSTM model, while the test set evaluates the model's performance.

BiLSTM Model for SA: Input text is first transformed into a fixed-length vector representation by an embedding layer; next, a BiLSTM layer is added to the model to learn about the text's context and meaning. In conclusion, a dense layer with a softmax activation function is utilized to predict the sentiment of the text. The architecture of the BiLSTM model is shown in Table 2.

The BiLSTM performs both forward and backward evaluations of the input sequence, allowing gathering contextual information from past and future aspects of the input sequence, making the method well-suited for NLP applications such as SA. The BiLSTM model takes preprocessed text data as input and returns a sentiment score that might be positive, negative, or neutral. The model is built with cross-entropy loss and optimized with the Adam optimizer. Various metrics are used to determine the effectiveness of the proposed SA model using the testing set. After testing, the SA model is saved to predict the sentiments of a Foursquare text review as positive, negative, or neutral.

Table 2. Architecture of proposed bidirectional long short-term memory model

Layer (type)	Output shape	Parameter
Embedding (Embedding)	(None, 50, 32)	160,000
Conv1d (Conv1D)	(None, 50, 32)	3,104
Max_pooling1d (MaxPooling1D)	(None, 25, 32)	0
Bidirectional (Bidirectional)	(None, 64)	16,640
Dropout (Dropout)	(None, 64)	0
Dense (Dense)	(None, 3)	195
Total params: 179,939		
Trainable params: 179,939		
Non-trainable params: 0		

3.3. POI Recommendations Model

In the "POI Recommendation System using sentiment analysis," the Foursquare dataset contains reviews for different POIs and their corresponding user IDs, POI IDs, and coordinates. Fig. 3 depicts a schematic diagram of the POI Recommendation Model, which includes the system processes. The Foursquare dataset review column is fed into the SA model to predict sentiment scores, which are then used to recommend POIs to users based on their choices.

Rows containing null or missing values, duplicate rows, and unnecessary columns are dropped as a part of data preprocessing. The model uses tokenization, removing stop words and other unnecessary words, and lemmatization to preprocess the text review data of the Foursquare dataset. In tokenizing and padding the review data, the function tokenize_pad_sequences() takes in the text data and tokenizes it using the Tokenizer() method from the Keras library. It then converts the tokenized text into sequences of integers using the texts_to_sequences() method of the Tokenizer object. Finally, it uses the pad_sequences() method from TensorFlow.Keras library for padding the sequences with zeros to ensure sequences of the same length. The preprocessed text is then fed into the trained SA model, which predicts the sentiments. The predict_class () function is used to predict the sentiment class of each text entry, which can be negative, neutral, or positive.

The predict_class() function takes in a text as input, tokenizes and pads it using the same Tokenizer and padding method as before, and uses the loaded model to predict the sentiment class of the text. The model takes in a sequence of words, and for each word, it produces an output that is used to predict the sentiment score for the entire sequence. The function returns the predicted sentiment class. The predicted sentiment scores are -1, 0, and 1. Here, 1 represents positive sentiment, 0 represents neutral sentiment, and -1 represents negative sentiment.

Once the sentiment scores are predicted, they are

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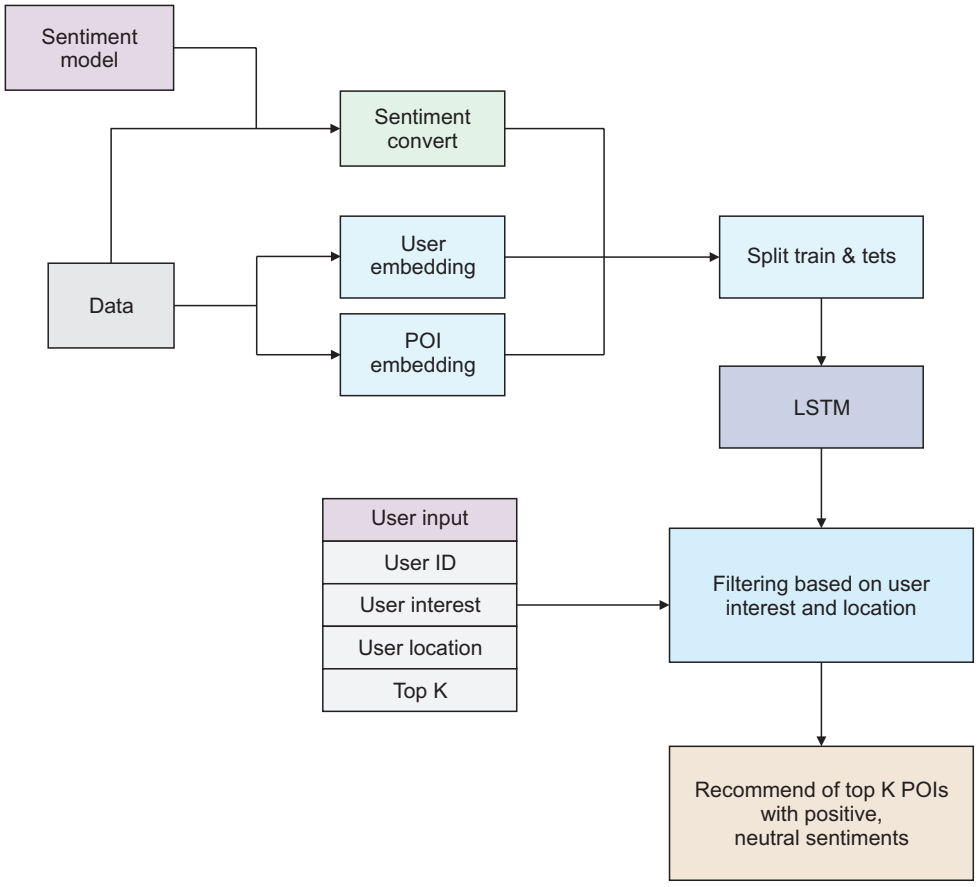


Fig. 3. Schematic diagram of POI recommendation model. POI, point of interest; LSTM, long short-term memory.

added as a new column in the Foursquare dataset, called "score." These scores are then used to filter and recommend top-k POIs with positive or neutral sentiment to the user.

To recommend POIs, the user and POI embedding are generated using the cleaned and preprocessed Foursquare dataset. User embeddings are a vector representation of each user based on their interactions with POIs. In contrast, POI embeddings are a vector representation of each POI based on the sentiment scores of the reviews. The embeddings are generated using a Word2Vec technique in the *gensim* library.

After applying the sentiment model, user and POI embedding are generated to represent each user and POI in a vector space. These embeddings are used as input features (X), and the predicted sentiment (score) is used as the target variable (y) for splitting and training the LSTM model. The dataset was then split 70:30 into train and test sets. Next, the system trains the proposed LSTM model as the architecture shown in Table 3 displays using the embedding and the user's ratings for the POIs. The trained model predicts the sentiment of POIs based on user and POI embeddings.

Table 3. Proposed architecture of LSTM model for point of interest recommendation system

Layer (type)	Output shape	Parameter
Embedding (Embedding)	(None, 100, 32)	160,000
Conv1d (Conv1D)	(None, 100, 32)	3,104
Max_pooling1d (MaxPooling1D)	(None, 50, 32)	0
LSTM (LSTM)	(None, 32)	8,320
Dropout (Dropout)	(None, 32)	0
Dense (Dense)	(None, 1)	33
Total params: 171,457		
Trainable params: 171,457		
Non-trainable params: 0		

LSTM, long short-term memory.

Then, the test dataset is used and preprocessed by tokenization, removal of unnecessary words, and lemmatization to filter the dataset based on the user's interests.

Further, a dataset is created using the list of keywords related to the user's interest (a few users' interests are defined, such as restaurant, museum, mall, library, hotel, educational, and emergency services). The process filters the data by keeping only the rows where the preprocessed "text" column contains keywords related to the particular user's interest. It then shortens the resulting data. For example, if a user is interested in "restaurants," we will filter the Foursquare dataset to include data related only to restaurants, cafes, and bars. Similarly, if a user is interested in "museums," we will filter the dataset only to include data related to museums such as museums, galleries, and historic sites.

This step ensures that the recommended POIs correspond to the user's interests, making it more likely that the user will visit and appreciate the places. To create the list of keywords related to user interest, we can combine manual curation and automated techniques, such as keyword extraction from users' previous check-ins or search queries. Applying a filtering mechanism to the dataset according to the user's interests guarantees that the suggested POIs are directly related to the user's preferences and desires. This enhances the user's overall experience and level of satisfaction.

The next step in the recommendation model is to take user input for their ID, location, interests, and the number of top recommendations they want. Based on this input, the system filters the dataset to show POIs that match the user's interests and are within a certain radius of the user's location.

After the dataset has been refined based on user interests, it is further filtered based on the user's location. It ensures that the recommended POIs are within a reasonable distance of the user's current location. The filtering is done by calculating the distance between the user and the POI's location using the coordinate information available in the dataset, increasing the likelihood that the user will visit and enjoy the places suggested. The top POIs with positive or neutral sentiments are recommended to the user.

This study aims to give users tailored suggestions based on their interests, geography, and sentiment score. These recommendations can be positive or neutral, considering the sentiment of previous evaluations. Overall, this study blends SA with geographically specific recommendations.

4. RESULTS AND DISCUSSION

This study's findings about the SA model and POI recommendation model using SA are presented, analyzed, and interpreted in this section to draw meaningful conclusions.

4.1. Sentiment Analysis Model

Table 4 displays the performance metrics of the SA model after 50 training epochs. These evaluation metrics showed that the model is good at categorizing the sentiment of text data (reviews) as positive, negative, or neutral. The model has an accuracy of 0.9952, which means that 99.52% of all reviews in the dataset were correctly classified as positive, negative, or neutral sentiment, a precision of 0.9953, which means that 99.53% of all reviews predicted as positive sentiment were positive, and a recall of 0.9951, which means that 99.51% of all actual positive reviews in the dataset were correctly predicted as positive sentiment by the model, and F1 score of 0.9952, showing that it predicts the sentiment of reviews in the election dataset fairly accurately. The comparative results of the proposed SA model and other state-of-art problems (Ale-

Table 4. Performance comparison of proposed sentiment analysis model with other state-of-art

Author	Model	Dataset	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)
Dang et al. (2020)	Deep learning	Tweets airline	90.45	93.06	95.09	94.06
Khruahong et al. (2022)	BiLSTM	YouTube comments	85.78	83.25	87.01	85.08
Alemayehu et al. (2023)	BiLSTM	Amharic political	85.27	85.24	81.67	83.42
	GRU	Amharic political	88.99	90.61	89.67	90.14
Proposed method	BiLSTM with BOW	Tweets airline	98.86	98.91	98.84	98.88
		Amharic political	98.87	99.05	98.50	98.77
		India election	99.52	99.53	99.51	99.52

BiLSTM, bidirectional long short-term memory; GRU, gated recurrent unit; BOW, Bag of Words.

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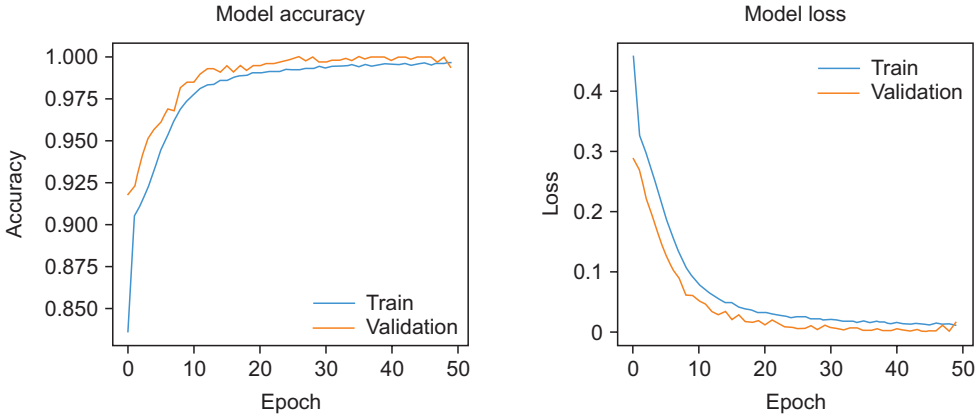


Fig. 4. Graphs of accuracy and loss of sentiment analysis model.

mayehu et al., 2023; Dang et al., 2020; Khruahong et al., 2022) are also presented in Table 4, which clearly shows that the proposed models outperform the others in performance. Further, it is observed that the proposed models outperform others when applied to the other datasets, such as Tweets Airline and Amharic Political.

A high F1 score suggests that the model has an appropriate balance of precision and recall, which are important for effective SA. Furthermore, the model consistently obtained good accuracy, precision, recall, and F1 score across 50 epochs, implying that the model is stable and does not overfit the data. The model's improved performance, as shown in Table 4, can be due to implementing a BiLSTM with feature extraction using BOW, a deep learning model capable of properly capturing the sequential information in the review. Furthermore, the elimination of stop words and tokenization of the text data improved the model's performance by lowering noise and boosting the quality of the input data. Overall, these findings illustrate that the SA model is highly accurate in predicting the sentiment of reviews and may be applied to analyze reviews in other datasets, as shown in Table 4.

Fig. 4 illustrates the accuracy and loss of the proposed SA model. It shows that our model is working accurately. Validation and training accuracy increase as the epochs increase. Similarly, validation loss and training loss decrease as the epochs increase.

The SA model's confusion matrix is displayed in Fig. 5. This method may be used to gauge how well the SA model is doing. Results show that 24,372 negative feelings, 24,373 neutral sentiments, and 24,469 good sentiments are all accurately predicted. The dataset also shows that the number of erroneous predictions is relatively low.

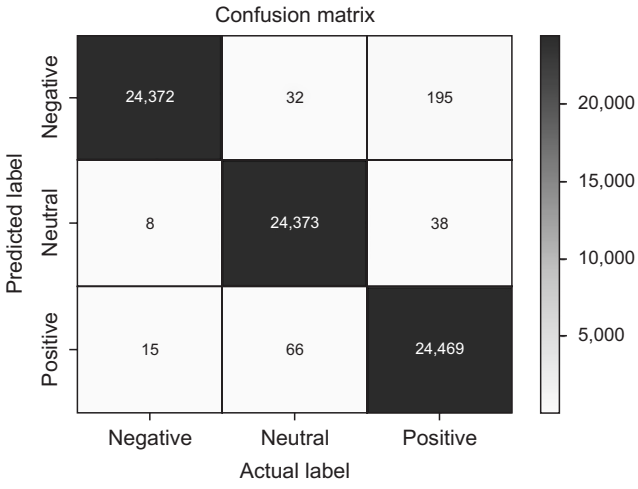


Fig. 5. Confusion matrix of sentiment analysis model.

4.2. POI Recommendation Model Using SA

The proposed POI recommendation model is subsequently evaluated with the help of a test set that consists of thirty percent of the dataset. The model is trained using the training dataset, while the testing dataset determines the system's performance.

The POI recommendation model's output is the recommended POIs based on the user's input. The recommended POIs are ranked based on the SA of the reviews linked with each POI and are filtered depending on the user's location and interest. When filtering data based on user interest, the model's performance may vary according to user input. If the user input is correct or complete, the predictions and accuracy of the recommendations may be improved.

Overall, the POI recommendation model provides a useful feature for users to discover and explore new locations of interest based on their location and SA. If the

recommended POIs are relevant and have positive sentiments, they can be considered successful recommendations. Further research can explore ways to improve the model's performance and accuracy, such as incorporating additional features, using more advanced deep learning models, or optimizing the model architecture. With further improvements and enhancements, the system has the potential to become a valuable tool for users looking to discover new and interesting places to visit.

The recall@k results for the proposed top POI recommendation model are provided in Table 5, along with a comparison to the outcomes of preceding models. The proportion that recall@k calculates out of the entire number of relevant items that might have been suggested is the percentage of relevant things that were recommended out of the total number of relevant items. Even though Zhou et al. (2019) have recall@5, recall@10, recall@15, and recall@20 values of 0.06, 0.10, 0.12, and 0.14, respectively, the recommended model recall@k climbs as k increases and reaches over 50%. Liu and Wu (2021) concluded that the values for recall@5, recall@10, recall@15, and recall@20 are, respectively, 0.19, 0.23, 0.28, and 0.32. Their research obtained this knowledge. For recall@5, recall@10, recall@15, and recall@20, respectively. Wang et al. (2019) obtained the values of 0.27, 0.32, 0.399, and 0.47. These values were recorded in their study. The researchers collected all of these values. Zhang et al. (2019) state that recall@5, recall@10, recall@15, and recall@20 values are 0.09, 0.15, 0.17, and 0.20, respectively. These values may be compared to one another. This set of values was obtained in a related manner. Yu et al. (2019) established that the values for recall@5, recall@10, recall@15, and recall@20 are, respectively, 0.12, 0.16, 0.19, and 0.22. The values Dai et al. (2019) found for recall@5, recall@10, recall@15, and recall@20 are 0.14, 0.17, 0.22, and 0.24, respectively. The researchers collected all of these values. It has been determined by Lu et al. (2019) that the values of recall@5, recall@10, recall@15, and recall@20 are 0.17, 0.24, 0.25, and 0.28, respectively. It was possible to acquire these values. The proposed model performed significantly better in terms of recall@5, recall@10, recall@15, and recall@20 when compared to the research works published by Zhou et al. (2019), Liu and Wu (2021), Wang et al. (2019), Zhang et al. (2019), Yu et al. (2019), Dai et al. (2019), and Lu et al. (2019). This was determined by comparing the suggested model to the research works performed by the authors above. Fig. 6 compares the proposed model and studies for recall@5, recall@10, recall@15, and recall@20.

Table 5. Comparison of recall@k of proposed point of interest recommendation model with other state-of art

Author	Recall@5	Recall@10	Recall@15	Recall@20
Zhou et al. (2019)	0.06	0.10	0.12	0.14
Liu & Wu (2021)	0.19	0.23	0.28	0.32
Wang et al. (2019)	0.27	0.32	0.399	0.47
Zhang et al. (2019)	0.09	0.15	0.17	0.20
Yu et al. (2019)	0.12	0.16	0.19	0.22
Dai et al. (2019)	0.14	0.17	0.22	0.24
Lu et al. (2019)	0.17	0.24	0.25	0.28
Proposed	0.35	0.45	0.475	0.485

Table 6 shows how the proposed model stacks up against other state-of-the-art recommendations for top POIs in terms of precision@k. Precision@k is a measure that determines the percentage of the top k suggestions that are relevant or wanted by the user. It is evident from Table 6 that the precision@k of the suggested model drops with increasing k and approaches 38% approx. Still, the results for precision@5, precision@10, precision@15, and precision@20 were 0.07, 0.057, 0.049, and 0.043, respectively, according to Zhou et al. (2019). The precision@k values were not observed by Liu and Wu (2021). Ac-

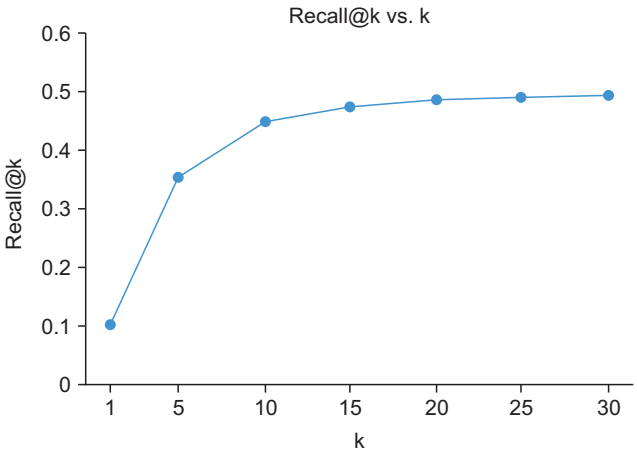


Fig. 6. Performance of proposed POI recommendation model for recall@k versus top k POI recommendations. POI, point of interest.

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Table 6. Comparison of precision@k of proposed point of interest recommendation model with other state-of-art

Author	Precision@5	Precision@10	Precision @15	Precision@20
Zhou et al. (2019)	0.07	0.057	0.049	0.043
Wang et al. (2019)	0.38	0.345	0.326	0.288
Zhang et al. (2019)	0.12	0.011	0.01	0.005
Yu et al. (2019)	0.018	0.02	0.011	0.001
Dai et al. (2019)	0.028	0.026	0.017	0.001
Lu et al. (2019)	0.045	0.038	0.028	0.02
Proposed	0.85	0.63	0.478	0.384

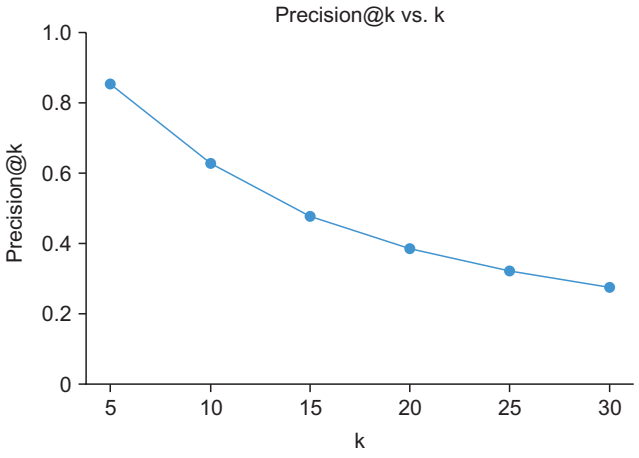


Fig. 7. Performance of proposed POI recommendation model for precision@k versus top k POI recommendation. POI, point of interest.

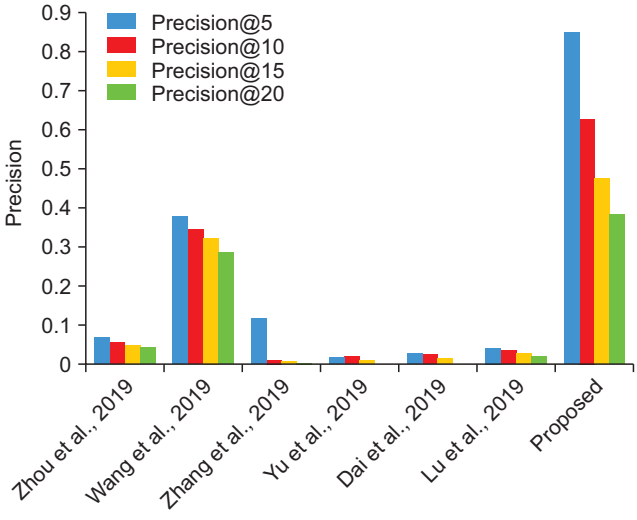


Fig. 8. Comparison of results of precision@k for top k point of interest recommendation.

cording to Wang et al. (2019), the various precision values were 0.38 for precision@5, 0.345 for precision@10, 0.326 for precision@15, and 0.288 for precision@20. According to the study by Zhang et al. (2019), the accuracy values for precision@5, precision@10, precision@15, and precision@20 were 0.12, 0.011, 0.01, and 0.005, respectively. Yu et al. (2019) documented precision values of 0.018, 0.02, 0.011, and 0.001 for precision@5, precision@10, and precision@15, respectively. The precise values for precision@5, precision@10, precision@15, and precision@20 achieved by Dai et al. (2019) were 0.028, 0.026, 0.017, and 0.001, respectively. Lu et al. (2019) achieved precision values of 0.045, 0.038, 0.028, and 0.02, respectively, for precision@5, precision@10, precision@15, and precision@20. Concurrently, the suggested POI recommendation models yielded values of 0.85 for precision@5, 0.63 for precision@10, 0.478 for precision@15, and 0.384 for precision@20. Therefore, in terms of accuracy@5, accuracy@10, accuracy@15, and accuracy@20, the suggested model surpassed other state-of-the-art.

The graph of the precision@k with the k of the POI Recommendation Model is displayed in Fig. 7. It is observed that the values of precision@k decrease as k increases, and the proposed model has the best precision@k values as compared to other state-of-the-art (Fig. 8). Fig. 9 illustrates the bar graph comparing the results of recall@5, recall@10, recall@15, and recall@20 between the research presented by Zhou et al. (2019), Wang et al. (2019), Zhang et al. (2019), Yu et al. (2019), Dai et al. (2019), and Lu et al. (2019), and the model that proposed.

Fig. 10 presents recommended top k POIs with coordinates for a given user using the web application developed for the proposed model.

5. CONCLUSIONS

This study focused on developing a POI recommendation system that effectively integrated the SA model with the POI recommendation model. By integrating these components, the system demonstrated a deeper understanding of user preferences and emotions expressed in their reviews, resulting in a more targeted recommendation process. The system provided a more targeted recommendation process by filtering reviews based on user interests. The LSTM model was utilized to identify long-term dependencies in sequential data, resulting in precise and personalized POI suggestions.

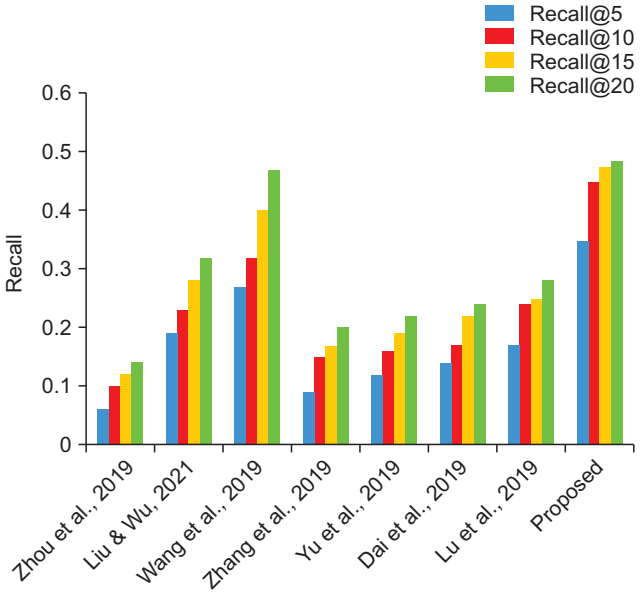


Fig. 9. Comparison of results of recall@k for top k point of interest recommendations.

The proposed system effectively generates personalized and relevant user recommendations based on interests, location, and sentiment labels from user-generated text reviews. The proposed system consists of six main steps: data preprocessing, SA using BiLSTM, converting reviews to sentiment labels, POI recommendation modeling using SA model, filtering data based on user interest and location, and designing the user interface. The proposed model leverages the power of SA to understand user preferences and emotions expressed in their reviews, in order to train a recommendation model that employs user embeddings, POI embeddings, and sentiment labels to offer pertinent POIs to the user based on user interests, produce a more targeted recommendation process, and anticipate the sentiment of reviews for different points of interest. In recognizing the sentiment of user reviews, the SA model achieved decent accuracy (99.52%), precision (99.53%), recall (99.51%), and F1-score (99.52%) as compared to other state-of-arts. The POI recommendation algorithm also did well when proposing relevant points of interest to users based on their interests and location, with recall (48.5%) and precision (85%) compared to other state-of-arts. The study demonstrated that the proposed model can effectively generate personalized and relevant POI recommendations, helping users discover new and interesting POIs. It showcases the potential benefits of integrating SA into any recommender system for users and businesses.

Another fact that should be mentioned here is that the SA model is prepared on one dataset (an election dataset). Then, this model was used to develop the proposed POI recommendation model using the Foursquare dataset with

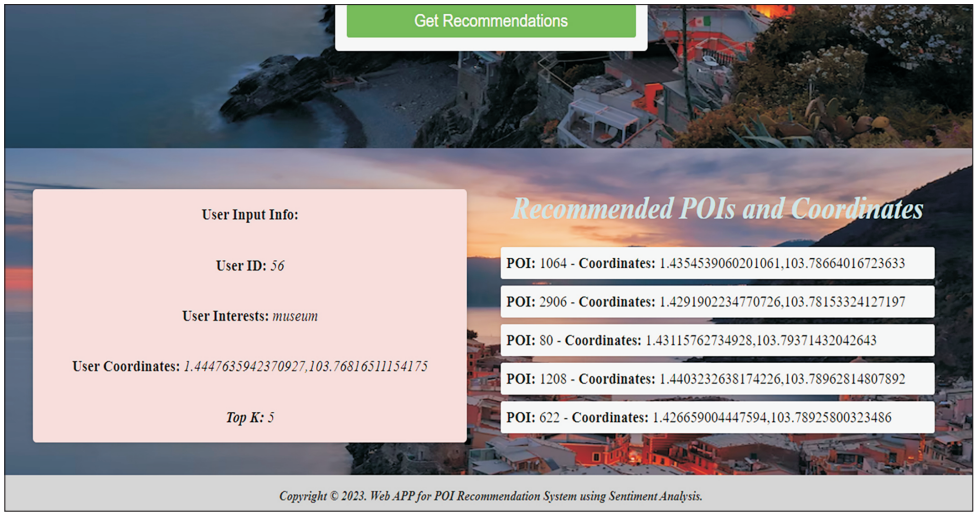


Fig. 10. Recommended top POIs with coordinates for a given user. POI, point of interest.

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LSTM, which gives it more strength to extract the characteristics of two different datasets and inculcate them into a single model. This strength makes it more generalizable and applicable to other datasets and scenarios.

As the proposed model is trained and tested using only two datasets (the election dataset for SA and the Foursquare dataset for POI recommendation), this model will perform optimally for the applications that match the domains of these two datasets. Otherwise, this model might perform sub-optimally for other domains.

Further, the following points/suggestions can be considered for future work: incorporating more data sources, implementing more advanced recommendation algorithms, incorporating more features, personalizing for individual users, extending the radius of filtering, adding negative sentiment scores, incorporating real-time data, and improving scalability to handle large datasets or real-time recommendations. Discovering more customized, relevant, and engaging experiences when discovering new points of interest may be achieved by continuing to expand and enhance POI recommendation systems. Future research paths in this subject can benefit from investigating these topics.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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Is ChatGPT an Ally or an Enemy? Its Impact on Society Based on a Systematic Literature Review

Juliana Basulo-Ribeiro*
Department of Economics, Management, Industrial Engineering and Tourism (DEGEIT), Institute of Electronics and Informatics Engineering of Aveiro (IEETA), Intelligent Systems Associate Laboratory (LASI), University of Aveiro, Aveiro, Portugal
E-mail: basulojuliana@ua.pt

Leonor Teixeira
Department of Economics, Management, Industrial Engineering and Tourism (DEGEIT), Institute of Electronics and Informatics Engineering of Aveiro (IEETA), Intelligent Systems Associate Laboratory (LASI), University of Aveiro, Aveiro, Portugal
E-mail: lteixeira@ua.pt

ABSTRACT

The new AI based conversational chatbot, ChatGPT, launched in November 2022, is causing a stir. There are many opinions about this being a 'threat or a promise,' and thus it is important to understand what has been said about this tool and, based on the growing literature that has emerged on the subject, demystify its effective impact on society. To analyse this impact, a systematic literature review with the support of the preferred reporting items for systematic reviews and meta-analysis protocol was used. The data, scientific documents, were collected using the main scientific databases – SCOPUS and Web of Science – and the results were presented based on a bibliometric and thematic exploration of content. The main findings indicate that people are increasingly using this chatbot in more diverse areas. Therefore, this study contributes at the practical level, aiming to enlighten people in general – both in professional and personal life – about this tool and its impacts. Also, it contributes at the theoretical level, which involves expanding understanding and elucidation of the impacts of ChatGPT in different areas of study.

Keywords: new technology, ChatGPT, human factor, social impact, artificial intelligence

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***Corresponding Author:** Juliana Basulo-Ribeiro
https://orcid.org/0000-0002-3411-3519
E-mail: basulojuliana@ua.pt

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1. INTRODUCTION

After the COVID-19 pandemic, the volatile, uncertain, complex, and ambiguous world that appeared after the cold war evolved into the brittle, anxious, non-linear, and incomprehensible (BANI) world, which suggests that the world is not linear, and that the only constant we have is change. The latest evidence of this is the emergence of new artificial intelligence (AI) technologies.

AI can be defined as the intelligence of machines and has been shown capable of reproducing actions compared to humans, once possessing some of the capacities of the human mind (*Cambridge dictionary*, as cited in Walter et al., 2022). AI tools hold the potential to enhance our existence and that of those we cater to; however, they are incapable of substituting the human exchanges that distinguish us from technological advancements (Cox & Tzoc, 2023).

As such, AI is a concept that has been in vogue recently, and the chatbot named ChatGPT has been the subject of many opinions and has generated a great deal of curiosity. This platform has had dramatic growth when compared with others, such as Facebook and Spotify, as they needed roughly ten and five months respectively to reach one million users, and ChatGPT only needed five days to reach the same number of users (Ahmed, 2023).

As mentioned above, AI has evolved in recent times, and recently, in November 2022, ChatGPT appeared, a tool developed by a non-profit company, OpenAI, based in the United States (San Francisco). This tool is freely available at https://openai.com.

ChatGPT is a powerful AI language model that uses deep learning techniques to generate human-like text responses to natural language inputs. It is a type of generative pretrained transformer (GPT) model, and it has been trained on a large corpus of text data to improve its ability to generate coherent and contextually relevant responses (Bhattacharya et al., 2023; Gupta et al., 2023; Halaweh, 2023; Johinke et al., 2023; Panda & Kaur, 2023).

ChatGPT is a tool that has emerged from natural language processing (NLP), which is an area of AI focusing on assisting computers in comprehending and generating human-readable text, thus allowing the chatbot to understand what was asked by the user and respond in a way as humanlike as possible (Lin et al., 2023; Vaishya et al., 2023). It is based on the GPT architecture, which uses neural networks to do the natural language process, enabling it to give a response in accordance with the content of input text (Sallam, 2023).

Although it is still in its early stages, ChatGPT is expected to have a significant impact on various areas, such as healthcare, education, research, and scientific writing (Alkaissi & McFarlane, 2023).

According to the literature, and with the use of the tool, it was found that it responds quickly to what is asked, using information available in books, articles, and websites in a general way. However, this information is limited to September 2021 and prior and the tool does not have access to relevant literature (Akhter & Cooper, 2023; Vaishya et al., 2023).

The history of ChatGPT can be traced back to 2018, when OpenAI first released a language model called GPT-1, an evolution of the NLP technology that was designed to generate humanlike text based on a given prompt or topic, with 5 GB of text.

Due to the success of GPT-1, OpenAI was inspired to develop even more advanced language models. In February 2019, they released GPT-2, which was trained on a larger dataset of over 40 GB of text. GPT-2 could generate remarkably coherent and natural-sounding text and perform language translation, and it quickly gained attention from researchers and enthusiasts in the AI community.

Following that, OpenAI released a third iteration of the model, GPT-3, in June 2020, which was even more advanced than its predecessors. GPT-3 was trained on an enormous dataset of approximately 45 TB of text, and it was capable of a wide range of natural language tasks, including code writing, article generation for news, mathematical addition, and much more.

ChatGPT was released by OpenAI on November 30, 2022, which is a variant of the GPT-3 AI chatbot specifically designed for use in chatbot applications. It is trained to act like a human being in understanding context and generating appropriate responses based on that context. This chatbot has the potential to recognize impossible, or even inappropriate questions and respond accordingly (Floridi, 2023; Short & Short, 2023; Taecharungroj, 2023; Tlili et al., 2023; Wang et al., 2023a).

ChatGPT, a recent milestone in AI, stands as a testament to the transformative capabilities of cutting-edge language models. A member of the GPT family, ChatGPT boasts an astonishing 175 billion parameters, making it one of the most expansive language models to date (Gilson et al., 2023; Wang et al., 2023b). This vast capacity enables ChatGPT to excel in understanding and generating natural language text (Zhang, 2023). Its foundation lies in the concept of deep learning, particularly leveraging the transformer architecture, which has revolutionized

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the field of natural language processing (Hashana et al., 2023; Zhang, 2023). By pretraining on massive text datasets from the Internet, such as web pages, books, research articles, and other sources, ChatGPT acquires a profound semantic understanding, enabling it to generate coherent and contextually relevant responses (Dwivedi et al., 2023; Titus, 2024; Zhang, 2023).

The digital era has brought about a rapid evolution in technology, and the introduction of ChatGPT has the potential to greatly shape the future technological and digital landscape (Taecharungroj, 2023). Therefore, Elon Musk, cofounder of OpenAI, the company that developed ChatGPT, signed a letter in which the suspension of AI is proposed, to assess the danger it can bring. In this letter it is stated that AI systems which can compete with humans in intelligence can pose significant risks to society and humanity. Moreover, Sam Altman, who is the OpenAI CEO, said in an interview that AI is going to reshape society. Thus, there have been many comments expounding that AI tools should be aligned with human values (Tlili et al., 2023).

The digital age has unleashed an unprecedented expansion of intelligent technologies, among which ChatGPT has emerged as an intense focus of interest, given its versatile applications and the rapid rate at which it has achieved widespread adoption. However, while literature on its capabilities and applications proliferates, there is a discernible gap in the systematized understanding of its actual impact on society—especially from the human perspective. This study aims to bridge this gap, offering a critical and detailed analysis of the effects of ChatGPT on the social, economic, and cultural fabric.

Through meticulous analysis of the existing literature, we seek not only to map the implications of adopting this technology across various sectors but also to understand how it reconfigures human interactions, decision-making processes, and social values. Ultimately, by elucidating the multifaceted impact of ChatGPT, this work comes as a first analysis of the tool and what is already known about its impacts.

Papers related to ChatGPT are appearing in scientific databases at an increasingly rapid pace. However, most of them are not complete articles (more than 50% of the studies), demonstrating the importance of a systematization of concepts in terms of impact and clarification of the concept itself, to understand what is being said about ChatGPT. Furthermore, Taecharungroj (2023) states that it is important to study the impact of this technology on people's futures.

For all these reasons, a systematization was developed, for which a critical and exploratory analysis was carried out of what has been published, studying the trends of this theme. Thus, our work contributes to an initial exploration of this topic, ChatGPT and the human factor, trying to understand what is being said in the literature about the impacts of ChatGPT in society.

This study is structured as follows: Section 2 details the objectives we want to achieve with this study and describes the method used to answer them to achieve the main goal; Section 3 presents the results of the study; and Section 4 depicts the conclusions (final remarks, contributions and implications, limitations, and future work) regarding the field under analysis.

2. GOALS AND METHODS

2.1. Goals

The primary aim of this study was to examine how ChatGPT is affecting individuals, and to disseminate information to both the scientific community and the public about what has been discussed on this topic in the literature, to help people adapt as effectively as possible and try to mitigate the impact. Hence, the main goal of this study is to assess the impact of ChatGPT in society. With a view to ascertaining the answer, it was necessary to answer five other more specific/smaller objectives, stated below. The first three have the objective of understanding the characteristics of the selected studies from the two databases, while the remainder aim to comprehend precisely what is addressed in each of the works.

To better understand the reality that we wanted to investigate, we orientated our research towards identifying the main areas, countries, and authors that do the most work in this field. Therefore, the following guiding objectives were raised:

(1) Identify the most addressed areas in this field;
(2) Rank the most influential countries in this field;
(3) List the most recognised authors in this field.

With regard to a more detailed analysis of the literature on the very concept associated with ChatGPT and how it impacts society in terms of fields of action and people, the following guiding objectives were defined.

(4) Understand how it impacts on each area;
(5) Assessing the impact of ChatGPT on people, i.e. understanding the benefits and challenges of the tool.

2.2. Methods

With the aim of answering these objectives and reaching the main goal, a systematic literature review (SLR) was conducted, as it is a method that can be used for "identifying and critically appraising relevant research, as well as for collecting and analysing data from said research" (Snyder, 2019).

Therefore, this was the method chosen to understand how ChatGPT is currently impacting society, and Snyder (2019)'s approach was used in carrying out this study, starting from the design phase, then moving on to the conduction and analysis phase, and ending with the writing phase. PRISMA – preferred reporting items for systematic reviews and meta-analysis – methodology was used in the last phase according to the guidelines stated by Page et al. (2021). Fig. 1 shows a scheme of the methodology used and what was done in each phase.

In the design phase, we defined the research objectives guiding our study on "ChatGPT." The intention was to develop a comprehensive and general study on the topic, ensuring that no relevant work was omitted. To this end, the research objectives were carefully designed to align with the objectives of the study and provide a solid basis for the investigation.

During the conduction phase, we proceeded to search for studies in the SCOPUS and Web of Science (WoS) databases using the query "ChatGPT." The search was limited to the specific day of April 12, 2023, to capture the most recent studies up to that date. We used the PRISMA methodology to manage the selection of scientific studies, resulting in 279 documents, of which 50 were duplicates.

In the analysis phase, after excluding duplicates and applying the inclusion criteria (language, availability of full text, and type of document), we were left with 77 scientific studies for final analysis. Each of these studies was then subjected to a more detailed analysis to answer the specific research objectives, dividing the analysis into bibliometric analysis for the first objectives and a thematic exploration of content for the rest.

In the final writing phase, the information collected and analysed was synthesized into a coherent narrative. The writing went through several revisions to ensure clarity and precision, shaping the results of the research into a format suitable for publication.

Each of these phases is crucial to the development of systematic and well-founded research, and Fig. 1 serves as a visual representation of the study's methodological flow.

2.2.1. Data Collection

In the initial phase, a query needed to be stipulated to collect studies from the databases, SCOPUS and WoS. The query used was reduced to the concept "ChatGPT," to develop a general and broader study on this topic, not leaving behind any work that refers to this topic.

Given that this is an emerging concept, and that more and more people are talking about its implications in the most diverse areas, with comments on pros and cons, there are several studies being published in the databases every day. Therefore, it was necessary to close the search in the databases on a specific day, 12 April 2023, to start the analysis phase. PRISMA methodology was utilized to manage the selection of the scientific studies. On that date, 279 scientific documents (SD) were found in the databases, 184 from SCOPUS and 95 from WoS, of which 50 were duplicates in the databases. After removing these duplicates, 229 articles remained to select those which met the inclusion criteria:

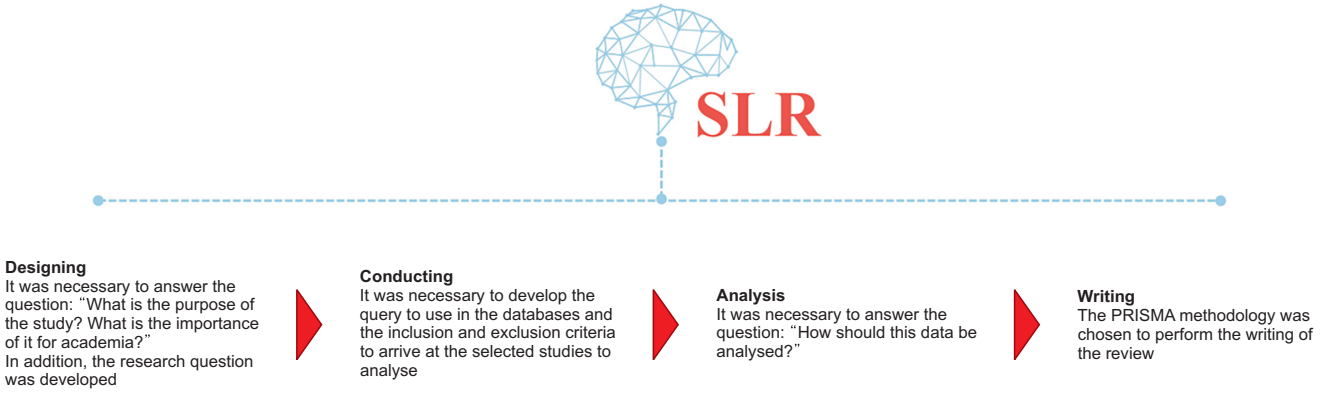


Fig. 1. Methodology used to conduct the study. SLR, systematic literature review; PRISMA, preferred reporting items for systematic reviews and meta-analysis.

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- Language: English or Portuguese; due to our proficiency in both Portuguese and English, we chose to select articles in these two languages to ensure a more accessible and comprehensive analysis – two studies were excluded;
- Availability: full studies available for download – six studies were excluded;
- Document type: only complete studies, such as articles or review articles, were included, resulting in the exclusion of 144 studies, including notes, editorials, letters, errata, and short surveys.

With this screening, 152 SD were excluded, due to their failure to meet inclusion criteria (stated above), and with 77 SD being retained for final analysis. Of these 77 SD, none were excluded after reading the title and the abstract, in order to go deeper into their content. Fig. 2 schematises the procedure performed and described above.

2.2.2. Data Analysis

Fig. 1 illustrates the comprehensive study methodology. Within this methodology, the third part, which is the article analysis phase designed to extract information to address the research objectives, is comprised of two distinct types of study, each utilizing a unique approach.

The investigation's structure follows a dual approach. The first four specific objectives were explored through a meticulous bibliometric analysis. For objectives 4 and 5, a thematic exploration of content was conducted, where a thorough reading of the articles allowed for an in-depth understanding of the themes discussed.

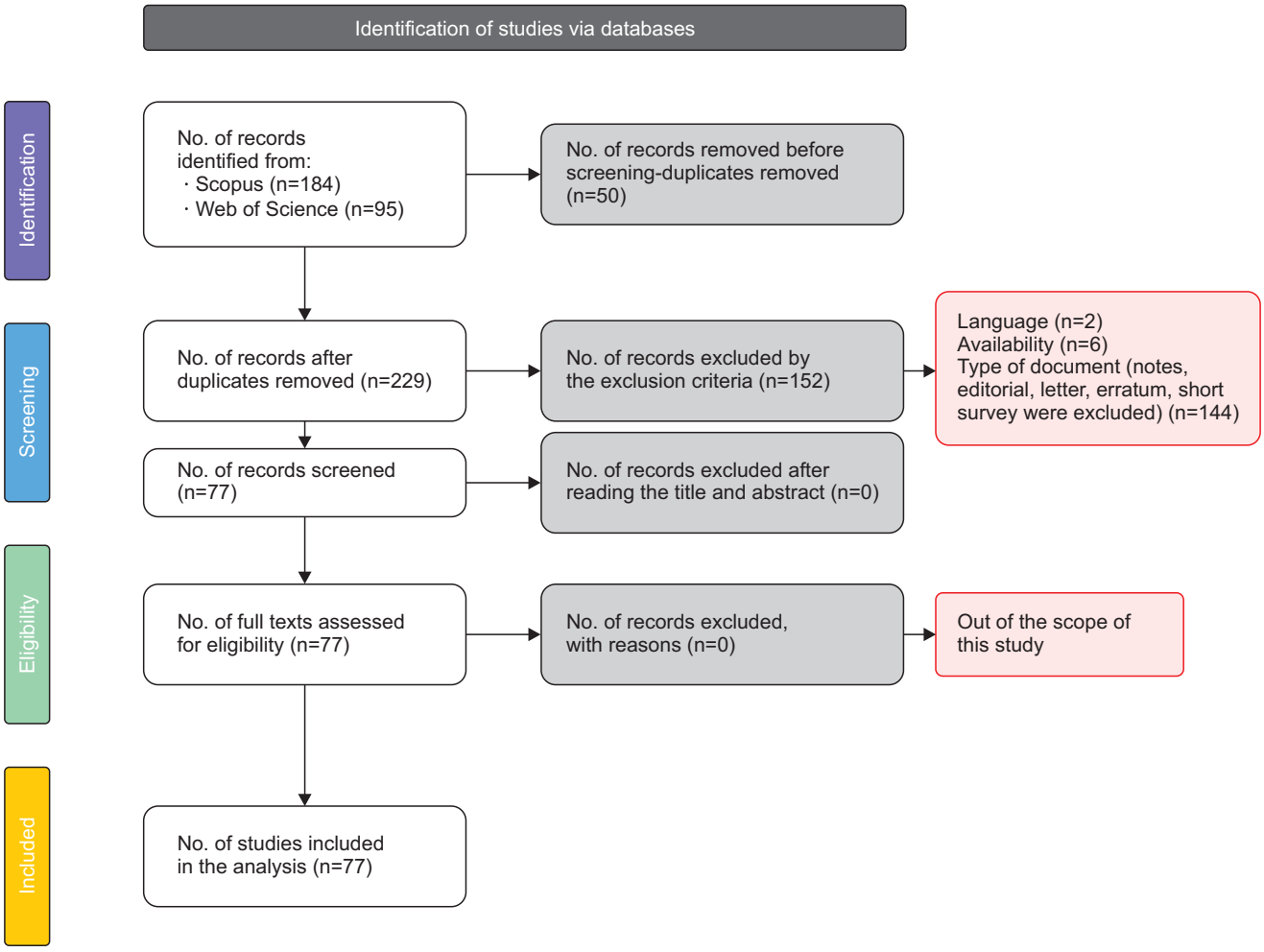


Fig. 2. PRISMA-based flowchart. PRISMA, preferred reporting items for systematic reviews and meta-analysis.

3. RESULTS AND DISCUSSION

This section is divided into two subsections: The first presents a bibliometric analysis and the second a thematic exploration of content. In each section, the results of these studies and some discussion of each topic can be found.

3.1. Bibliometric Analysis

This subsection presents the bibliometric analysis carried out to understand the reality we wanted to investigate. We orientated our research towards identifying the main areas, countries, and authors producing the most work in this field.

3.1.1. Analysis by Area

The literature presents studies of the various applications of ChatGPT in different domains, including health, education, and social, among others. The classification of studies into subject areas was based on the primary focus of the research. For instance, 'Education' encompasses studies primarily concerned with pedagogical processes, while 'Health/Medicine' includes research focused on clinical and health-related outcomes. 'Social' relates to studies on societal interactions and social structures, and 'Multidisciplinary' includes studies that integrate methods and theories from two or more academic fields. 'Others' comprises studies that do not align with the main categories. Fig. 3 shows the percentage of studies that addresses each of the abovementioned areas, with the majority addressing the theme of health and education, both with 27%. A considerable percentage (20%) refers to more than one area and can be considered multidisciplinary. It should be noted that the least addressed domain in the literature is the social, and it may be considered an emerging area of research. However, it is imperative to recognise that AI technology profoundly shapes our everyday experiences, and its influence weaves seamlessly through various domains and asserts itself as a fundamental force in all aspects of life.

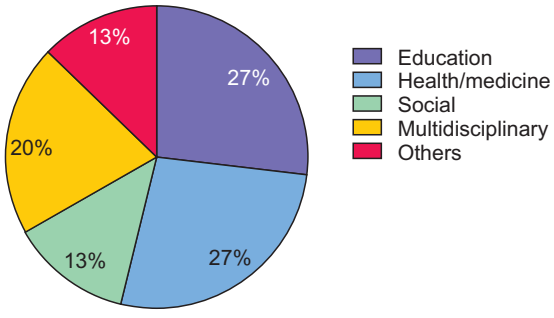


Fig. 3. Selected studies divided by areas, in percentage.

3.1.2. Analysis of the Geographical Distribution of the Papers

Fig. 4 offers a visual representation of the distribution of ChatGPT-related research, as gleaned from the analyzed papers, across 12 countries. Dominating the chart, the United States leads with an impressive count of 28 published articles. Fig. 4 is indicative of the country's robust research ecosystem and could be directly linked to its status as the home base of OpenAI, the entity behind ChatGPT. China and the United Kingdom follow with six and five publications, respectively, which suggests active engagement in the domain but also highlights a substantial gap in output compared to the United States. The graph's descending order illustrates the disparity in research contributions, which may reflect the varying levels of investment in AI technologies, and the concentration of academic and research institutions. It is important to consider that this chart also serves as a prompt for further inquiry into the factors that drive such disparities, including economic, educational, and policy differences among nations.

3.1.3. Analysis of Most Recognised Authors

Fig. 5, as visualized through the VOSviewer (Leiden University, South Holland, Netherlands) tool, demonstrates the authorship landscape in the realm of ChatGPT research. In our context, 'Recognised' refers to authors who are widely recognized for their contributions to the field, as evidenced by citations, peer recognition, and impact on the subject area. This term was used to encapsulate the esteem in which these authors are held within the

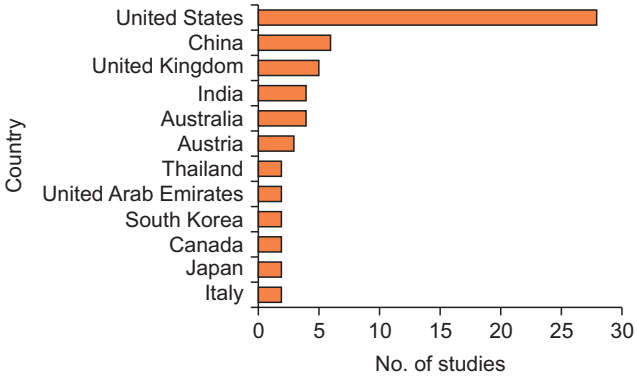


Fig. 4. Top 12 countries which contributed to the papers selected for this study.

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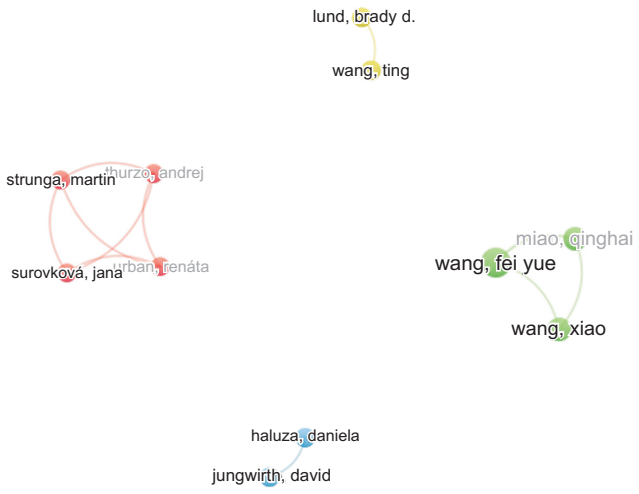


Fig. 5. Most recognised authors in the field (using VOSviewer).

academic community. The same definition applies to its usage in Fig. 5. The illustration divides authors into clusters by country, suggesting a tendency towards national collaboration within the field. The yellow cluster signifies the United States, green for China, blue for Austria, and red for Slovakia, each color representing a distinct research community. Notably, the clusters do not overlap, indicating that cross-country collaborations are currently limited or non-existent. This separation could reflect a variety of factors such as funding sources, institutional affiliations, or existing research networks. The absence of interlinking lines between clusters may point to potential opportunities for cross-border partnerships that could enrich the research through a diversity of perspectives. Furthermore, the size of the clusters may give insights into the relative volume of research output from each country, with larger clusters possibly representing a higher number of studies or a greater number of authors engaged in ChatGPT research. Understanding these dynamics is crucial for developing strategies to foster international cooperation and knowledge exchange in this rapidly evolving field.

Although ChatGPT is not among the selected "authors" with most studies, it appears in the SCOPUS and WoS databases as an author, being co-author in at least five studies. This information was obtained from the two databases mentioned. However, there are articles that argue that ChatGPT should not be considered an author since, as it is a search engine, albeit more sophisticated and advanced, it has no responsibility for what it writes (Lee, 2023; Sallam, 2023), while others refer to it only as a tool used to carry out the study (D'Amico et al., 2023; Macdonald et al., 2023).

3.2. Thematic Exploration of Content

This second subsection presents a thematic exploration of content in the literature to understand the concept associated with ChatGPT and its impact on society, in terms of fields of action and people.

3.2.1. ChatGPT and Its Impact in Each Area

The applications of ChatGPT are many, with future applications being all the ones we can imagine, and this has been increasingly researched over time (Du et al., 2023; Short & Short, 2023).

Emerging from the thematic exploration of content, the most prominent themes identify education and healthcare as key areas where ChatGPT exerts considerable influence. The selected papers, particularly evident in Fig. 3, underscore the significant impact that ChatGPT has had within these domains. This section, therefore, aims to expound on specific instances of ChatGPT's applications, detailing the scope and nature of its effect in both education and health.

3.2.1.1. Education.

Tlili et al. (2023) found in their study that "ChatGPT has the potential to revolutionize education in different ways." Evidence was found for at least two distinct approaches to the use of this chatbot in education, (1) scientific writing and academic publishing, and (2) education in general.

3.2.1.1.1. Scientific Writing and Academic Publishing.

Within education, one of the issues raised is scientific writing and the use of ChatGPT for this purpose. This is a concern as it may promote misinformation, as although the texts appear very credible, they may be nothing more than a compilation of truths with false information. This is called artificial hallucinations – when a chatbot generates seemingly realistic information that does not correspond to the truth (Alkaissi & McFarlane, 2023; Wang et al., 2023a).

Moreover, it is notable that the citations provided are not linked to any document/work, yet they appear linked to convincing text, which may end up misleading many people. Therefore, given that journals are not in the habit of checking citations one by one, it will be necessary to adopt policies and standards that control the use of this tool (Akhter & Cooper, 2023; Alkaissi & McFarlane, 2023; D'Amico et al., 2023; Lund et al., 2023; Manohar & Prasad,

2023).

Another issue that the use of ChatGPT raises is the issue of plagiarism, which is referred to by several authors as a concern (Sallam, 2023). Is it considered plagiarism when this tool is used in the preparation of scientific papers? Since plagiarism is defined as the use of ideas/texts from other people presented as the author's own, if the authors from which that information comes are cited, or it is even mentioned that the model was used in the preparation of that work, it should not be considered plagiarism (Cox & Tzoc, 2023; Halaweh, 2023; Lund et al., 2023).

Furthermore, the information that ChatGPT produces is highly dependent on the question asked of it, and it is possible to use it as a valuable tool that helps to produce the document and publish it in a faster way, helping to better express ideas. Also, it can promote equity between researchers that are not native English speakers since it can help to edit English texts. However, this information should be used critically, and not be accepted as absolute truth (Akhter & Cooper, 2023; D'Amico et al., 2023; Nachshon et al., 2023; Sallam, 2023).

As stated by Cox and Tzoc (2023), "In the future, AI tools may serve as research assistants, conducting virtual experiments, analyzing data, copywriting and editing text, and generating citations." This may make us think that it is a tool that can help with scientific writing, making it more productive (e.g. it can execute a rough draft of text, used as the insight for the study), but it would not replace humans in this task (Cox & Tzoc, 2023; Iskender, 2023).

For all these reasons, there are authors who argue that journals' policies and norms should be adopted now for publications to maintain their rigorous scientific standards. Furthermore, they propose clear identification of whether AI has been used to produce the work, and the use of a tool that evaluates if it has been used or not (Alkaissi & McFarlane, 2023; Cotton et al., 2023; Lund et al., 2023). Tlili et al. (2023) state that chatbots should be responsible for the information they provide, thus being aligned with human values and ethical questions.

3.2.1.1.2. Education in General.

Lin et al. (2023) suggest two kinds of uses for the chatbot ChatGPT in general education. On one hand, he reports that it can be used as a "learning companion," which helps the student to better understand what is studied. On the other hand, it can also help teachers to be more effective by playing the role of "simulated student." Thus, this technology can help teachers prepare materials, quizzes, lesson plans, syllabi, and much more, and can help the learning process of students, working as a tutor that supports them (Cox & Tzoc, 2023; Iskender, 2023; Tlili et al., 2023).

Despite having benefits, this technological tool, like all others, presents challenges, such as the fact that it can generate different answers with the same request prepared by different users, and the information provided by it should not be taken as 100% correct (Kung et al., 2023; Panda & Kaur, 2023; Tlili et al., 2023). Also, the use of this tool can lead to a non-development of important skills: critical and independent thinking, creativity, and problem-solving (Choi et al., 2023; Iskender, 2023). In this way, ChatGPT causes others to need digital and information literacy, so that students are taught by teachers to look critically at a text and understand whether it has been written by AI or a human (Cox & Tzoc, 2023).

There are entities that are embracing this new technology, but there are also others that are banning its use, as it allows students to "cheat" on their assignments (Tlili et al., 2023). However, Cox and Tzoc (2023) state that it will be necessary to make more complex assignments rather than making factual questions. Therefore, considering everything stated above, it is important for guidelines and policies to be defined to control and facilitate its use in schools and universities (Cotton et al., 2023; Halaweh, 2023; Tlili et al., 2023).

Moreover, teachers and students should seek to adapt and acquire skills so that they can adopt new teaching and learning philosophies in this new technological era (Crawford et al., 2023; Halaweh, 2023; Tlili et al., 2023). At no point will this tool be able to replace the teacher, mainly due to a lack of personalization and human interactions inside the classroom (Halaweh, 2023; Iskender, 2023).

Furthermore, fairness, accuracy, and equity should be ensured among students in using and accessing the tool, particularly for disadvantaged students and students with disabilities, among others, because at this point it is not accessible to everyone (Iskender, 2023; Tlili et al., 2023).

In terms of education, ChatGPT is both a harbinger of progress and a beacon of caution. Its potential as a learning enhancer and equaliser is clear, but it underlines the need to develop critical digital literacy among both students and educators. The tool's ability to serve as a 'learning companion' and 'simulated student' could revolutionise pedagogy and individual study habits, promoting accessibility and support in academic activities. However, the paradoxical nature of its impact – in which it can simultaneously foster and stifle critical thinking and creativity – calls for a differentiated and in-depth approach to its

integration into educational structures.

The varied impact of ChatGPT demands a conscientious balance: embracing its technological prowess to enhance teaching and learning, while guarding against inadvertently promoting intellectual complacency. The risk of dependency on automated knowledge requires an enhanced commitment to cultivating independent thinking and problem-solving skills in students. Furthermore, the dialogue around ChatGPT in education serves as a wake-up call for the formulation of proactive policies to guide its ethical use, ensuring fairness and equity, especially for those who may be digitally disadvantaged.

The conclusion drawn from the corpus of research is unequivocal: ChatGPT is not a panacea for educational challenges, nor a harbinger of academic obsolescence, but a fundamental tool for language learning.

3.2.1.2. The Field of Health/Medicine.

The other area most addressed in the literature when talking about the impacts of ChatGPT is health. Below, the information collected about the benefits and challenges that this model entails in this area is presented. As benefits of ChatGPT in health, within the selected papers, the following were found:

- It enables improved efficiency in healthcare, for example by rapid analysis of patient data (Bhattacharya et al., 2023; Budler et al., 2023; Haluza & Jungwirth, 2023; Jungwirth & Haluza, 2023; Sallam, 2023; Salvagno et al., 2023);
- It can help prepare literature reviews and access important and up-to-date information quickly, improving health literacy (Bhattacharya et al., 2023; Choi et al., 2023; Eysenbach, 2023; Khan et al., 2023; Sallam, 2023; Salvagno et al., 2023);
- It can free doctors and researchers in this area from repetitive tasks, such as transcription of medical records or diagnosis of patients, among others, saving time to put efforts into experiments and drug development, or even spend more time on patient care (Bhattacharya et al., 2023; Budler et al., 2023; Sallam, 2023);
- It helps in the preparation of documentation (D'Amico et al., 2023; Khan et al., 2023; Sallam, 2023);
- It may assist in the advancement of personalized medicine for each patient (Gilson et al., 2023; Sallam, 2023);
- It can help in decision-making for some treatments (Bhattacharya et al., 2023; Haluza & Jungwirth, 2023; Hirosawa et al., 2023; Khan et al., 2023; Sallam, 2023);
- It enables faster access to health care in emergencies – as it can be used to provide patients with information about their health – especially those patients from rural areas, without having to go to a physical location, and helps to alleviate pressure or demand on these spaces (Bhattacharya et al., 2023; D'Amico et al., 2023; Haluza & Jungwirth, 2023).

Although its adoption brings benefits for health, ChatGPT also brings challenges, among which the following ones were highlighted:

- As mentioned above, the information provided by ChatGPT may not be entirely true, so this could have serious consequences when talking about health (D'Amico et al., 2023; Sallam, 2023);
- Further, the lack of information about which data sources ChatGPT uses to provide the answers about health is a danger in this field (Sallam, 2023; Vaishya et al., 2023);
- Once again, as mentioned earlier, the lack of responsibility associated with the content provided by ChatGPT can be unfavourable when it responds wrongly to what was requested (Sallam, 2023);
- Both privacy and personal data security issues should be raised when using health AI tools (D'Amico et al., 2023; Eysenbach, 2023; Sallam, 2023);
- The tool shows a lack of personal and emotional perspective that is needed in health care delivery and shows that humans are irreplaceable in their skills and knowledge, at least for now due to the limitations of AI (D'Amico et al., 2023; Khan et al., 2023; Sallam, 2023).

Both the benefits and risks in using ChatGPT or integrating it into healthcare should be considered. However, as in other areas, the chatbots that are in vogue nowadays should not be ignored.

In the dynamic field of health and medicine, ChatGPT stands at the frontier of digital innovation, poised to redefine facets of healthcare delivery and medical research. Its capability to process vast datasets with speed and precision heralds a shift towards efficiency, where healthcare professionals can pivot from mundane tasks to focus on patient-centric care and innovative research. The implementation

of ChatGPT for rapid literature reviews, transcription of medical records, and aiding in diagnostics underlines the potential to enhance health literacy and access to healthcare, particularly in under-resourced regions.

Yet, with these advancements come critical challenges that necessitate rigorous scrutiny. The reliability of ChatGPT's medical information, the opacity of its data sources, and concerns over privacy and data security represent significant obstacles. The gravitas of health-related decisions amplifies the consequences of misinformation, making the tool's current limitations a matter of high stakes. Furthermore, the inability of ChatGPT to replicate the nuanced personal and emotional interactions fundamental to healthcare underscores the irreplaceable nature of the human touch in medicine.

As the healthcare sector considers the integration of ChatGPT, a balanced evaluation of its risks and benefits is essential. While AI's potential to advance personalized medicine and support clinical decision-making is promising, the exigency for transparent, ethical, and responsible use cannot be overstated. Policies that safeguard patient confidentiality and validate the accuracy of AI-generated information must be paramount. ChatGPT may offer a glimpse into the future of medicine—one where AI assists but does not supplant the human expertise, empathy, and ethical judgment that are the hallmarks of healthcare. The path forward is one of cautious optimism, advocating for a symbiotic relationship between AI and healthcare professionals to foster a future where technology complements the human elements of medicine, rather than competing with them.

3.2.2. ChatGPT and Its Impact on the Human Factor

3.2.2.1. Benefits and Opportunities of ChatGPT in the Human Factor.

Despite people feeling threatened by AI, it can raise the human dimension to another level. In Table 1 (Chen, 2023; Cox & Tzoc, 2023; Haluza & Jungwirth, 2023; Lin et al., 2023; Panda & Kaur, 2023; Taecharungroj, 2023) some of the benefits and opportunities that ChatGPT, an AI tool, brings to the human factor can be seen.

As can be seen in Table 1 (Chen, 2023; Cox & Tzoc, 2023; Haluza & Jungwirth, 2023; Lin et al., 2023; Panda & Kaur, 2023; Taecharungroj, 2023), ChatGPT emerges not only as a technological breakthrough, but also as a benefit for human inclusion and efficiency. Its potential to empower vulnerable populations underlines AI's role in reducing the accessibility gap, whether through helping people with disabilities or providing companionship to the elderly. The technology's ability to simplify processes stands out in high-demand environments, offering a scalability solution that human resources alone cannot match. For individuals in remote areas, ChatGPT acts as a digital

Table 1. What are the benefits and opportunities of ChatGPT in the human factor?

Benefit	Explanation	Sources
ChatGPT can help vulnerable people	ChatGPT can be used to provide information and services, and reduce loneliness in an accessible and efficient way for people with disabilities, including visual or hearing impairments, the elderly, and other vulnerable populations, thereby promoting inclusion	(Haluza & Jungwirth, 2023; Lin et al., 2023; Panda & Kaur, 2023; Taecharungroj, 2023)
ChatGPT can help to increase efficiency	It can help to develop multiple business processes and governments, since it can handle many requests simultaneously, making it an ideal solution for services that experience high volumes of customer and citizen interactions, providing efficient and effective communication with them, which can replace human customer services, reducing costs	(Haluza & Jungwirth, 2023; Taecharungroj, 2023)
ChatGPT can contribute to people from remote areas	Chatbots powered by AI are simplifying the process of obtaining information quickly and efficiently for individuals residing in remote regions with restricted access to healthcare providers, eliminating the need for hospital visits and long waiting times	(Haluza & Jungwirth, 2023; Panda & Kaur, 2023)
ChatGPT is an assistant that is ready 24/7	This gives us instantaneous and easy access to information and knowledge about a wide range of topics anywhere, anytime, and in multiple languages, without having to wait for someone to explain it or translate it	(Chen, 2023; Panda & Kaur, 2023; Taecharungroj, 2023)
ChatGPT can work along with other services	ChatGPT can be integrated with other tools or services (e.g. Microsoft and Google are going to integrate this AI tool)	(Cox & Tzoc, 2023; Panda & Kaur, 2023)

AI, artificial intelligence.

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lifeline, bringing services and expertise that geography would restrict. What is more, its omnipresence ensures that information and assistance are only a query away, at any time. The synergy between ChatGPT and services established by humans promises seamless integration into existing ecosystems, improving user experiences and operational efficiency.

3.2.2.2. Challenges of ChatGPT in the Human Factor.

Despite having so many benefits and opportunities in our lives, ChatGPT also presents challenges for the human factor (Table 2) (Cox & Tzoc, 2023; D'Amico et al., 2023; Dwivedi et al., 2023; Emenike & Emenike, 2023; Halaweh, 2023; Iskender, 2023; Khan et al., 2023; Nautiyal et al., 2023; Panda & Kaur, 2023; Sallam, 2023; Taecharungroj, 2023; Thurzo et al., 2023; Tlili et al., 2023).

In the landscape of AI advances, ChatGPT's impact on the human factor is twofold, affecting both the dynamics of human interaction and the framing of the more professional arena. As educators and healthcare professionals navigate the integration of this technology, the need for oversight of information accuracy and ethical considerations becomes paramount. It is essential to adapt the use of ChatGPT with a conscientious approach, ensuring that it complements human expertise without replacing the irreplaceable value of critical thinking and emotional intelligence.

It is crucial to ensure that ChatGPT and other technologies based on AI are developed and used in an ethical and inclusive manner, with transparency, equity, and fairness, to avoid reproducing prejudice and discrimination in society (Cox & Tzoc, 2023; Sallam, 2023; Taecharungroj, 2023).

The impacts of ChatGPT on the human factor are closely related to those specified in the fields of education and medicine. Both areas rely on people for their practical execution, and therefore, by impacting the field itself, it also impacts the people involved directly and indirectly. In the field of education, it affects both teachers and students, and in the field of healthcare, it affects both healthcare professionals and patients.

Table 2. What are the key challenges and societal impacts of implementing ChatGPT?

Challenge	Explanation	Sources
The information provided by ChatGPT can be true, or sometimes fake	ChatGPT may not always give totally correct information for our input. Since it is Internet-based, and knowing that not everything written there is true, we may be using false information as true, which in areas such as health can be critical in people's lives. ChatGPT might have harmful behaviours, such as dishonesty, manipulation, and misinformation Also, the information it provides is limited to the training data, which may lead to a lack of accuracy or irrelevant answers (a lack of knowledge to answer complex questions)	(Nautiyal et al., 2023; Panda & Kaur, 2023; Tlili et al., 2023)
ChatGPT can replace some jobs	ChatGPT and other innovative AI tools will affect a variety of jobs, from the most predictable (already expected to be replaced) to the least predictable (those previously taken for granted). As such, it is necessary to understand what implications this tool will have for the job market, and it is urgent to understand what skills and knowledge are needed for the next generation to succeed in a new era	(Iskender, 2023; Taecharungroj, 2023)
ChatGPT is not comparable to humans, regarding human capabilities	What distinguishes us as humans are our emotions, the social component, and motivation, among other characteristics. AI models only aspire to have these characteristics; however, although they are not there yet, they are taking steps daily towards what is called artificial general intelligence, which could have a particularly serious impact on humans	(D'Amico et al., 2023; Khan et al., 2023; Sallam, 2023; Taecharungroj, 2023)
The data given to ChatGPT is not secure	The issues of privacy, security, and reliability of personal data are another factor that needs to be explored when talking about the challenges of using ChatGPT	(D'Amico et al., 2023; Halaweh, 2023; Panda & Kaur, 2023; Thurzo et al., 2023)
The tool is not promoting equity and inclusion	It may raise questions about equity and inclusion in the use of the tool, e.g. due to the paid version being accessible only to those with funds to use it, and the fact that the tool works better in English than in other languages	(Cox & Tzoc, 2023; Dwivedi et al., 2023; Emenike & Emenike, 2023; Nautiyal et al., 2023)

AI, artificial intelligence.

4. CONCLUSIONS

4.1. Final Remarks

At the time of the launch and availability of this online tool there were questions, such as: "How did people from OpenAI think the benefits of using ChatGPT and making it available for everyone who has access to the Internet would outweigh its risks?" This work tries to understand the impact that this tool is having in society and thus contributes to coming closer to the answer to this question.

As stated earlier, the only constant in the world is change, and the impact of this whole new paradigm of ChatGPT and AI technologies and its integration into our lives are very uncertain. So, as stated by Taecharungroj (2023), it is important for people to constantly adapt and be flexible to change, and not try to run away from it, to get as much benefit as possible from these new technologies. Therefore, people need to start looking at technology as an ally and not as a threat. By way of example, Microsoft and Google are two companies that will not ignore the tool that is already replacing some of its uses, and will even integrate ChatGPT in the coming months, which leads us to conclude that everything and everyone should pay attention to the impacts of these tools and try to mitigate them (Cox & Tzoc, 2023).

As mentioned above, the most productive country in this field is the USA, followed by China. There is at least one other language model based on the GPT architecture, Wu Dao, which was developed in China, and which is significantly larger than the original ChatGPT version. Perhaps this could be the reason why China is the second country with the most articles among those selected. Moreover, three of the authors with the most articles in this area are affiliated with the university where the software was developed, the Beijing Academy of Artificial Intelligence.

According to the bibliometric analysis carried out on the 77 articles, it can be concluded that the main areas where the impacts are discussed are education and medicine, which were exactly those that were investigated in the thematic exploration of content throughout this study.

One the one hand, regarding education, in terms of scientific writing and publishing, we found evidence that ChatGPT is indeed a tool that allows generation of text in a clear, fast, and comprehensive manner, which suggests its use in the writing of academic literature. However, it falls somewhat short of what is required of it, since the information it generates is not reliable enough for publication. Therefore, the use of this tool should be discouraged, as it can promote misinformation, both by providing false information and by using non-existent citations (Manohar & Prasad, 2023). It should be used critically and only as an auxiliary tool, since it is a tool that helps and accelerates the part of writing a manuscript (Akhter & Cooper, 2023). On the other hand, regarding education in general, the challenge proposed by some articles is how conversational chatbots can adjust the way they behave and respond in a customized way, according to the human features it is dealing with (Lin et al., 2023).

Regarding healthcare, these chatbots can be a good alternative/help to aid in relieving the health system, answering some questions and providing some information to the patients, alleviating their anxiety and clearing their doubts, reducing the need for visits to the physical space (hospital), and making room for those who really need more specialized and personalized help (Budler et al., 2023; D'Amico et al., 2023).

Sallam (2023) also investigated the benefits and challenges of ChatGPT in the areas covered in this study. However, our research target (databases) is different from those used by this author. Also, Du et al. (2023) and Gao et al. (2023) address another distinct application of ChatGPT, which is its application in areas such as autonomous driving, human and vehicle interaction, and intelligent transportation systems, pointing out that this approach brings many challenges, including the privacy and security of sensitive passenger data and ensuring that the chatbot provides truthful information, to promote trust between the vehicle and its passengers.

Therefore, and as previously mentioned, many authors argue that standards and guidelines are needed to enable responsible and controlled use of AI tools and reconstruct study and research programmes to better integrate them (Nautiyal et al., 2023; Sallam, 2023). Thus, if the tool is used responsibly and according to specific standards, ChatGPT can be a valuable aid in the advancement of medicine and education, while also helping to overcome language barriers (Lund et al., 2023; Sallam, 2023).

One of the challenges pointed out about ChatGPT regarding the human factor is that of equity, inclusion, and fairness about the use of these tools by everyone. Therefore, there are authors who argue that it is a matter of time before this tool starts to be paid for, and therefore will further promote inequity (Dwivedi et al., 2023).

As the world continues to grapple with the BANI landscape, marked by its brittleness, anxiety, non-linearity, and incomprehensibility, the rapid ascent of ChatGPT has not only garnered intense curiosity but also ignited important

conversations about the role of AI in our society. This remarkable AI tool, with its exponential user adoption rate, symbolizes a pivotal moment in our digital evolution, prompting leaders like Elon Musk and Sam Altman to voice their concerns about its implications for humanity. With a surging number of papers and studies focusing on ChatGPT, there is a pressing need for a comprehensive understanding of its impact, potential dangers, and benefits. This study seeks to address these issues, shedding light on the significance of ChatGPT in shaping the ever-evolving landscape of human interaction and technology.

Moreover, it should be noted that, just as the use of calculators, computers, and the Internet, among other technologies, was doubted in the past, today we are facing a new paradigm of technology, and what we doubted before are now mechanisms aiding our daily lives. Thus, the inclusion of ChatGPT in the most diverse areas, even if in a considered way, will allow a better understanding of what is not only its potential, but also its limitations, and can contribute to adapting these same areas to the reality in which we live in the twenty-first century. In conclusion, for all the reasons stated above, ChatGPT and AI tools have the potential to elevate the human dimension to another level.

The bibliometric analysis reveals a focused integration of ChatGPT in health and education sectors, signaling an active pursuit to leverage AI in areas critical for societal advancement. With the United States leading in the

Table 3. Data synthesis of the study

Bibliometric analysis	Thematic exploration of content
Analysis by area • ChatGPT applications are diverse, with a focus on health and education (both at 27%) • A significant portion (20%) addresses multiple areas, reflecting multidisciplinary research • Social applications of ChatGPT are less explored but can be considered an emerging field	ChatGPT and education • ChatGPT's role in education includes scientific writing, academic publishing, and general learning assistance • Concerns include the potential for misinformation, plagiarism, and dependence on ChatGPT's generated content • While ChatGPT can aid in research tasks, it should be used critically, and policies are needed to ensure rigorous scientific standards • ChatGPT is used in education to enhance scientific writing and serve as a 'learning companion.' However, concerns about plagiarism and overreliance on the tool have been raised. It may assist in various educational tasks but should not replace human input entirely
Analysis of geographical distribution • The United States is the most prolific country in ChatGPT research, with 28 articles • China follows with six articles, and the United Kingdom with five articles	ChatGPT and healthcare/medicine • ChatGPT offers benefits such as improved efficiency in healthcare, literature review assistance, and time savings for healthcare professionals • Challenges include the potential for incorrect information, transparency of data sources, privacy, and the lack of a personal and emotional perspective • The benefits and risks of integrating ChatGPT into healthcare should be carefully considered
Analysis of most recognised authors • Authors are grouped into clusters by country, indicating collaboration within their respective regions • Some authors debate whether ChatGPT should be considered an author, as it is a tool rather than a contributor to research	ChatGPT and the human factor • ChatGPT has the potential to enhance the human dimension, offering numerous benefits and opportunities • ChatGPT offers benefits such as assisting vulnerable populations, increasing efficiency, and being available 24/7 • Challenges involve ethical and inclusive development, transparency, and addressing biases to avoid discrimination in society • Challenges include the accuracy of information, potential job displacement, and the limitations of artificial intelligence compared to human capabilities. Ensuring privacy, security, and equity is crucial
Overall impact • ChatGPT's influence extends beyond individual fields, affecting the professionals and people involved • It presents both opportunities and challenges in various domains, emphasizing the importance of ethical and inclusive use	

number of publications, this points to a strong AI research ecosystem potentially driven by the presence of OpenAI, indicating regional influences on technological adoption. The clustering of authors by country, as shown by the VOSviewer, suggests a predominance of national collaboration and highlights a gap in international research partnerships, presenting an opportunity for a more global exchange of ideas and knowledge in AI.

The thematic exploration of literature content in ChatGPT underscores its pivotal role in redefining educational and healthcare landscapes. Its deep learning foundations and GPT architecture empower it to process language in a way that closely mirrors human interaction, positioning it as an innovative tool that could reshape pedagogical and clinical practices. In education, it offers a promise of augmented learning experiences, while in healthcare, it could influence both clinical decision-making and patient interactions. This transformative potential, however, comes with the responsibility to address the ethical dimensions of AI deployment, ensuring that its integration supports human expertise without compromising ethical standards or exacerbating inequalities.

Overall, these analyses situate ChatGPT at the intersection of technological innovation and human-centric application, emphasizing the need for a thoughtful and ethical integration of AI in pivotal societal sectors.

In summary, our analysis delves into the multifaceted influence of ChatGPT, spanning fields as diverse as education, healthcare, and the broader human factor. As the human dimension evolves alongside AI technologies like ChatGPT, our findings emphasize the critical importance of responsible integration, transparency, and the mitigation of biases in our society. Table 3 presents the data synthesis of the study, highlighting the main outcomes.

4.2. Contributions and Implications

Given the exponential growth in studies related to ChatGPT, there is a need for research that systematizes the concepts in terms of impact and clarification of the concept itself. Thus, a SLR was conducted with the aim of assessing the impact of ChatGPT in society, by means of which it can be concluded that people are surprised and scared at the same time with the appearance of this tool.

As a result, this study features at least two contributions, which can help both academia – with a theoretical contribution – and practitioners – with practical contributions:

(1) Theoretical - this involves expanding understanding and elucidation of the impacts of ChatGPT in different areas of study, and also clarification of the concept itself;

(2) Practical – this aims to inform people in general (both in professional and personal life) about the benefits of the tool and warning about the dangers, leading them to a more prudent use of it.

4.3. Limitations and Future Work

Despite these two contributions, this work has some limitations. On one hand, the contributions are based only on secondary data sources, scientific articles; and on the other hand, since the tool has recently appeared, and given the growth in the number of studies published daily (which showed the need for systematization), the review had to be done over a short period of time. Due to the novelty of this tool, ChatGPT, it is normal that first studies end up raising several questions and prompting future works, more than providing detailed answers for those questions.

For further investigations, the plan is to follow the trends of the topic (ChatGPT and its impacts), with a systematization of works, due to the number of studies being published daily. Furthermore, it was found that there is a need to carry out awareness raising actions on the impact of ChatGPT, to avoid fears and mistrust within the main fields. Moreover, there is a need for regulation at the beginning of the use of ChatGPT, since this type of AI tool is becoming almost indispensable nowadays, and with the passage of time, to avoid the inappropriate use of it. Then, the undertaking of a work with guidelines about the tool itself, and how it should be used should be proposed. Also, although ChatGPT is a helpful tool, people look on it as a threat, and so in order to counteract this, the development of mechanisms is proposed that would allow people to start taking a different perspective on AI. Finally, after widespread use of the tool, it would be interesting to understand its impact on users by resorting to primary data sources (i.e. talking directly with them).

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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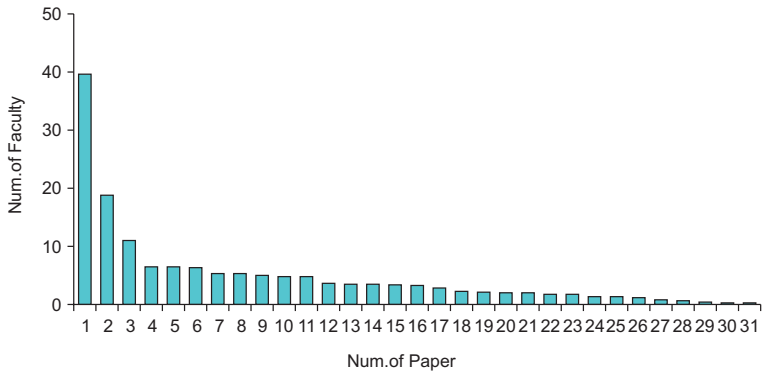


Fig. 1. Distribution of authors over publication count.

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Table 1. The title of table goes here

Study	Time period study	Data
Smith Wesson (1996)	1970 - 1995	684 papers in 4 SSCI journals
Reeves [a (2002)	1997 - 2001	597 papers in 3 SSCI journals
Jones Wilson [b (2011)	2000 - 2009	2,166 papers in 4 SSCI journals

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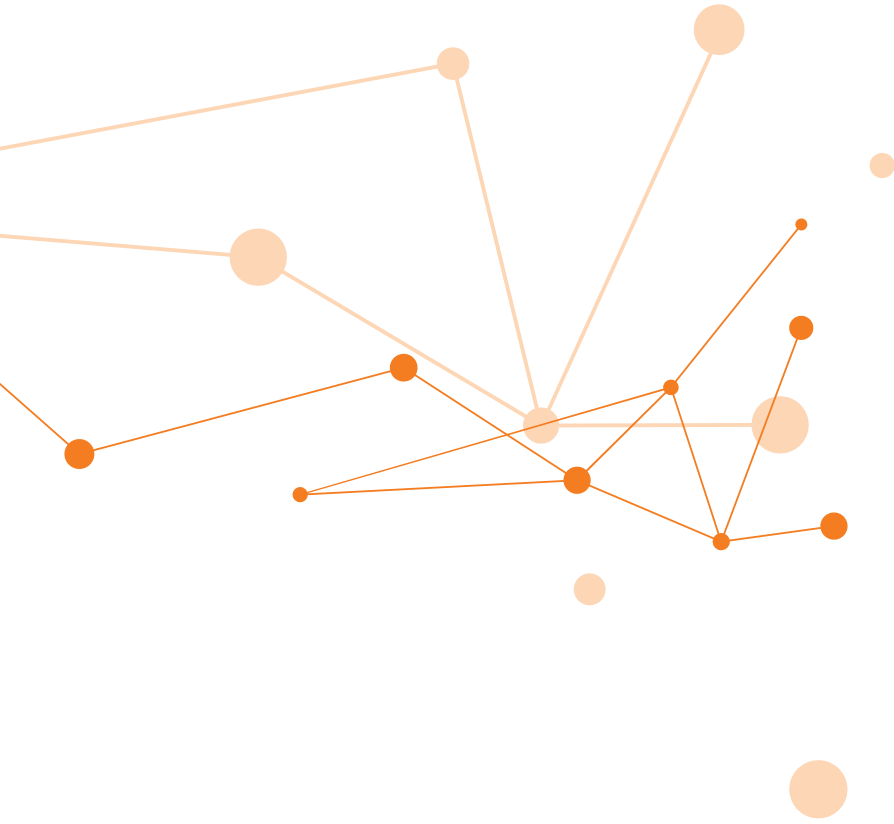
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