UDC 001.895:004]:027.7(100)
DOI: 10.31866/2616-7654.13.2024.307116

INNOVATIVE TECHNOLOGIES AND THEIR APPLICATION IN ACADEMIC LIBRARIES

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For citation:
Leong J. (2024). Innovative Technologies and their Application in Academic Libraries. *Ukrainian Journal on Library and Information Science*, *13*, 44–60. https://doi.org/10.31866/2616-7654.13.2024.307116

The aim of the article is to research and critically analyse the use of innovative technologies in academic libraries of foreign countries.

Research methods used in the study. To achieve the goal, a systematic approach, scientific analysis, synthesis, generalisation and systematisation was used. The methodology of the article was formed by a complex of approaches to scientific knowledge – objectivity, connection between theory and practice, cognitive, structural and functional.

The scientific novelty consists in revealing the specifics of the application of innovative technologies in academic libraries of foreign countries, performing a critical analysis, the advantages and disadvantages of the introduction of new technological trends, namely: artificial intelligence, blockchain, robotics and automation systems, virtual reality and immersion technologies, the Internet of Things.

Main conclusions: The discussion in this article demonstrates that there are risks and limitations of in applying technology in the library. User privacy, information security, financial and human resources, and the creation or reinforcement of social injustice all deserve careful consideration in the process of selecting and implementing new technology in the library. With that awareness and consideration, information professionals can then move beyond accessing new products, to advocating for equity-diversity-inclusion (EDI) -oriented design practices. Before fully embracing a technology, information experts may critically explore the social justice concerns and empower user with their findings in their digital literacy programs.

Keywords: academic library; innovative technologies; artificial intelligence; blockchain; robotics and automation systems; virtual reality and immersion technologies; Internet of things.

INTRODUCTION

The overarching objective of this paper is to investigate and reflect critically the application of innovative technologies in academic libraries. What are these new technologies and how are they being adopted in responding to emerging pedagogy and research in an academic environment? What are the benefits, impact, and concerns of implementing these new technologies in library setting from the perspectives of users, staff, and the public community? How can academic libraries embrace the values of equity, diversity, and inclusion in developing services and programmes around these new technologies?

Major technological changes have affected universities and academic libraries in recent years in the shadow of the pandemic. These changes have disrupted ways of learning, teaching and research required and expected by students and faculty mem-

bers. Academic libraries are often early adopters of innovative technologies in an effort to extend experiential learning to support teaching, learning and research in higher education. They have responded to these rapid changes by taking up and implementing a range of technologies to facilitate and support the changes in pedagogy and research environment in both physical and online delivery. Academic libraries have focused more on engaging the communities and experiential learning with immersive and innovative technology.

The aim of the article is to research and critically analyse the use of innovative technologies in academic libraries of foreign countries.

RESEARCH METHODS AND MATERIALS

Methods used in the study. To achieve the goal, a systematic approach, scientific analysis, synthesis, generalisation, and systematisation was used. The methodology of the article was formed by a complex of approaches to scientific knowledge – objectivity, connection between theory and practice, cognitive, structural, and functional.

RESEARCH RESULTS

This paper presents the findings of the literature review and an environmental scan of the application of innovative technologies in academic libraries. The qualitative and critical reflection approach is used in reading and interaction with scholars and practitioners in this field. This approach is appropriate as there are sufficient case studies that usefully describe and analyse the application of new technologies in academic libraries. Questions guiding the discussion and investigation include:

1. What were the services and programs developed primarily with innovative technologies in response to the change in teaching, learning and research environment?
2. What were the objectives, rationale and context for these services and programmes?
3. What were the outcomes?
4. Who planned and implemented the work?
5. Was there evaluation of the services and programmes? What were the results?
6. What worked well and what lessons were learned?
7. What are the benefits, impact, and concerns of implementing these new technologies?
8. Were values of equity, diversity and inclusion considered in the planning and implementation process? How were these values embedded in the services and programmes around these new technologies?

Five Innovative Technologies and Their Implications

I have identified five emerging technological trends in scope of this paper, namely artificial intelligence, blockchain, robotics and automation system, immersive technology, and internet of things. Their applications in academic libraries and their implications are discussed as follows:

1. ***Artificial intelligence***

This discussion of applications and implications of artificial intelligence (AI) in academic libraries has been in the information science discourse for decades. AI has entered library areas such as search and information discovery, collection management, academic publishing, information literacy, and references services. With the rise of

generative AI such as ChatGPT, AI becomes a hot topic in academia and issues of privacy, data security, academic integrity and threats to job continue to dominate the discussion. A deeper understanding of this technology and how it affects academic libraries becomes more important than ever for information professionals to get involved in the development and stewardship of this technology.

Association of College and Research Libraries (ACRL) published a comprehensive collection of case studies discussing the rise of AI in academic libraries. In this work, Hervieux and Wheatley (2022) define AI, with emphasis on its fluidity, as "the development of machines to accomplish tasks and reproduce thought processes that are normally seen in humans; this simulation of intelligent behaviour is unique from other automation as it requires the computer to use human reasoning or thinking to perform tasks" (p. ix). Machine Learning (ML), a subset of AI or its own field, refers to a computer algorithm's ability to "observe and detect patterns in data with the goal of being able to predict future decisions and outcomes from said data" (Hervieux & Wheatley, 2022, p. ix). With this fluid and approachable definitions of AI and ML, ACRL's edited volume illustrates how information professionals have embraced new technologies in their work. It consists of 12 case studies of AI initiatives in user services, collections, and discovery, as well two discussion papers exploring ethical implications and machine information behaviour in future applications. These 12 case studies are summarised in Table 1. Significant observations of these case studies include the critical role of librarians in building programmes of AI literacy, the opportunities of collaborations, community engagement, the emphasis on the involvement of information professions in data training and system development, and advocacy of equity, diversity, and inclusion.

Table 1.

Case studies of the applications of AI in academic libraries

Institution	Theme	Time	Discussion
University of Toronto	Empowering a University Community through an Open Learning Pilot	2019–2020	• Success of an AI Community workshop program; • Strengthening critical understanding and awareness of AI; • Building AI competency; • Advocating for diversity.
University of Rhode Island	AI Lab: Evolving to Meet the Needs of Students and Research Communities	2018–2020	• Creating an AI Lab in an academic library; • Collaboration of multiple colleges, academic groups, and university technology services; • AI Summer Camp demonstrating the Lab's commitment to inclusivity and community engagement; • Workshops to explore the possibility of human rights violations and discrimination propagated by unethical adoption of AI technology; • Inclusion of the library in the research agenda around the application of AI technologies.

Продовження табл. 1

University of Ottawa and Concordia University	Improving Machine Translation Literacy on Campus	2019	• Supporting informed use of machine translation for international students through literacy instruction; • Workshop introducing concepts of privacy/confidentiality, academic integrity, algorithmic bias, and awareness of the variety of translation tasks, tools, and input.
Toronto Metropolitan University (formerly known as Ryerson University)	Incubating AI – The Collaboratory	2019 – 2021	• Creating the Collaboratory, a multi-disciplinary research space; • Examples of scholarship produced from its collaborations and AI applications include This Criminal Does Not Exist to uncover the inherent biases within facial recognition technologies, AI Journal Club for interdisciplinary discussion, and Remastered Exhibition demonstrating the application of ML in art industry.
McGill University	Creating an Academic Library Workshop Series on AI Literacy	2020	• Developing a three-part workshop series in instigating conversation around AI Literacy: AI Literacy, AI Ethics and Bias, and AI in Research; • Introducing ROBOT test: Reliability, Objective, Bias, Ownership, Type.
Western Michigan University	Using Robotics for an Exam Week Activity in the Library	2019	• Success of using robotic animals as a replacement for therapy pet visits in outreach; • Received mostly positive responses with some mixed or negative comments; Attracted students for reasons beyond relaxation, including curiosity, connection to their own pet, and participating in an empirically driven survey.
Stanford University	Subjectivity and Discoverability of Images	2019	• Using computer vision combined with machine learning to classify images and improve the accessibility of collections; • Comparing Google Vision with Clarifai, pre-trained only versus with the input of a small set of training data; • AI solutions cannot replace cataloguers; Cataloguers, supported by AI technology, can scale up their work and provide expertise in AI's training process.

Продовження табл. 1

OhioLink	AI-Informed Approaches to Metadata Tagging for Improved Resource Discovery	2019	• The use of unsupervised machine learning to improve the discovery of electronic theses and dissertations; • Using Python to extract metadata, including title, abstract and keywords; • Using Doc2Vec and DBPedia to train and generate a corpus of text; • AI generated subject and concept tags rated by authors as "somewhat relevant"; • LAD, a topic modelling tool, to enhance internal information discovery; • Human input and machine automation need balance.
Raymond A. Mason School of Business at William & Mary	Robotic Process Automation in Metadata Curation and Scholarship Discoverability	201-- 2020	• How metadata for an institutional repository can be automated by robotic process; • The automation retrieves clean and exact records from WorldCat satisfactorily while more complex records require manual research, leading to a complementary automation.
National Archives (UK)	A Machine Learning Club for Information Specialist	2019 to 2020	• Bringing together professional and scholarly conversations on the use of ML in information sciences in a series of lunchtime talks, assisted by Google Colab; • Topics include data analysis, data cleaning, and ML algorithms.
University of Edinburgh	Adopting Handwritten Text Recognition (HTR) Technologies to Support Research	2019–2020	• The use of Transkribus software to support the digitisation of handwritten text in libraries; • Transkribus, developed by an EU consortium, uses deep neural network machine learning technology; • Training of the software requires significant resources and careful planning to make it useful, sustainable and integrated with existing infrastructure; • Issues include implications for energy usage and carbon emissions.
Auburn University	Using IBM Watson for Discovery and Research Support	2019–2020	• A library-industry partnership of applying machine learning & natural language processing enabled by IBM Watson to institutional research discovery; • Development of AI/ML tools require extensive human intervention;

Ridley (2022), in the concluding article of this edited volume on AI's future development, brings our attention to machine information behaviour for further discussion of AI and machine learning in the information studies. As the adoption and AI and ML becomes more widespread, machine information behaviour (MIB) may create challenges for the services, resources and programs that academic libraries offer based largely on human information seeking behaviour. A preliminary integrated human and machine information behaviour model is offered in Figure 1.

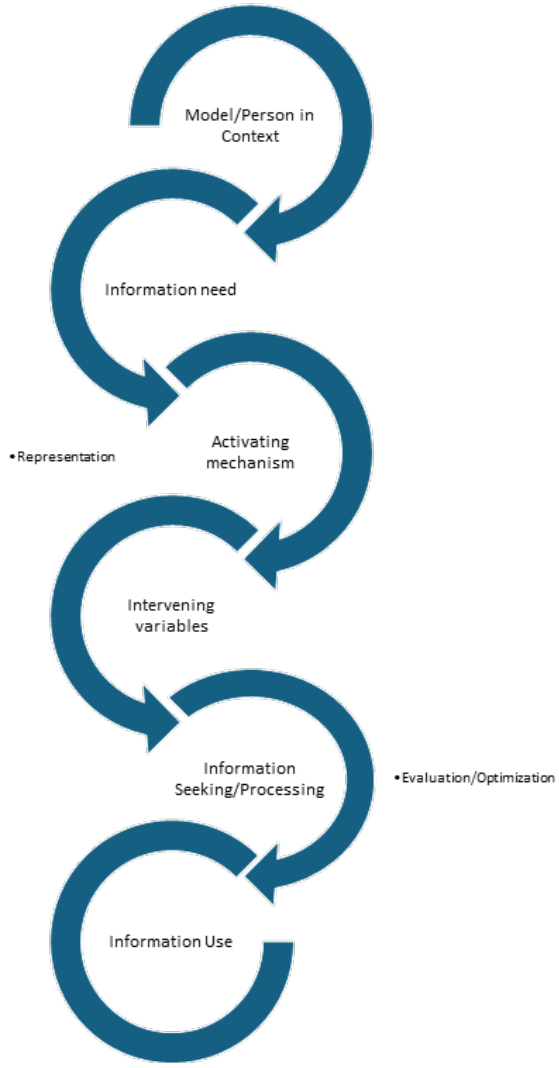

Fig. 1. Combined model of machine and human information behaviour, adapted from Ridley (2022).

Instead of a person, machine information behaviour begins with a system model that performs optimization, evaluation, and information representation throughout the process. Understanding these characteristics of MIB can help librarians better prepared for developing collections, programmes, and services using this emerging technology.

The development of chatbots for enhancing library reference services appears to be the pioneer of the applications of AI in academic libraries and most discussed in literature. McKie and Narayan (2019), for example, discusses the use of chatbots to improve the user experience for university students by reviewing literature and reflecting on a prototype developed at the University of Technology Sydney (UTS). They propose that information specialists can adapt emerging technologies such as chatbots to innovate, improve and support library services and emphasize that "designing a positive experience for the user is essential to ensure that such technological solutions are sustainable" (p. 268). They also advocate for the engagement of librarians in "the conversational design of the library chatbot in collaboration with the technology developers in order to make it useful, friendly, trustworthy, and customisable for university students" (p. 268).

Kaushal and Yadav (2022) conduct a qualitative study examining the perceived risks and challenges behind the adoption of chatbots in libraries. They discuss how chatbots could help deliver positive experience to library users as well as stakeholders. Conducting interviews with stakeholders of academic libraries, including library staff, doctoral students, and the faculty, to understand their perspectives on the use of Chatbots. Their findings suggest that most stakeholders they interviewed supported the usage of chatbots. These interviewees believe that "integrating chatbot technology with an existing library information system could deliver diverse services, which in turn would help in research and scholarly communication" (Kaushal & Yadav, 2022, p. 215). However, the interviewees also point out high "perceived risk" in employing chatbots. They "raised some serious concerns with respect to privacy intrusion by chatbots, and with respect to chatbots' comprehension of task complexity, which are issues that must be addressed by chatbot developers while designing them, specifically for libraries" (p. 215).

Wan (2022) explores the extent of library chatbots in assisting reference librarians in providing simple interactive services to the new generation of students. Developing a pilot project on the business platform Engati, Wan demonstrates the potential of a chatbot: answering simple reference questions and contributing to the enhancement of cultural diversity in academic libraries with its multilingual feature. As AI chatbot development become less demanding, Wan's pilot project demonstrates that locally developed AI chatbots are possible and they could provide low-threshold solutions.

With breakthroughs in the development of Natural Language Processing, Deep Learning, Artificial Neural Networks, and Voice & Speech Recognition, programming more sophisticated AI Chatbots become possible for librarians who have experience in computer programming. These Chatbots not only provide answers to simple reference questions but may also recognize and authenticate individual users for personalized experiences. The release of ChatGPT (Chat Generative Pre-Trained Transformer) by OpenAI in 2022 demonstrated the significant impact and power of AI tools. In five days, it attracted over one million users which increased to 100 million in two months, to try out ChatGPT's many capabilities ranging from providing humanlike conversationally responses to questions, composing stories from prompts, generating computer code, translations, and summarising, classifying and analyzing texts and data (Holland,

2023). Despite its popularity and seemingly superior capabilities, there are many limitations of ChatGPT, which includes not following user's explicit instructions, making up nonexistent or wrong facts, not being able to explain how to arrive at its own decision or prediction, and generating biased, toxic, and outdated output (Holland, 2023).

Despite the shortcomings discussed above, the ability of ChatGPT and other AI tools to provide generally logical, articulative, fully formed answers trained by 45 TB text data and 175 billion parameters challenges conventional reference services (Holland, 2023). Librarians are revisiting their reference consultations conducted in form of reference interviews involving using library resources and evaluating the credibility of open sources available on the internet. They are turning these challenges into opportunities for libraries to improve their services by automating simple reference transactions and releasing their limited resources, especially time, to address more complex tasks. This process may involve working with IT professionals in the development of AI tools in libraries and collaborating with faculty members on the instruction of correct use of AI tools with academic integrity, transparency, and honesty. As always, librarians are also helping users to develop their critical thinking skills by comparing AI-generated responses with reliable, valid library resources, and emphasizing the ethical adoption of AI with proper research and citation practices.

Besides chatbots, another emerging application of AI technology in libraries seems to be book recommender systems (Khamis, 2023). In reviewing various machine learning algorithms and their applications in building book recommender systems, Khamis classifies recommender systems into three major categories: content-based, collaborative filtering, and hybrid systems. Two book recommender systems and the logic behind them are illustrated to enable the adaptation of these two systems in library setting. The first system adopts an unsupervised machine learning algorithm that makes recommendation based on the coded characteristics of the books in the system. The second system, yielding more satisfactory results, requires input from users as it recommends books based on both the coded features of the books and the review and reading history of users.

In implementing AI and ML in libraries, such as chatbots and recommender systems, there are technical and ethical challenges. With the rapid development of technology, technical issue may be overcome with additional resources. Ethical concerns seem to be more complex and require further investigation. Cox (2022) summarises the key ethical issues raised by AI in general, including both those inherent to the technology and those arising from the nature of the AI industry. By analysing existing studies that have discussed aspects of the ethical issues for information professionals, Cox (2022) provides a set of eight ethics scenarios that have been developed and shared in an open form to promote their reuse. A summary of these eight scenarios is presented in Table 2.

These scenarios draw our attention to the issues of information sharing, security, privacy, power dynamics, and the implicit bias of machine learning algorithms in AI's future development. These ethical issues have significant impact on users and information professions in adopting AI tools in libraries. As Nayyer and Rodriguez (2022) point out, AI and ML technologies "can embed and magnify prejudices and stereotypes, and they can perpetuate errors and limitations in training and accumulated datasets" (p. 165). Researchers have attempted to mitigate these shortcomings by supplying corrective data and decision-making paths to help train AI tools, as well as fixing datasets to alleviate impact of embedded implicit bias. There is also need for regulatory

guidance to provide a framework for AI. With their established expertise, academic librarians are well-positioned to collaborate with developers in providing meaningful, creative, and ethical insights for addressing information security, privacy, and implicit bias in AI development.

Table 2:

Eight scenarios of ethical issues in the applications of AI

Areas of concerns	Ethical scenarios
Supporting first responders	Data managers raise objections to sharing data for a system to support.
Nudges	Library asked to contribute data to a tool that nudges students to improve their well-being.
The voice assistant	A library offers a voice assistant service to the public.
A special collection	A donation is predicated in enabling access to controversial content.
Forum moderation	Automating the moderation of public forum.
The recommender system	Recommendations based on past reading may hinder exploring new areas of interest.
Stakeholders	Involvement of stakeholder communities in an AI project.
Project partners	Concerns about power and ethics in a joint project.

2. ***Blockchain***

Research visibility and discovery have been major research support areas for academic libraries. This service has been facilitated and disrupted at the same time by the increasing number of research profiling platforms, such as ORCID, Google Scholar, Research Gate and Digital Object Identifiers (DOIs). Many researchers do not have time and intent to join and maintain an update profile in any of these platforms. The use of blockchain technology in peer review and publication process may address this challenge by automatically updating and validating the profiles of researchers starting from the manuscript review process. In this section, the applications and consequences of this record and transaction keeping technology will be explored.

Holland (2020) introduces blockchain technology (BT) and its potential applications in libraries in her paper "Emerging Technology and Today's Libraries." BT combines cryptographic techniques and peer-to-peer networks to create, time-stamped, tamper-resistant, secure, and transparent records of transaction or event using Distributed Ledger Technology. Bitcoin, a peer-to-peer electronic cash system is the most well-known application of BT. Digital Science, Katalysis and ORCID have been developing projects to record peer review activities related to scholarly publication using BT. The application BT in these projects allows the review and publication process to be independently validated while authors' scholarship can be updated in appropriate research profiling platforms simultaneously to ensure recognition and validation.

BT can also potentially facilitate the sharing and authenticating of unique digital objects for cultural institutions, such as libraries, museums, archives, and art galleries. WorldCat, in the form of consortium blockchain, has been performing this function with the catalogue records of libraries all over the world. With BT, the actual content of libraries' digital assets and data can be stored, circulated, tracked, and validated securely on the

Internet. Digital rights management of these assets can be enhanced with BT, which are best suited for "uniquely identify, verify, control and transfer content" (Makori, 2020, p. 41).

Applications of BT in libraries include digital preservation and tracking, development of community-based collections, interlibrary loan systems, enhancing reliability and trustworthiness of data, and improving library services. Panda and Kaur (2023) suggest that BT may be applied in libraries to enhance their services, including circulation services, collection development, storage, and data management. BT's applications in the following areas appear to be also applicable in academic libraries:

- Scholarly publishing – the decentralized feature of BT may address the publisher-centric, piracy, author rights issues.
- Secure online access – BT can create a secure and private digital identity protecting users' privacy and personal identity.
- Research Data Management – BT can help with the planning, organization, storage, protection, security, curation, and support of research data for open scholarship.

In their systematic literature review of 39 recent publications on blockchain and libraries, Bashir and Warraich (2023) identify the following major areas of application of BT in libraries:

- Digital rights management
- Intellectual property and scholarly publishing
- Decentralisation
- Establishing trust and protects privacy
- Library verification of credentials
- Interlibrary loan, resource sharing and voucher system
- Increases efficiency and integrity
- Building a distributed, permission-less metadata

BT, as an innovative technology requiring robust digital infrastructure and Internet connection, comes with some challenges. Blockchain networks require high energy consumption, high-speed Internet and secured data transfers that may create more intense digital divide. BT appears to be complex, rapidly changing, costly to develop. Finally, the social and legal regulation and monitoring of this technology are yet to be developed, posting concerns and risks in equity and legitimacy.

3. ***Robotics and Automation***

Automated storage and retrieval system (ASRS) appears to be an early example of the adoption of robotics in academic libraries. This system has been installed in most high-density storage facilities. The application of robotics in other areas may still be in its infancy, such as in automating the sorting, transporting, and shelfing of materials and providing directional touring services. Nevertheless, for its connection to the success of makerspace, an important library service today, it is worthwhile to examine the impact of robotics on academic libraries.

One of the most significant benefits of developing an ASRS is to free up space in the library for study space and innovative services, such as makerspace and media lab. At the time when the use of electronic resources continues to increase, high density storage with automated storage and retrieval system enabled by robotic technology appears to be perfection solution for preserving and managing low-use print collections.

In an ASRS system, books are stored in large metal trays of bins which are arranged according to their sizes accommodating various dimensions of books that are usually

divided into small, medium, and large. These bins are stacked vertically in a high vault and can be identified by its barcode or built-in senor, such as radio frequency identification (RFID). Typically, when an item is requested, a robotic arm kicks into action to find the right bin and bring it to the staff station to retrieve the exact item in the bin. The item will be delivered to a service point for pickup by the user while the bin will be taken back to the vault by the robotic arm (McCaffrey, 2021).

The new space created by ASRS opens up new inspiration leading libraries to provide innovative services and centres. One of them appears to be makerspace which is equipped with various robotic tools, equipment and workstations addressing the "increased interest in learning practical skills and crafts" (Carlson, 2022, p. 17). Cline Library at Northern Arizona University, for example, established The MakerLab as early as 2017, which is:

> [A] multiple disciplinary collaborative workspace allowing [library] community to learn, explore, discover, and create in ways that foster imagination, promote creativity, and solve real-world problems. The Makerlab's equipment supports hi-tech to low-tech making and discovery options including a MakerBot Innovation Center consisting of twenty 3D printers, 3D Scanners, electronic prototyping kits, and a variety of crafting tools and supplies. The MakerLab facilitates the design and creation of personal and academic projects, group projects and assignments, and experience-based instruction sessions and workshops. (Holthe & See, 2022, p. 35)

Similar to Cline Library's The MakerLab, academic libraries have deployed a makerspace facilities for advancing their institution's experiential learning initiative, fostering partnerships, enhancing the visualization and usage of their special collections through 3D scanning and printing, promoting open-access barrier-free inclusive environment and creative process, and connecting maker literacy to ACRL's Framework for Information Literacy (Holthe & See, 2022; Wyatt & Garrett, 2022; Phillips & Brown, 2022; Nagle, 2022; Vecchione, 2021). Peery (2021) compiles an edited volume *Maker Literacy for Academic Libraries: Integration into Curriculum* introducing how University of Texas at Arlington Libraries and partners, including The DeLaMare Science and Engineering Library at the University of Nevada, Reno, the Digital Media Lab in the W. E. B. Du Bois Library of University of Massachusetts Amherst, and University of North Carolina at Chapel Hill Libraries, employ their makerspace initiatives to create, refine and expand the list of maker competencies for students to obtain through maker-based course assignments and curriculum integration.

In the cases discussed in Peery's edited volume, many libraries also extend the development of makerspace to include virtual reality and immersive technologies, which will be discussed in the following section.

4. ***Virtual Reality and Immersive Technology***

Immersive technology, including virtual reality, augmented reality, and mixed reality, has become mainstream technology. Academic libraries are increasingly equipped with this technology for use by students and faculty, and to enhance library services with gaming, simulations, virtual tours, digital exhibits, and other immersive and experiential applications. In this session, the benefits and concerns of using immersive technology in academic libraries will be contested.

Immersive technology gained its popularity in science fiction, such as Ray Bradbury's "The Veldt" (1950), Gene Roddenberry' *Star Trek: The Next Generation* (1987–1994), and Stephen King's *The Lawnmower Man* (1992) and gaming industry (Kirsch, 2020). In recent years, it has moved from an emerging technology towards a mainstream technology for improving shopping, indoor navigation, driving functionality, teaching, and experiential learning.

Kirsch (2020) observes that immersive technology has been adopted in libraries and education institutions in many contexts. Academic libraries have begun to purchase and circulate VR equipment, and facilitate the creation VR content for library services, including gaming, simulations, tours, exhibits, therapeutic programming, virtual events, and library instruction. For example, Google Expeditions is used in classrooms and library outreach for students and library users to virtually visit foreign countries and immerse in important cultural events. Realizing the therapeutic benefits of VR, some libraries offer relaxation and mindfulness programs and events by providing VR services (Kirsch, 2020). There are also initiatives to preserve cultural collections, provide 360-degree tours, deliver staff training, and enhance makerspace services via immersive technology.

One popular application of immersive technology appears to be in the library's gamification efforts to incorporate "elements of gameplay in nongame situations" (Crowe & Sclippa, 2020, p. v). Evolved and became popular since early 2000s, the concept of gamification refers to the "use of video game logic and psychology in real-world environment" (Heffernan & Chartier, 2020, p. 194). Fascinated by the popularity of video games and its deep engagement feature, research on gamification is conducted and it is suggested that "people respond naturally and efficiently to competition, reward, and simulated risk" (Heffernan & Chartier, 2020, p. 194). Information professionals began to explore games and gamification in academic libraries to incorporate a combination of these elements in their services and programs for reaching out to students and scholars who grew up with video game culture. Shiparo Library at Southern New Hampshire University, for example, develops an in-house geospatial app that combines gamification, mobile and virtual technologies into the exploration and orientation of library and campus resources and services (Heffernan & Chartier, 2020). An augmented and virtual reality tour of the library has been developed at St. Cloud State University Library followed by a gamified library instruction (Miltenoff, 2020).

Offering immersive technology to library community helps the libraries become more visible, possibly leading to increased publicity, recognition, donations, or grants. Additional benefits include enhancing immersive, active, deeper, and experiential learning because VR makes course content more real and helps students "remember content better, ask more questions, and experience a place rather than just viewing it" (Kirsch, 2020, p. 183). There are both benefits and challenges in terms of accessibility in the adoption of immersive technology. People with mobility issues or students with anxiety or attention deficit disorders can take advantages of this technology to experience places that they normally will not be able to visit and block out distractions to help with their attention focus. However, students with vision or hearing impairments will not benefit from immersive technology which is primary a visual and audio experience.

Key challenges associated with immersive technology involve the costly setup, maintenance, and replacement. There are also user reports of dizziness and issues with motion sickness in using VR equipment such as goggles (Miltenoff, 2020). This tech-

nology is relatively new and requires additional efforts in staff training and administration support. There are concerns in privacy as personal data and usage patterns may be stored from VR equipment. In creating content for VR, copyright can be an issue as the content generation process may involve licensed software, users, and staff. Working as a team with clear communication and scheduling, matching skills with needs, and understanding the requirements of accessibility and user experience, information professionals can create and implement services and programs that gamify tours, training, and even library events with immersive technology.

5. ***Internet of Things***

The term "Internet of things" (IoT) refers to any physical objects that are connected to the Internet. These linked objects often use the same Internet Protocol allowing for communication, such as through radio frequency identification (RFID). In academic libraries, RFID has been used in collection management and self-service provision. With smartphones, quick response (QR) codes and other wearable devices, Internet of things has potential for many new applications. As trusted data and communication are essential for the establishment of this connectivity, data protection, security, privacy, and ethical issues need to be considered carefully (Atkinson, 2021).

The term IoT first appeared in Kevin Aston's presentation he made at Procter & Gamble company in 1999 (Liang, 2020; Holland, 2020). In her introduction of this concept, Holland (2020) points out five key elements of IoT:

(1) Identification – such as a unique QR code or a radio frequency;

(2) Sensing – collecting local data for central processing;

(3) Communication technologies – networks and protocols connecting objects and the system, such as Wi-Fi, Bluetooth, and Low-Power Wide-Area Network;

(4) Computation – hardware and software that process the collected data real-time; and

(5) Services related to identity, information aggregation, collaborative-aware and ubiquitous.

IoT enables remote control of doors, lighting, self-service kiosks, and public computers in library buildings. It allows the opening and management of libraries without staff members, significantly extending library opening hours and services while optimizing energy consumption. Library materials embedded with sensors, such as RFID or Bluetooth beacons, support mobile wayfinding and recommender services (Hahn, 2020). They allow automated inventory check, searching for or tracking of a specific item, better security mechanism, and user check out and in of library materials (Nambobi et al., 2020). Apart from early applications of IoT in self-checkout, stock-taking, access control, asset tracking, and monitoring network and space, coupled with immersive technology and AI, the libraries may develop innovative, responsive, situated, and tailored services to meet the twenty-first century library users' needs (Liang, 2020).

The IoT applications in libraries face challenges in technology infrastructure, standardization, security, and privacy. The installation of a networked environment with sensors in all its assets entails significant costs and commitment. Selecting the types of network and sensors requires expertise of information and communication technology. The rapid development of IoT creates difficulty in standardization of communication protocols and networking requirements. Libraries may partner with their home institute's information technology unit to address these issues. The hacking of Toronto Public Library

in October 2023 raises tremendous concerns about the cyber-security of libraries, and information privacy. Libraries may invest in encryption, identity management, security, and privacy protection mechanism to ensure information security and privacy in the IoT.

Innovative Technologies and Social Justice

The discussion in each innovative technology demonstrates that there are risks and limitations of in applying technology in the library. In addition to user privacy, information security, financial and human resources, the creation of "the New Jim Code" requires careful consideration in the process of selecting and implementing new technology in the library (Benjamin, 2019, p. 5). In discussing race and technology, Benjamin suggests that technology, claimed to be neutral in terms of racial bias, reinforces existing discriminating system. "The New Jim Code" refers to "the employment of new technologies that reflect and reproduce existing inequities but that are promoted and perceived as more objective or progressive than the discriminatory systems of a previous era" (Benjamin, 2019, pp. 5–6).

In selecting and implementing new technologies in libraries, we need to carefully examine if the discriminating patterns and biases of past users have passed on to the algorithms and training data. In designing new services and programs, we need to ask if there is any hidden assumption of racial difference, including seemingly positive affirmations or celebrations of presumed cultural differences, leading to biases? Technologies, designed and implemented by human, can carry racist judgment in the designing, encoding, and training process. Racism may in fact be "magnified and buried under layers of digital denial" (Benjamin, 2019, p. 12). "Tailored" services enabled by AI and IoT may have serious downside when these services involve targeting and stereotypical repression in "encoding race, ethnicity, and gender as immutable characteristics that can be measured, bought, and sold" (Benjamin, 2019, p. 21).

Understanding that technology can be racist is the first important step to ensure services embracing new technologies in libraries uphold the equity, diversity, and inclusion (EDI) values. Technology, creation of human society structured by interlocking forms of domination, may amplify social hierarchies based on race, class, and gender. Related to the concerns of privacy, technology makes surveillance or control more sophisticated and efficient, targeting or ignoring the underprivileged groups. Ironically, the same technology may claim to offer fixes for social bias, but may still end up reproducing, or even deepening, systemic discriminating practices.

Applying new technologies in libraries demands the awareness of the potential bias these technologies may propagate. With that awareness, information professionals can then move beyond accessing new products, to advocating for EDI-oriented design practices. Before fully embracing a technology, information experts may critically explore the social justice concerns and empower user with their findings in their digital literacy programs. Systematically, as Colegrove (2022) aptly suggest, "selecting and implementing technology in the library demands careful choices, with professional ethics as a guidepost, working within guidelines of organizational policy to move the library ever close toward more fully realizing its mission and vision" (p. 98).

CONCLUSION

This literature review examines five major areas of emerging technology that deserve the attention of information professionals for future-proofing academic libraries.

Implementing innovative technologies may prepare libraries to become scholarly hubs connecting technology, entrepreneurship, innovation in knowledge and society, and community engagement. Nevertheless, the discussion in this paper demonstrates that there are risks and limitations of in applying innovative technologies in the library. User privacy, information security, financial and human resources, and the creation or reinforcement of social injustice all deserve careful consideration in the process of selecting and implementing new technology in the library.

In this paper, I have discussed the opportunities, challenges, and future directions for the application of innovative technologies in academic libraries. I have illustrated that applying new technologies requires awareness and understanding of the potential bias and implications on information privacy and security these technologies entail. Building on this awareness and understanding, librarians can advocate for EDI-oriented design practices, address social justice concerns, as well as comply with our professional ethics and organisational policy.

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УДК 001.895:004]:027.7(100)

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ІННОВАЦІЙНІ ТЕХНОЛОГІЇ ТА ЇХ ЗАСТОСУВАННЯ В АКАДЕМІЧНИХ БІБЛІОТЕКАХ

Мета статті полягає в дослідженні та критичному аналізі застосування інноваційних технологій в академічних бібліотеках зарубіжних країн.

Методи дослідження. Для досягнення поставленої мети було використано системний підхід, науковий аналіз, синтез, узагальнення та систематизацію. Методологію статті сформував комплекс підходів наукового пізнання – об'єктивності, зв'язку теорії із практикою, когнітивний, структурно-функціональний.

Наукова новизна полягає у розкритті специфіки застосування інноваційних технологій в академічних бібліотеках зарубіжних країн, здійсненні критичного аналізу, переваг і недоліків запровадження нових технологічних тенденцій, а саме: штучний інтелект, блокчейн, робототехніка та системи автоматизації, віртуальна реальність і технології занурення, Інтернет речей.

Основні висновки. Обговорення в цій статті демонструє наявність ризиків і обмежень у застосуванні технологій у бібліотеці. Конфіденційність користувачів, інформаційна безпека, фінансові та людські ресурси, а також створення або зміцнення соціальної несправедливості – все це заслуговує на ретельну увагу у процесі вибору та впровадження нових технологій у бібліотеці. з такою обізнаністю та уважністю інформаційні професіонали можуть вийти за межі доступу до нових продуктів до захисту практик проєктування, орієнтованих на справедливості та різноманітності (EDI). Перш ніж повністю прийняти технологію, інформаційні експерти можуть критично вивчити проблеми соціальної справедливості та розповісти користувачам про свої висновки у своїх програмах цифрової грамотності.

Ключові слова: академічна бібліотека; інноваційні технології; штучний інтелект; блокчейн; робототехніка та системи автоматизації; віртуальна реальність і технології занурення; Інтернет речей.

The article was received by the editorial office on 23.02.2024