Library and Information Science Research 44 (2022) 101202

Contents lists available at ScienceDirect

Library and Information Science Research

journal homepage: www.elsevier.com/locate/lisres

State of the art review

A systematic review of library makerspaces research

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ARTICLE INFO

Keywords:
Makerspaces
Systematic literature review
Libraries

ABSTRACT

Despite the abundance of research on library makerspaces, systematic reviews of library makerspace research are lacking. As research on library makerspaces advances, the field needs reliable empirical findings to examine the impact of library makerspaces and identify research areas that are valuable for future research. Guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement, 43 out of 838 records were selected for the systematic review. The overall trend of research methodologies and theories, settings, participants, research purposes, as well as tools, technologies and programming in library makerspace research were identified. The findings reveal that qualitative studies that were descriptive in nature were the predominant approaches. While appropriate literatures were explored, theoretical frameworks were less used. This systematic review contributes new areas and directions for future research, including the need for expansion of research methodologies and theoretical frameworks and investigation of diverse users and types of making.

1. Introduction

Over the past decade, makerspaces have increasingly been integrated into libraries. Makerspaces are "informal sites for creative production in art, science, and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products (Sheridan et al., 2014, p. 505). While makerspace generally refers to physical spaces where people have access to digital and physical tools and community members' expertise in making, it also includes the intangible communities and programming for creating and sharing (Pettersen, Kubberød, Vangsal, & Zeiner, 2020). Although makerspaces did not originate from libraries (e.g., Dougherty, 2012), scholars and practitioners in the field of library and information science (LIS) have found that makerspaces have value in supporting patrons' interest-driven learning and creative problem-solving (Bevan, Gutwill, Petrich, & Wilkinson, 2015; Kim & Zimmerman, 2021; Vossoughi & Bevan, 2014) and developing information/media literacy (Carmen, 2021). Therefore, public, school, and academic libraries have established makerspaces in their facilities or offered maker programming (Association of Science-Technology Centers and Urban Libraries Council, 2014; Curry, 2017). The development of library makerspaces also led to an increasing number of research studies on library makerspaces in LIS, but few studies provided a meta-understanding of this research area. Thus, this paper aims to systematically revisit previous empirical studies on library makerspaces and provide insights for future research in the field.

1.1. Problem statement

While existing literature reviews on makerspaces provide an overview of current knowledge on makerspaces across settings (e.g., Mersand, 2021; Vossoughi & Bevan, 2014), the LIS field would benefit from a systematic review of the library makerspace research. First, previous literature reviews of makerspace research do not fully address makerspaces in library settings. Given that makerspaces that are governed by libraries aim to provide free access to resources and promote democracy and diversity for the public good (American Library Association, 2006), empirical findings from membership or admission-based makerspaces may be difficult to apply to library makerspace settings. Thus, a review of studies on library makerspaces is needed for researchers and library professionals to inform their practice and decision-making based on empirical findings that are specifically from library makerspaces. Second, traditional literature reviews are considered subjective due to reliance on authors' knowledge and lack of systematic summary of a topic (Grant & Booth, 2009). Currently, without a systematic review of the literature on library makerspace studies, it is difficult to determine

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https://doi.org/10.1016/j.lisr.2022.101202
Received 31 May 2022; Received in revised form 21 September 2022; Accepted 8 October 2022
Available online 19 October 2022

the state of research advancements in library makerspace research and assess whether the existing research is adequate for comprehensive and evaluative knowledge of the influence of library makerspaces.

Therefore, this study aims to fill this knowledge gap by assessing the state of the empirical, theoretical, and methodological advancements in library makerspace research in academic, public, and K-12 school library settings and propose an agenda for future research. Following the guidelines and traditions for writing systematic reviews, answering a specific research question by systematically collecting, analyzing, and gathering research findings (Harris, Quatman, Manring, Siston, & Flanigan, 2013; McKibbon, 2006; Munn et al., 2018; Phelps & Campbell, 2012), this systematic review addresses the following research question: what are the research patterns and trends in library makerspace studies in different settings (i.e., academic, public, school, combined) from 2000 to 2021? Further, the following questions are asked in this systematic review:

Across the research studies on library makerspaces,

- What are the settings and who are the participants?
- What research methodologies are applied and what methods are used for data collection and analysis?
- What are the purposes of the investigation?
- What central findings have emerged?
- What theoretical frameworks or literatures are explored?; and
- What tools, technologies, and maker programming have been reported?

2. Literature review

2.1. Library makerspaces

The maker movement promotes individual and collective efforts in creating physical and digital artifacts; it entails making activities, makers, and makerspaces (Halverson & Sheridan, 2014). The maker movement emerged in mid-2000s for communities of people who were interested in technology-based "do-it-yourself" (DIY) creations, focusing equally on the process and the outcome of making (Dougherty, 2012). As building the community is central to the maker movement, the ethos of making quickly spread to various community-serving institutions and educational settings (Halverson & Sheridan, 2014), including libraries. Indeed, libraries' missions to provide space, resources, and learning opportunities for community members (Samsuddin, Shaffril, & Fauzi, 2020) align closely with the central values of the maker movement and have been reinforced in libraries to support the sense of community and belonging for their patrons (Koh, Snead, & Lu, 2019). Further, learner-centered philosophies of the maker movement have empowered user-centered and hands-on practices of library makerspaces (Andrews, 2017).

As libraries began to incorporate the maker movement into their programming and built makerspaces, library makerspaces offered various forms of support through group programs, workshops, and one-on-one sessions. Consequently, library makerspaces have contributed to expanding libraries' roles in knowledge creation (Huvila, Douglas, Gorichanaz, Koh, & Suorsa, 2020) and expanded the roles of library professionals as facilitators (Williams & Willett, 2019). However, despite many studies highlighting the impact of library makerspaces, few have conducted a meta-level analysis of library makerspace studies to explore the research patterns and discuss the future directions of this research area. In addition to existing selective literature reviews of makerspaces, a systematic review focusing on library makerspace research is needed to review and analyze the characteristics of makerspaces to identify research areas that need to be explored further in LIS. Thus, this systemic review provides an overview of empirical research studies about makerspaces across academic, public, and school libraries.

2.2. Systematic review tools

A systematic review applies explicit and systematic strategies that limit bias to assemble, appraise, and synthesize relevant studies on a topic of investigation (Cook, Sackett, & Spitzer, 1995). This calls for explicit tools to guide the selection, inclusion, and synthesis of relevant literature. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement supports researchers to transparently report the systematic review process with a 27-item checklist on seven topics: title, abstract, introduction, methods, results, discussion, and other information (Page et al., 2021). The PRISMA statement has been adopted in the systematic review to guide the review process.

Given that study designs included in the systematic reviews are heterogeneous, the challenge related to the appraisal of the quality of studies should also be addressed to ensure that systematic review results are trustworthy, valid, and reliable. The MMAT (Mixed Methods Appraisal Tool) was developed to appraise the methodological quality of mixed studies reviews (Hong et al., 2018). It provides screening questions to determine if clear research questions are present and if collected data addresses the research questions. Further, it provides methodological quality criteria to determine if the methodological approach and data collection methods are suitable to answer the research questions.

3. Methodology

A systematic review methodology was used to identify and categorize the library makerspace research in LIS from August 2021 to March 2022 using the PRISMA flow diagram (Page et al., 2021). First, an electronic literature search was conducted according to the inclusion criteria. Second, research papers that met the inclusion criteria were reviewed based on the filtering criteria. Third, data from selected research papers were extracted to perform qualitative analysis.

3.1. Search strategy and inclusion criteria

3.1.1. Databases

In September 2021, a keyword search was conducted from online bibliographic databases that are considered two leading index systems for citations in library and information science: EBSCO (including ERIC) and APA PsycINFO. These databases cover literature from LIS, psychology, education, and integrated databases. These indexed databases were chosen to ensure the quality of articles in this systematic review.

3.1.2. Identification

A combination of terminologies that refer to makerspaces and the term "library" such as "maker* AND librar*", "hacker* AND librar*", "learning lab AND librar*", "fab lab AND librar*", "make lab AND librar*" were used in searches. The terms, "tinker* AND librar*" were also included to cover articles that address makerspaces and maker activities in library settings. Only the publication types of academic journals, conference proceedings, and magazines were included; editorials were excluded. There was no limit on the publication date at this stage.

3.1.3. Screening

Three stages of screening took place based on eligibility, inclusion, and exclusion criterion. First, exact duplicates were filtered out. Then, title filtering was manually performed by researchers independently to identify articles if the title immediately communicated that the paper was not related to library makerspaces. Identified articles were discussed to remove articles irrelevant to the topic of this review.

Next, four inclusion criteria were used to select the articles: (1) written in English, (2) written between 2000 and 2021, (3) available in full text, and (4) peer-reviewed journal articles involving human subjects. A quick search in the databases showed that studies on makerspaces began to be published after 2010; however, the date range was expanded from 2000 to 2021 to identify any early studies. The

availability of full text was confirmed to ensure the accuracy of decisions to include or exclude the studies. Considering the importance of people and their community in library makerspaces, the choice was made to focus on articles involving human subjects from peer-reviewed journals. As such, articles without any method of data collection (e.g., conceptual papers, viewpoint articles, literature reviews) or those with non-human subjects (e.g., content analysis of library websites) were excluded. Then, abstract filtering was performed. Three researchers individually reviewed the abstracts and then discussed them to screen additional articles.

3.2. Data extraction and synthesis

A standardized spreadsheet was used to extract and categorize the articles. The research team coded the literature by classifying the text into categories by following stages of content analysis (Fraenkel, Wallen, & Hyun, 2012). A coding scheme was developed to systematically extract information relevant to the research questions. Then, the researchers coded the articles and modified the initial coding scheme iteratively to encompass all aspects of the study's research questions. The final coding scheme included the following categories: (1) general study information (e.g., bibliographic information and metadata), (2) country, (3) library type (i.e., academic, public, school, two or more combined library settings), (4) analysis method, (5) participants, (6) participant size (i.e., less than 10, 10 to 20, 20 to 30, more than 50), (7) setting (i.e., urban, rural, suburban), (8) research purpose, (9) theoretical framework or explored literatures, (10) tools and technologies, (11) maker programming, and (12) study findings.

The study design category followed the categories outlined in the MMAT (Hong et al., 2018). A few studies used both qualitative and quantitative data sources and analytical approaches but could not be considered mixed methods research because they did not use convergent, sequential explanatory, or sequential exploratory designs to integrate data. The research team labeled these studies as qualitative and quantitative studies (i.e., Lille, 2016; Melo, 2020; Stephens, Hubbard, Neville, & Melgoza, 2021). The analysis method was determined based on the categorization of research methods in MMAT. Based on this information, the research team categorized the analysis method into qualitative, quantitative, and mixed methods approaches. In each of the coding categories, a similar process was repeated to generate subthemes.

Three researchers each coded one-third of the articles. The coding results were first checked by the first author, then checked individually by three researchers. During this second round of coding, each researcher checked the coding of the section that they were not coding in the first round and marked areas of disagreement, which were discussed to establish consensus by checking the original articles. An overview of the coding results from the systematic review is presented in Appendix 1. To ensure the validity of the findings, an appraisal of the risk of bias was performed based on the MMAT (Hong et al., 2018). When Appendix

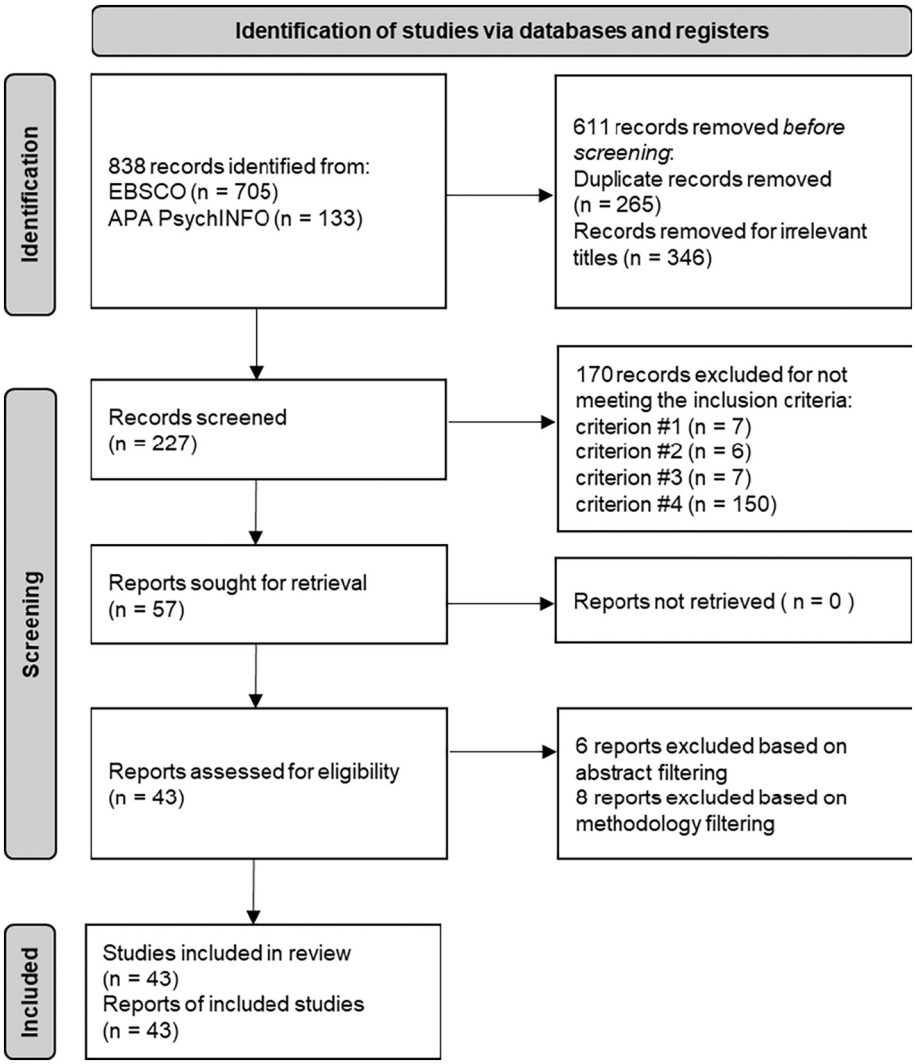

Fig. 1. Flowchart of the systematic literature search.

1 was created, the findings of the coding results were rechecked.

4. Results

The search identified 838 studies, 705 studies from EBSCO and 133 studies from APA PsycINFO (Fig. 1). Of those, 265 exact duplicates were filtered. 346 studies were further excluded as their titles were irrelevant. 170 articles were filtered for not meeting the inclusion criterion. Out of 57 remaining articles, six articles were removed based on abstract filtering as they related to makerspaces in LIS curriculum or laboratory spaces. Further, eight articles were removed that did not meet two criteria in this study. For instance, a case study of a pilot makerspace to provide practical recommendations without any method of data collection was excluded. Content analyses based on online resources were also excluded. Consequently, 43 articles remained.

4.1. Overview

Research on library makerspaces gained attention in 2012 and increased rapidly after 2016 (Table 1). Studies were published the most from *Library Hi-Tech* ($n = 6$), *Public Library Quarterly* ($n = 4$), and *Journal of Librarianship and Information Science* ($n = 3$). Other publication outlets included, but not limited to, *Library Quarterly, Reference Services Review, Journal of the Association for Information Science and Technology, Learning, Media and Technology, and Library & Information Science Research* (each, $n = 2$). See the full list of publication outlets in Appendix 1.

4.2. Participants and settings

Of the 43 studies, many focused on public library makerspaces ($n = 17$), followed by academic library makerspaces ($n = 14$), library makerspaces in two or more combined settings ($n = 11$), and a K-12 school library makerspace (n = 1). Most studies were conducted in the U.S., and three studies included data from two or more countries (Table 2). Several studies that included participants from two or more libraries were conducted in international countries (e.g., Cao, Wu, & Stvilia, 2020; Hussain & Nisha, 2017; Liang, Lu, Liu, & Su, 2019). The location of the makerspace was predominantly urban ($n = 16$) or urban/suburban ($n = 6$), although many studies did not report the specific location ($n = 17$). A few studies were conducted in mixed settings ($n = 2$). Studies conducted in rural libraries (n = 2) were rare.

Makerspace providers and facilitators were the predominant type of participants (Table 3). Studies also focused on makerspace users (i.e., patrons), and two or more groups of participants. One study conducted an autoethnography focusing on the researcher's experience. Among makerspace users, university students, tweens, and teens were most frequently included. Out of 43 studies, 34 studies included one type of participant and 9 studies included two or more types of participants (Table 4). The sample size of the participants varied, with more than 50 participants being the largest representation ($n = 15$). Participant size of less than 10 participants was the second largest representation ($n = 11$), followed by participant size between 10 and 20 ($n = 7$), 20 to 30 ($n = 5$), and 30 to 50 ($n = 3$). Two studies did not report the participant size.

Table 1
Publication period.

Publication period	Frequency	Percentage
2012–13	2	4.7%
2014–15	4	9.3%
2016–17	12	27.9%
2018–19	13	30.2%
2020–21	12	27.9%

Table 2
Country in which the study was conducted.

Country	Frequency	Percentage
USA	31	72.1%
China	2	4.7%
Australia	1	2.3%
Denmark	1	2.3%
Estonia	1	2.3%
India	1	2.3%
South Korea	1	2.3%
New Zealand	1	2.3%
2+ countries	3	7.0%
n/a	1	2.3%

Table 3
Number of studies for each participant type.

Participant type		Frequency		Percentage
Makerspace providers/ facilitators	Library/makerspace staff	24	19	55.8%
	University students and staff		5	
Makerspace users/ patrons	Children	9	1	21.0%
	Tweens and teens		4	
	University student and/or staff, faculty, others		3	
	Library patrons (children and adults)		1	
Researcher		1		2.3%
Makerspace providers and makerspace users	Library staff and patrons	8	5	18.6%
	University student employees and patrons		2	
	Makerspace owner and makerspace competition participants		1	
Makerspace providers, makerspace users, and research team		1		2.3%

Table 4
Number of participant types in the studies.

Number of participant types		Frequency		Percentage
One participant type	Makerspace facilitators/ providers	34	24	79.1%
	Makerspace users/ patrons		9	
	Researcher		1	
Two participant types	Library staff and patrons	8	5	18.6%
	University student employees and patrons		2	
	Makerspace owner and makerspace competition participants		1	
Three participant types	Makerspace providers, makerspace users, and research team	1		2.3%

4.3. Research purposes and central findings

Six purposes of investigation were identified: (1) providing a landscape (n = 5), (2) examining behavior and practices ($n = 10$), (3) focusing on people in makerspaces ($n = 9$), (4) assessment and evaluation ($n = 7$), (5) reporting the makerspace design, programming, and technologies ($n = 8$), and (6) exploring emerging issues ($n = 4$). Central findings within each category that shared the same research purpose are presented.

4.3.1. Landscape

Five studies that illustrated the landscape of makerspaces were conducted in different countries, Australia (Slatter & Howard, 2013), China (Cao et al., 2020), Denmark (Einarsson, 2021), India (Hussain & Nisha, 2017), and the U.S. (Davis, 2018), and provided information about the prevalence of library makerspaces in each country. Slatter and Howard (2013) and Einarsson (2021) focused on public library

makerspaces in Australia and Denmark, respectively, and pointed out the undefined practices and charges that were added to the libraries. Both studies highlighted the value of community engagement, access to technologies and tools, and patrons' learning. Davis (2018) investigated academic library makerspaces' goals, programs, policies, and outcomes in the U.S., especially those supporting higher education and research. Davis showed that academic library makerspaces considered equal access to technology as their core commitment and focused on supporting patrons' new literacy needed for the digital age. Undergraduate students were the most popular patrons in academic library makerspaces. Cao et al. (2020) and Hussain and Nisha (2017) examined makerspaces from all types of libraries. While Cao et al. focused on commonalities and differences of makerspaces depending on their library types, Hussain and Nisha paid more attention to the trend of library makerspace professionals. Cao et al. showed that public and academic libraries in China generally managed makerspaces with in-house staff and budget, while school libraries relied on external resources. Both studies suggested that supporting patron learning was the central purpose of the libraries in their studies.

4.3.2. Behavior and practices

Ten studies in this category had the following sub-themes of research purpose: (1) users' information behaviors and knowledge demand, (2) outcome and impact of maker activities, and (3) users' learning experiences. The studies about users' information behaviors and knowledge demand explored makerspaces from diverse types of libraries. Li (2021) analyzed how teenagers interacted with information in a school library makerspace and a public library makerspace. Koh (2013) explored how teenagers collaboratively created and shared information during maker activities with Scratch in a digital library. In their investigation of community and academic library makerspaces in China, Liang et al. (2019) paid attention to the makers' knowledge demand and how library makerspaces supported them.

The studies about the outcome and impact of maker activities demonstrated that building community culture was an important outcome. Beavers, Cady, Jiang, & McCoy (2019) and Li and Todd (2019) highlighted the maker culture of an academic library makerspace and the youth-centered participatory culture of public and school libraries, respectively, as the desired outcomes and impact of maker activities in library makerspaces. Also, many studies (Bilandzic, 2016; Curry, 2017; Hollett and Ehret, 2017; Noh, 2017; Willett, 2018) positioned users' learning experiences at the center of their analysis. For younger users, Noh (2017) examined if elementary school students' creative thinking abilities developed throughout a library makerspace program. Hollett and Ehret (2017) focused on high school students' design experiences with Minecraft in an urban library. Bilandzic (2016) conducted ethnographic observation of patrons from varied age range at the Hack the Evening (HTE) meetup group at a state library and demonstrated that patrons' learning behaviors were intrinsically motivated, self-directed, and socially interconnected with each other.

4.3.3. People in makerspaces

Nine studies focused on people involved with library makerspaces, including makerspace providers/facilitators and makerspace users/patrons. Four studies investigated makerspace facilitators' competencies and their understanding of making. Koh and Abbas (2015) showed that core competencies were related to management, program development, grant writing and fundraising, technology literacy, and facilitating learning. Williams and Willett (2019) suggested that these competencies are achieved as professionals redefine their role as "information providers, educators, facilitators, content-level experts, artists, and coordinators" (p. 804). Barniskis (2016) demonstrated that public librarians' perception of the makerspace was framed around addressing the problem of the digital and socioeconomic divides in private makerspaces. Similarly, Lakind, Willett, and Halverson (2019) showed that many library professionals framed their makerspace as places of connection rather than "a room with equipment" (p. 239).

Three studies investigated approaches and needs for professional development. Moorefield-Lang (2015a) showed that the type of professional development that library makerspace staff received was ad-hoc and informal, mainly receiving peer support or using online resources, and suggested the need for more structured training opportunities. Horton (2019) showed that library staff wanted to learn about administrative procedures such as funding, makerspace management, safety, and policy protocols and expand their skills in specific makerspace technologies (e.g., 3D printing, robotics). Highly mentioned preferred methods included visiting other makerspaces, books, workshops, conferences, and online tutorials. To explore different approaches for professional development in makerspaces, Purpur, Radniecki, Colegrove, and Klenke (2016) conducted a case study of outreach for a mobile makerspace in an academic library. They demonstrated that mobile makerspace efforts could support professional development by incorporating non-traditional makerspace services and technology.

Lastly, two studies investigated makerspace patrons' change in perception and satisfaction with makerspaces. Williams and Folkman (2017) demonstrated that students developed interest and willingness to learn about making and became more comfortable with the concepts of making and makerspace-related technologies. Radniecki and Winterman (2020) found overall high user and student employee satisfaction with maker services that used undergraduate students for specialized consultations around research data services.

4.3.4. Assessment and evaluation

Out of seven studies focusing on assessment and evaluation, three studies defined the outcomes and successes of a library makerspace and proposed frameworks. Gahagan and Calvert (2020) investigated to what extent assessment methods adequately capture the intended outcomes of the chosen makerspace and highlighted several challenges in conducting assessment work at library makerspaces. Teasdale (2020) explored the definitions of success in one library makerspace involving adult makers' digital fabrication and suggested seven criteria for determining success: provide access to digital fabrication technology; learn to use technology; foster entrepreneurship; nurture creativity; strengthen communities and families; support intrinsic rewards; save money. Valvidia and Subramaniam (2014) developed an evaluative framework for developing virtual informal learning programs with three levels of consideration to develop the organizational mission, perform needs assessment, and formulate goals.

Two studies developed an assessment matrix and instruments. Cun, Abramovich, and Smith (2019) identified different maker activities, different categories of makerspace patrons, and provided an assessment matrix demonstrating how summative and formative feedback can help library staff and patrons learn and succeed in makerspaces. Yin, Hadad, Tang, and Lin (2020) focused on developing instruments to assess how computational thinking (CT) skills and dispositions are integrated into maker-based learning activities. Further, two studies assessed the impact of specific maker services. Lille (2016) evaluated a pilot maker project in a public library makerspace in Estonia. Stephens et al. (2021) assessed the impact of librarian-student consultations during design competitions in academic makerspaces. This study showed that librarians' information skills supported students in locating information at every stage of the design process.

4.3.5. Makerspace design, programming, and technologies

Out of eight studies investigating aspects related to makerspace design, programming, and technologies, three studies examined the process of designing, planning, and implementing the library makerspace. Moorefield-Lang (2019) showed that planning for a second makerspace was more intentional (knowing what to seek) and community-oriented (providing connections to areas that traditional library programming could not). Passehl-Stoddart and Snipes (2020) identified the challenges of involving university students and employees

who were patrons of the makerspace in the co-design process, namely the unfamiliarity with the space and the lack of examples to guide the co-design process. Six case studies of "on-the-move" mobile makerspaces outlined elements to consider in developing mobile makerspaces, such as travel logistics, mode of transportation, receiving funding, and ways to securely transport and furnish technologies and materials (Moorefield-Lang, 2015b).

Two studies focused on users' preferences and perceptions of the design of the library makerspace. Hynes and Hynes (2018) suggested that if the primary goal of makerspace is to encourage participation from students from across disciplines, not just engineering, the design of the academic library makerspace should consider providing a sense of familiarity to encourage students to explore what is possible in the space. Bieraugel and Neill (2017) compared five academic library spaces that supported creativity and innovation. The study showed that students perceived the on-campus makerspace as encouraging nearly all types of innovation behaviors and exploration, but not reflection. They suggested the need to encourage students to engage in questioning and reflection in makerspaces.

Lastly, three studies described the implementation of maker programming and technologies. One study proposed using an ancient embroidery technique of "laid work" to create fiber copies of hidden images to teach pattern design (Carmen, 2021). Radniecki (2017) described how online tutorials, group workshops, and individual consultations with 3D modeling experts helped users develop new skills to utilize makerspace equipment that supports 3D modeling. The study illustrated that group workshops had low attendance and appeared to impact fewer users than online tutorials and individual consultations. Letnikova and Xu (2017) demonstrated that college students gained more interest and better understood a biological structure through a 3D printing assignment that was designed through collaboration between the library and teaching faculty.

Even when not a specific focus of the study, 27 out of 43 studies mentioned which tools and equipment were used in library makerspaces. Nineteen studies utilized physical tools and technologies, two studies utilized Minecraft, and four studies included the use of both physical and digital technologies. The range of physical tools and technologies was wide, including 3D printers, 3D scanners, CNC machines, power tools, laser cutters, hands-on maker kits (e.g., Makey Makey, littleBits, Arduino), and media production technologies (e.g., cameras, GoPros).

Also, 22 studies mentioned the design of their library maker programming. Several studies discussed the use of library stations, instructional workshops, and programs to introduce maker tools and technologies. These programs were offered as drop-in sessions, librarian-led programs, or open-ended programs in public libraries. In academic libraries, maker fairs, maker contests, maker-based curriculum and projects, instructional workshops, and library stations were offered. While most maker programming included the use of emerging technologies (e.g., 3D printer, Raspberry Pi), some used traditional tools such as sewing lessons, furniture restoration, and cocktail-making workshops (Gahagan & Calvert, 2020). Pop-up outreach maker events were also discussed in a few studies (Moorefield-Lang, 2015b; Purpur et al., 2016). One study included several professional development events (e.g., online workshops, on-campus conferences to showcase maker projects, campus presentations) to develop an awareness of the maker movement for LIS students and library professionals across the state (Williams & Folkman, 2017).

4.3.6. Emerging issues

Four studies addressed emerging issues in library makerspaces, such as intellectual freedom, intellectual property (IP), and diversity, equity, and inclusivity (DEI). All studies were conducted in the U.S., and they began to appear in 2018. Two studies investigated library makerspace staff's attitudes and experiences with intellectual property or intellectual freedom. Bossaller and Haggerty (2018) showed that librarians had no prior experience engaging in IP training, except for general copyright training, and highlighted the need for IP training to prevent future copyright issues as patrons use, remix, and create materials in makerspaces. Radniecki (2018) demonstrated that IP policies in library makerspaces were mostly limited to preventing IP infringement. The study emphasized the importance of providing education on how to protect privacy, where to find information about IP protection, and developing more targeted IP services and resources at library makerspaces.

Two studies focused on DEI issues. Melo (2020) showed that only small percentages of library makerspace stations (i.e., sewing, electronic textiles, crafts) seemed to welcome women-identified makers and highlighted the need to examine the extent to which materials facilitate and inhibit the mobility of women-identified makers. Moorefield-Lang and Dubnjakovic (2020) demonstrated that constructs related to Theory of Planned Behavior (i.e., attitude, subjective norm, behavioral intention and perceived behavioral control) significantly predicted school librarians' intention to implement accessible makerspaces. In particular, the perceived behavioral competence (the sense of mastery and control over outcomes) was the most significant predictor of the intention to implement accessible makerspaces.

4.4. Research methodologies and methods

4.4.1. Methodologies

Out of 43 studies, 24 studies used qualitative methods, 14 used quantitative methods, two used mixed methods, and three used both quantitative and qualitative methods. While early studies only used qualitative research methodologies, methodologies have become diversified since 2016 (Fig. 2). Quantitative methods were highly used in studies published between 2016 and 2017, and most of them were conducted in academic library makerspaces.

For qualitative studies, one study (Moorefield-Lang, 2015a) was judged as having an unclear risk of bias because it did not have a clear research question. As such, it was difficult to determine whether the data collection methods were adequate to address the research question. For quantitative descriptive studies, one study (Letnikova & Xu, 2017) was judged as having an unclear risk of bias because their study was described as qualitative case study when the study used surveys. For the two mixed method studies, they were judged as having a low risk of bias. Another study (Stephens et al., 2021) was judged as having an unclear risk of bias because the study was referred to as mixed methods because they used survey and student reflection as data sources. However, the study provided no rationale for using a mixed methods design and it did not follow the convergent, sequential explanatory, or sequential exploratory designs characteristics of a mixed methods approach.

4.4.2. Data sources

Most studies (23 out of 43) used a single source of data (Table 5). Interview was the most common data source used in 24 studies, either alone or as one of multiple data sources. For instance, studies that identified library professionals' competencies and their understanding of making conducted qualitative analysis with interviews with professionals as the only data source (Koh & Abbas, 2015; Moorefield-Lang, 2015a; Williams & Willett, 2019). Surveys were used in 14 studies either alone or one of multiple data sources. For instance, studies that investigated library makerspace staff's preference for training conducted quantitative analysis with surveys as the primary data source (Horton, 2019; Purpur et al., 2016; Williams & Folkman, 2017). Two studies measured learning outcomes by using pre- and post-tests. Observation data was not used until 2016. It was used in nine studies along with other data sources, such as interviews. Observation data was collected through fieldnotes, video recordings, or both.

Data sources began to diversify in 2016 (Fig. 3). Multiple data sources were frequently used in studies with research purposes to: 1) explore behaviors and practices, 2) propose ways to conduct assessment and evaluation, 3) examine people in makerspaces, and 4) interrogate

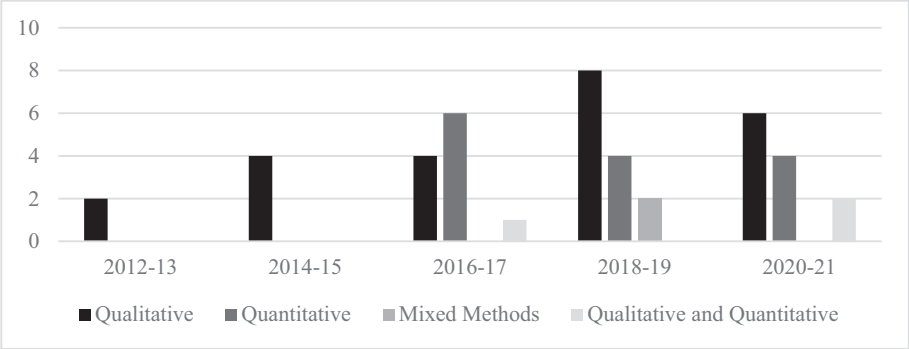

Fig. 2. Research methodologies by publication period.

Table 5
The number of data sources.

Data source		Frequency for sub-category	Frequency total	Percentage
One data source	Interview	10	23	53.5%
	Surveys	9		
	Learning outcome (pre- and post-test)	2		
	Researcher's experience	1		
	Focus groups	1		
Two data sources	Interview & another data source (e.g., survey, observation)	6	9	20.9%
	Survey & another data source (e.g., observation, case study)	2		
	Online forum & literature	1		
Three or more data sources	Interviews & two other data sources (e.g., documents, observations, focus groups, video recordings of interaction, field notes)	8	11	25.6%
	Survey & two other data sources (e.g., learning outcomes, student employee consultation data, user-created booking data)	3		

emerging issues within library makerspaces. Given that there is no "one size fits all" approach in developing makerspaces, studies that aimed to define the outcomes and successes of a makerspace employed qualitative approaches with more than three data sources, including observation, interviews, focus groups, documents, and archival records. Multiple data sources were also used in mixed methods and qualitative and quantitative studies. Studies that aimed to develop assessment instruments and assess the impact of maker services employed two or more data sources such as interviews, surveys, observations, and learning outcomes. Participant sizes were often large, with more than 50 participants (Lille, 2016) or between 30 and 50 (Stephens et al., 2021). Studies that explored issues of intellectual property in makerspaces used interviews, surveys, and a case study with participants sizes larger than 30. Studies that explored issues of DEI used "quantitative and qualitative" approaches based on their research questions. Of the studies using two or more data sources, four adopted a design-based research or similar approach, which focused on patrons' situated learning experiences by designing and implementing maker sessions or interventions (Cun et al., 2019; Hollett & Ehret, 2017; Lakind et al., 2019; Yin et al., 2020).

4.5. *Theoretical frameworks and literature*

All studies reviewed appropriate literature related to their topic of investigation to guide their analysis. Examples of literature topics included library makerspaces, professional development in library makerspaces, new librarianship, boundary work, research data services in libraries, academic library makerspaces, mobile makerspaces, library measurement methods, and outcomes evaluation methods. Notably, eight out of 43 studies provided explicit theoretical/conceptual frameworks or models, beyond reviewing the concept of makerspaces, the roles of libraries, or assessment methods (Bilandzic, 2016; Einarsson,

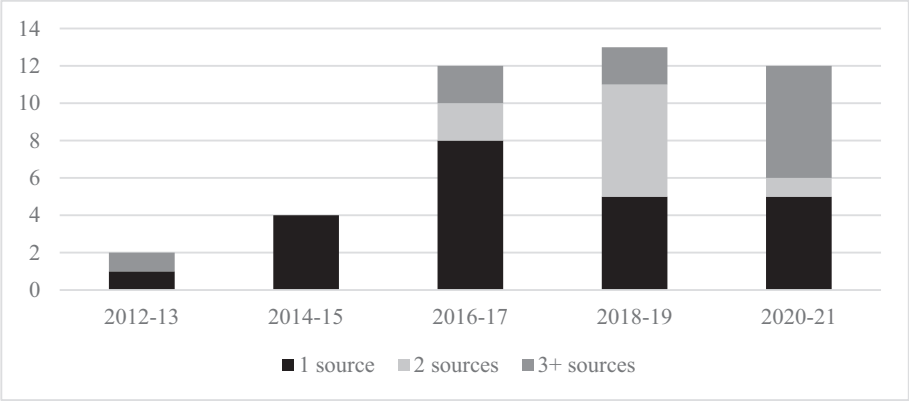

Fig. 3. Number of data sources.

2021; Hollett & Ehret, 2017; Hynes & Hynes, 2018; Li, 2021; Noh, 2017; Teasdale, 2020; Willett, 2018). In addition to introducing literature backgrounds, these studies used explicit theoretical frameworks to make alignments across their studies' purposes, analyses, and discussions. Across these eight studies, varied theoretical frameworks were used, but many were based on sociocultural perspectives of learning. For instance, Teasdale (2020) and Einarsson (2021) conceptualized their studies based on Engeström's activity theory (Engeström, 1987), which is based on the sociocultural perspective to understand complicated systems surrounding people, tools, communities, and activities. Bilandzic (2016) investigated participants' motivation and learning based on connected learning theory. Willett (2018) built upon theories of constructionism and communities of practice. Further, Hollett and Ehret (2017) used a framework of civic rhythms in engaged citizenship, which emphasizes social and emotional productions of civic engagement. Two studies used cognitive psychology theories: Noh (2017) used a framework of different phases of creative thinking; and Hynes and Hynes (2018) adopted a framework for predictors of environmental preference, which is based on psychology on preference. Li (2021) was the only study using an information theory: a model of everyday information practices from Savolainen (2008).

Considering that most studies used in this systematic review were published in LIS-related journals (36 out of 43), it is notable that only a few articles from LIS journals ($n = 4$) used specific theoretical frameworks: *Library Quarterly* (Einarsson, 2021), *Journal of the Association for Information Science and Technology* (Li, 2021), *Library and Information Science Research* (Teasdale, 2020), and *Journal of Librarianship and Information Science* (Noh, 2017). The other four articles using specific theoretical frameworks were published in journals outside of the LIS discipline (e.g., *Learning, Media and Technology*).

5. Discussion

A systematic review of library makerspace research identified key research trends and patterns. Studies included in this systematic review contributed to understanding the landscape of library makerspaces, maker programming, and technologies as well as makerspace providers and users' behaviors and development. However, this systematic review also identified some common limitations of the current library makerspace research, which would highlight several areas of future research: 1) use of diverse and robust methods, 2) explicit use of theoretical frameworks, 3) investigation of school and rural library makerspaces, 4) investigation of diverse users, 5) exploration of diverse types of making, and 5) application of research findings.

The types of research methods should be expanded for LIS research on library makerspaces to make methodological advancements. Despite the trend to adopt different types of methodologies in recent studies, this review indicated that the dominant approaches were qualitative studies that were descriptive in nature. Also, the library makerspace research was highly driven by a single source of data, such as interviews or survey, even though, starting in 2016, methods began to diversify and include more than one source. Incorporating diverse methods (e.g., inferential statistics) and data sources (e.g., observation with patron interviews) could be helpful for data triangulation to enhance the trustworthiness of research (Creswell, 2013). To successfully understand the dynamic nature of the maker movement and its emphasis on collective activities (Halverson & Sheridan, 2014; Koh & Abbas, 2015), it would be critical to incorporate multiple measures and sources (Lin, Yin, Tang, Hadad, & Zhai, 2020).

Moreover, the operational definitions of the methods need to be standardized. For instance, this review demonstrated that some studies had unclear risks of bias due to incorrectly identifying the methodology as mixed methods when the study collected both qualitative and quantitative data (Stephens et al., 2021) and identifying the study as a qualitative case study when pre- and post-tests data were collected (Letnikova & Xu, 2017). In the future, mixed methods design studies need a clear rationale for their methodology and a particular category of mixed methods design (e.g., convergent, sequential explanatory, or sequential exploratory). Overall, a robust and rigorous approach towards research should be emphasized.

Perhaps because makerspace is a relatively new concept, most articles' literature reviews focused on introducing makerspaces without explicit theoretical frameworks or conceptual models. However, because the area of makerspaces is growing, deeper examinations rooted in various theoretical perspectives are expected, as many other scholarly areas would do. For instance, to better understand the complex interactions between makerspaces users (i.e., patrons and facilitators) and the use of makerspace tools within particular cultures of a makerspace, various theories such as information behavior, informal learning, or socio-emotional interactions may help. Further, this systematic review identified very few studies focusing on school and rural public library makerspaces. Library makerspace research began to be published in 2012 with studies focusing on public library makerspaces and grew from 2016 by diversifying the settings. However, except for one study about a school makerspace and two studies about rural makerspaces, the primary focus of settings was public libraries and academic libraries in urban or suburban settings. While the goal of establishing a library makerspace may be similar across settings, the current literature that heavily focuses on public and academic libraries in urban or suburban settings may be difficult to apply to K-12 school and rural libraries. For instance, online tutorials, group workshops, and individual consultations in academic library makerspaces have shown positive user satisfaction (Radniecki, 2017; Radniecki & Winterman, 2020; Stephens et al., 2021). However, these types of services may not be applicable to K-12 settings when only a few library professionals can be available to serve all students in the school building. Similarly, physical tools and technologies that are widely implemented at larger public libraries in urban settings may not be easily purchased and maintained in rural libraries due to different resources, skills, and constraints (e.g., fewer full-time employees, limited funding) (Real & Norman, 2017; Swan, Grimes, & Owens, 2013). Although library makerspaces in K-12 schools and rural areas may be less common than in public or academic libraries, future research into these contexts may help to understand the reasons why, which could lead to more appropriate guidance for makerspaces in these unique library environments.

Another area of future research is the investigation of diverse users' experiences and diverse types of making. This systematic review identified that library professionals working as makerspaces facilitators were the most common focus related to people. Among studies that focused on makerspace users, university students, tweens, and teens were the most common study participants. This research pattern could be attributed to the focus within the LIS field on strengthening library professionals' capacity and the general participation and attendance at library makerspaces. However, diverse users with various ages, interests, socioeconomic backgrounds, and abilities should be included to examine the impact of library makerspaces on patrons more broadly. Furthermore, despite the wide range of maker programming offered, science, technology, engineering, and mathematics (STEM) was at the foreground of library maker programming with the use of high-tech equipment. Future scholars should attend to diverse forms of making across different settings to expand conceptualizations of making and identify new areas of research.

Finally, future scholars and practitioners should apply central findings from library makerspace research to deepen and broaden scholarly advancements. For instance, it would be interesting to conduct a similar type of landscape study and compare the results to illustrate any change in pattern or shift in goals, types of programming, participants, policies, or outcomes over time. Practitioners and researchers are also encouraged to apply the research-informed assessment and evaluation frameworks to demonstrate the empirical application and outcomes.

5.1. Limitations

This systematic review has several limitations. First, the selection of studies published in English was a limitation since it could have excluded studies of library makerspaces in various countries. Also, the review relied on a limited number of databases which could have neglected studies that were unpublished or in gray literature. The systematic review included "librar*" as the common keyword in the search to identify articles in which the setting of the makerspace was the library. K-12 school makerspaces that were not part of a library were not the focus of this systematic review.

6. Conclusion

This study presents the first systematic review of library makerspace research across public, academic, and school settings in the LIS field. The systematic review filled the gap in understanding the research patterns and trends in library makerspace research. It further contributed new areas and directions for future research, including the need for expansion of research methodologies and theoretical frameworks and investigation of diverse users and types of making. With an increasing trend of more empirical studies on library makerspaces, this systematic review can inform future scholars to identify the relevant research purpose, methodology, and theoretical frameworks and expand the line of research on library makerspace to diverse settings and participants to provide further evidence about the different impacts of library makerspaces on the community.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.lisr.2022.101202.

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