On Hackathons: A Multidisciplinary Literature Review

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ABSTRACT

The number of hackathon events worldwide has nearly quadrupled in the last five years. Despite exponential growth across diverse industries and increasing interest across academic disciplines, our integrated understanding of the phenomena of hackathons is limited. We conduct the first multidisciplinary literature review of publications from 1999 to 2022 to understand the conceptualization of the phenomena over time. We find that hackathon research can be categorized into 4 core areas (purpose, format, processes, and outcomes). Research was first driven by a purpose (innovation, learning, and collaboration), followed by an examination of how formats adjust to purpose to influence what happens (processes) and what is produced (outcomes), and critical reviews of the hackathon phenomena. We contribute a unifying framework with these four core areas to inform future directions of hackathon research and practice, as well as a discussion of the need for longitudinal and multidisciplinary research of hackathons.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**.

KEYWORDS

hackathons, literature review, multidisciplinary

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1 INTRODUCTION

In 1999, ten people gathered together at an open source conference in Calgary for a day to develop a piece of cryptographic software [53]. More than two decades later, more than 27,000 people from across the globe gathered virtually to develop 1,500 products, processes, and policies to tackle the effects of COVID-19 pandemic at #WirVsVirus, the largest virtual hackathon to date [93]. Historically, hackathons were defined as 24-48 hour events where groups of people physically came together to work on software or hardware projects [43, 53]. As time went on, "hackathons" came to describe many kinds of time-limited creation events, technical and nontechnical, in-person and virtual. Despite the extraordinary expansion of hackathons across diverse contexts, our understanding of the phenomenon overtime is limited. Further, as academic inquiry reaches beyond computer science (CS), we lack an integrated conceptualization of hackathons across academic disciplines.

Previous hackathon literature reviews within human-computer interaction (HCI) have found hackathons as a means to structure learning, processes, and enable participation [90] or linked design aspects of hackathons as potential factors towards sustainable outcomes [78]. Yet, phenomena like hackathons that lie at the intersection of people and technology could be better understood from a synthesized, multidisciplinary perspective. Our work expands our understanding of the hackathons through a multidisciplinary literature review. With an integrated conceptualization of hackathon research, HCI researchers can radically enhance the rigor and communication of hackathon research as well as set a course for future meaningful research.

2 BACKGROUND

2.1 History of Hackathons

The term hackathon was coined in 1999 in Calgary as a portmanteau of "hacking" and "marathon" to describe an intense programming activity in a short, limited period of time [43]. Two weeks later, Sun Microsystems adopted the term when they held a hackathon in which they challenged employees to write a program for the new Palm V using the infrared port to communicate with other Palm users [53, 81]. In its earliest years, software engineering companies and large corporations hosted hackathons to motivate internal innovation or develop in-house solutions to specific company challenges. Not only did hackathons support new software development, hackathons supported the creation of new ventures such as GroupMe (later acquired by Microsoft) [7].

In 2008, the United States Government adopted hackathons to challenge citizens to develop "Apps for Democracy" [54]. In 2012, NASA (National Aeronautics and Space Administration) hosted the first International Space Apps Challenge, establishing the National Day of Civic Hacking [83]. In 2009, higher education welcomed hackathons in the first annual student-led hackathon, PennApps, at the University of Pennsylvania to help students apply their programming skills in a more real-world setting and as an opportunity to network with prominent technology company sponsors like Google and Microsoft [89]. In 2013, PennApps culminated in the creation of one of the largest organizations in the United States that support student hackathons, Major League Hacking[1]. That same

[1]https://mlh.io/about

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year, HCI researchers welcomed hackathons as a phenomena of inquiry [102].

2.2 Hackathon Research in HCI

HCI researchers have often focused on participants' perception of hackathons [88, 125], their use in CS education [82, 111], and the implications of hackathons as sites for technical innovation [31, 73]. Other reviews in HCI have noted that hackathons can be designed to structure learning and processes like collaboration or innovation, and enable broader participation in CS [90], but have left the question of "how" to do so in a way that ensures long-term, sustainable outcomes unanswered [78]. We lack a cohesive way to develop intentional modifications to hackathons that are driven by real-world motivations and reflect on why these changes matter. For example, diversifying participation in technical hackathons has been of particular interest to the HCI community [21, 24, 103], but simply having underrepresented groups (e.g., women) be physically present is not enough—the hackathon itself also has to change. Adjustments to things like team formation, project development activities, and a noncompetitive, collaborative atmosphere Decker et al. [21], Filippova et al. [27], Kos [63] were important to support the active engagement and enjoyment of minoritized participants. However, HCI research could gain greater insight from other disciplines on why these changes work and how to sustain these positive outcomes for all. More recently, HCI researchers have been exploring the sociotechnical challenges of virtual hackathons due to the COVID-19 pandemic [37, 101, 110], which prompts us to reflect on and push past the boundaries of our knowledge on hackathons.

We are left with questions of how to design sociotechnical systems for better hackathons and also whether our understanding is robust enough to apply our recommendations to hackathons in other domains with non-technical outputs, especially because of their rapid adoption across contexts. HCI researchers have great expertise to offer, but we must understand the state of hackathon research across other disciplines in comparison to our own.

2.3 Towards a Multidisciplinary Review

In the past decade,researchers from diverse fields including science & technology studies (STS), organizational studies, gender studies, innovation & entrepreneurship, education & learning, health & medicine, and more have published research that contributed to our understanding of hackathons. Education & learning has investigated how hackathons facilitate learning and apply skills from the classroom for individual students [65, 113]. Organizations studies and innovation & entrepreneurship have asked how people organize into or collaborate within teams [25, 109] and how innovation occurs or the entrepreneurial start-up outcomes of hackathons [85, 106], respectively. Gender studies and science & technology studies (STS) have also provided great theoretical contributions, with the former dissecting "hacker culture" and the attempts to increase inclusivity at hackathons [23, 24] and the latter reflecting on the hackathon's role and impact on complex societal issues that are inundated with digital solutions [51, 73]. While HCI research itself is diverse, we can learn from other disciplines' nuanced perspectives on the processes within a hackathon (at individual, organizational, and societal levels).

Individual disciplinary research of hackathons has strengthened our collective knowledge and practice of hackathons, but phenomena like hackathons that lie at the intersection of people and technology transcend disciplinary lines and could be better understood from a synthesized, multidisciplinary perspective. Multi- and interdisciplinary work is commonly seen throughout HCI research and provides a basis for not only fundamental comprehension, but also implications on real-world practice and future research (e.g., management scientists' perspectives in crowd work [60] or inappropriateness of explainable AI trends in real-world clinical settings [52]). With an integrated conceptualization of hackathon research, HCI researchers can radically enhance the rigor and communication of hackathon research, as well as set a course for meaningful future research. This work expands our current understanding of the hackathons and encourages the multidisciplinary approach to strengthen our own research, practice, and collaboration.

While hackathons have gone well beyond the purview of CS research, to our knowledge, no one has undertaken a literature review across disciplines. This literature review takes inspiration from the meta-narrative review method by Greenhalgh et al. [41] which emphasizes a multidisciplinary review approach, especially for interdisciplinary fields such as HCI. The role of the multidisciplinary review is to "expose the tensions, map the diversity and communicate the complexity of how various different traditions contribute to an understanding of the problem [space] as a whole" (p. 427) [41]. The motivation for this review is to provide a framework to expose the tensions (e.g., learning vs. producing, inclusive vs. exclusive, in-person vs. virtual), map the diversity and communicate the complexity of how various different traditions contribute to our understanding of hackathons over time and direct future research. We ask three questions:

- (RQ1) What areas in hackathons, if any, are researchers across disciplines prioritizing?
- (RQ2) How has research on hackathons changed over time?
- (RQ3) What can HCI researchers learn from other disciplines about hackathons?

Through a review of 111 publications across 10 diverse disciplines, we find that hackathon research began with studies of purpose (i.e., innovation, learning, and collaboration), followed by studies of how format adjust to purpose to influence processes and outcomes and critical reviews of the hackathon phenomena. To orient future work, we develop a framework of 4 core areas of hackathon research to illustrate our current understanding of what hackathons are (format), how they work (processes), and why we do them (purpose & outcomes). This paper contributes (1) a multidisciplinary literature review of hackathons that extends beyond HCI research, (2) a framework to conceptualize the research community's understanding of hackathons from the literature, and (3) future directions of hackathons for both research and practice.

3 METHODS

3.1 Search Strategy

Following the multidisciplinary meta-narrative review standard practices outlined by Greenhalgh et al. [41], we began with outlining an open-ended research question that posed: "What areas in hackathons, if any, are researchers across disciplines prioritizing?" (RQ1). We then searched for the term "hackathon" in the title, abstract, or keywords of peer-reviewed, full-text publications in English between January 1st, 1999 and June 30th, 2022 in multiple databases. We selected 1999 to ensure that our review could capture any potential peer-reviewed articles written about hackathons in its earliest days as the term "hackathon" is commonly attributed to the OpenBSD's own cryptographic hackathon in 1999[2]. As per the goals of a multidisciplinary literature review, we searched in a variety of databases to understand how hackathons had been understood from different perspectives. We started our search in the ACM Digital Library which returned 97 results. We then searched within the IEEE Xplore Digital Library which returned 144 total results, followed by non-CS-focused databases including JSTOR, EBSCO, ISI Web of Science, and PubMed Central which returned 667 results in total. We then reviewed relevant citations from these publications to find other relevant publications, resulting in 908 total publications.

3.2 Study Criteria

From the initial 908 articles, we removed duplicate publications and used the following exclusion criteria to reach our final sample of 111 publications for further analysis. We excluded publications from our dataset if the publication was:

- *Not a full-text research article or conference papers.* Extended abstracts, research proposals, dissertations, editorials, and exploratory work less than 4 pages long, including citations, were also excluded.
- *Not peer-reviewed.*
- *Not in English or not published to an English-language conference or journal.*
- *Not the focus of the research which was determined by the three criteria*:
  - Did not use the term "hackathon" throughout the manuscript and in multiple sections (e.g., related work, method, analysis, discussion, future work sections)
  - Did not have the term "hackathon" (or "hackathons") in more than 1% of total words used in the manuscript, including the abstract and excluding references (frequency of "hackathon")
  - Did not have at least 60% of content related to hackathons (this filters out publications that are not actually about the hackathon itself and only use "hackathon" to refer to an event)

We first read through the paper abstracts and if it was unclear whether it would be excluded, we then read through the full paper with the last criterion in mind to make our final decision.

We only searched the term "hackathon" because initial searches using related terms, such as "codefest" or "hackdays", returned 0 relevant or unique articles in both CS databases (e.g., ACM DL and IEEE) and non-CS databases (e.g., JSTOR and PubMed Central). Because the topic of hackathons is most prevalent in CS-related academic communities and non-CS communities were unlikely to use such specific terminology to refer to this phenomenon, we chose to use only "hackathon" in our review. With these criteria, we also found that there were no relevant publications prior to 2013, resulting in 111 publications from 2013 to 2022 available for further analysis.

[2]https://firstlinesoftware.com/blog/why-hackathons/

3.3 Limitations

This review, like all research, has the limitations based on its methods and the subjectivity of its authors, but also provides a unique, multidisciplinary perspective to hackathons that does not yet explicitly exist in the CHI community and enriches our collective knowledge of hackathons and their potential. Given the wide search scope of this literature review, we may have missed eligible publications in unfamiliar databases. We also restricted our study to English-only publications, reiterating a largely Western perspective on hackathons, their use, and the context and systems in which they are situated. We encourage the study of non-English publications in future work, as well as the consideration of the cultural and sociopolitical context of hackathons, especially ones that seek to create meaningful products and services within the constraints of their own medical, financial, political, and economic ecosystems.

3.4 Data Extraction & Analysis

We organized all qualifying literature in an Excel spreadsheet by metadata (e.g., publication type, its research database, authors, keywords, publication date, DOI, etc.) and relevant information from the publication itself including research questions, participants/data sample pool, key terms and definitions, data collection methods, analysis, findings, and calls for follow-up studies or future research areas.

We used Miro[3], an online visual collaboration tool, to organize our data and analysis. We began by categorizing publications based on preliminary descriptive attributes including year, discipline, publication venue, methods (for data collection and data analysis, respectively), and data sample type. We first analyzed the sample by categorical information including year, discipline, publication venue, and methods used for data collection and data analyses, respectively. Given that hackathon literature even within CS can be interdisciplinary, publications could be categorized in more than one discipline. The discipline(s) of a given publication were triangulated based on discipline of the publication venue and authors, keywords and abstract, and content of the paper, with particular attention paid to the findings and discussion sections of the literature. In addition, citations to specific fields of study, use of specific terminology, methods used for data collection and analyses, and the target audience of each publication's contributions were key determining factors to whether a publication was representative of speaking from and to a particular discipline.

We then conducted iterative rounds of thematic analysis on the key threads emphasized in discussion sections, research questions, and questions for future work from our sample that responded to our research questions. Given the exploratory nature of our study and its relevant inclusion of non-ACM literature, we also looked at the type of data samples present in hackathon research, data collection and analysis methodologies, and categorized each publication based on its type of contribution to the HCI community [126]. We noted that many publications often include a brief historical context

[3]https://miro.com/index/

of hackathons' initial prevalence within software developer companies and CS but did not necessarily present a cohesive history of hackathon research since it began. Thus, we also constructed a year-by-year timeline of the publication sample to illustrate and trace the evolution of hackathon research. First, publications were grouped together by their publication year and we recorded the total number of papers published for each year. Then, we evaluated each article and asked 3 guiding questions: (1) what venues & disciplinary perspectives was the publication written from?, (2) what were the research questions or research areas of interest?, and (3) what further questions or calls for future studies about hackathons were being presented?

We iteratively grouped research questions or topic areas together into increasingly broad thematic clusters (e.g., from "What factors discourage participants from attending?" [125] to "motivations to participate in a hackathon" to "participant hackathon experience" or from a focus on "how [specialization & creativity] can be managed" to achieve a desired invention during a hackathon [107] to "balancing project development processes" to "innovation"). We conducted a similar process for further questions or calls for future studies from literature as well. Finally, we analyzed these findings for any patterns within each year and across time.

We first present a summary of data sample types in research studies, data collection and analysis methodologies, and contribution types to HCI research in the Findings. With the thematic analysis from publication texts, categorization of contribution types, and analysis developed by the construction of the timeline, we synthesized our analysis and discovered an overarching framework of 4 core areas of hackathon research.

4 FINDINGS

We find research across 10 diverse disciplines in the sciences and humanities on hackathons. While the CS perspective dominates (N=65, 58.6%), we also find perspectives from Education & Learning (N=36, 32.4%), Innovation & Entrepreneurship (N=28, 25.2%), Science & Technology Studies (N=20, 18%), Organizational Studies (N=18, 16.2%), Health & Medicine (N=15, 13.5%), Gender Studies (N=9, 8.1%), Design (N=3, 2.7%), Arts (N=2, 1.8%), and Library & Information Science (N=1, 0.9%, see publications listed by discipline & totals of each discipline in Table 4 and all publications in Table 5 in the Appendix). We first contextualized our findings with a broad overview on the metadata of hackathon literature, followed by the 4 core areas, the constructed framework using the core areas, and the reiteration of the framework in a timeline of hackathon research.

4.1 Metadata on Hackathon Literature

4.1.1 Data Collection Methodologies. Researchers use mixed methods to collect both qualitative and quantitative data to understand how and what happens. Quantitative methods include surveys and collecting data from online databases or sources (through methods like web scraping or looking at archived data). Ethnography is the most common data collection method overall with about 69 papers citing some level of ethnography, including 5 that specifically mention digital ethnography. 30 of these papers explicitly mention authors either organizing or supporting the organization of the hackathon(s) observed.Taylor et al. [116], Nolte et al. [87], and Affia et al. [1] each also list their study method as explicitly action research. Semi-structured interviews are the second-most common (n=44), followed by surveys (n=37) with the two usually combined in a single study. Several publications (n=10) utilize digital data collection methods including scraping data online and looking at archival online or log data. These methods may be fewer, but are demonstrated in more recent publications where these tools are more available and accessible to the research community (e.g., [50, 77, 99]). 11 publications were literature reviews synthesizing research within their respective fields.

4.1.2 4 Data Sample Types (Participants, Publications, Projects, & Events). The 4 main types of data in hackathon research are participants, publications, projects, and events. "Participants" are people who are associated with hackathons in some way as either participants attending the hackathon ("hackers"), organizers, subject matter experts, sponsors, or judges. Literature will often report numbers of participants of the hackathon itself and the participants of the research study but use the term "participant" interchangeably, making it difficult to calculate an average number of participants across all studies and disentangle who is being discussed, especially considering the overwhelming use of ethnographic observation. Not all "participants" mentioned in literature are "hackers", but could include organizers and other stakeholders. The number of participants ranges from 6 to 956 participants but it is unclear if this number is inclusive of also any individual participating in hackathons. Research has also focused primarily on the perspectives and experiences of participants (86 publications), with only 7 publications that had organizers as participants. With only 2 studies, by Endrissat and Islam [25] and Porter et al. [100] respectively, that have explicitly interviewed volunteers or staff as participants, there are opportunities to conduct future research with and about other roles outside of mentor, participant, and organizer. Additionally, research has largely focused on singular aspects to complex identities (i.e., either race or gender) but could gain a more nuanced understanding with an intersectional lens (race, class, and gender) for hackathons that do support women and underrepresented minority students, such as returning students [45, 63].

"Publications" are the data sample type of the literature reviews [44, 78, 99]. The number of publications analyzed range from 51 to 381 articles using both qualitative (e.g., thematic coding, clustering, reflexivity) and quantitative (e.g., text scraping, word clouds, network analysis) methods. "Projects" are the data type of a much smaller portion of literature but common in case studies evaluating the projects of one or a few hackathons. They have recently become a sample type due to the increased interest in the continuation[50, 77] or perceived efficacy of hackathon projects [106]. Project data types are either qualitatively analyzed in case study review styles or quantitatively collected & analyzed through methods like scraping codebases like DevPost and GitHub or survival analysis for project continuation. The range of hackathon projects analyzed is from 5 to 22,183 projects.

"Events" are a common data type due to the prevalence of ethnographic observational methods in hackathon research. Events are often holistically analyzed and findings from this sample type are often shared in a "lessons-learned" style. The earliest hackathons observed in our sample are from 2012 and range from 1 to 20 hackathons studied in a single publication. While hackathons may be a one-off experience for participants, many are offered annually [59, 84] (or other regular frequency, e.g., [8]) with mostly the same organizing organization, general set of sponsors or collaborators, target audience, theme, and are usually recognized under a specific name (e.g., University of Pennsylvania's PennApps, NASA Space Apps Challenge, TechCrunch Disrupt Hackathon). However, there are no published research articles that study hackathons of the same series for more than 3 years. Many publications observed hackathon events in the United States but are observed in many other countries including Brazil, India, China, France, Germany, Mexico, Columbia, Uganda, Greece, the United Kingdom, Denmark, Netherlands, Estonia, and Australia. Virtual hackathons make the location of hackathon of events somewhat ambiguous as teams, organizers, and other stakeholders can be from all over the world.

4.1.3 Data Analysis Methodologies. The majority of papers (almost 75%) utilize qualitative analysis methods, particularly some kind of grounded theory approach and thematic analysis. However, only a handful of papers explicitly cite "grounded theory" (e.g., [24, 37, 103, 106, 107]) and "thematic analysis" or "thematic coding" (e.g., [17, 24, 45, 72] as their method of analysis but many others heavily insinuate derivatives of thematic coding in their available descriptions of their analysis processes (e.g., [63, 109]. The lack of rigor in the descriptions of qualitative analysis made recording the analysis methods in hackathon literature challenging. Several papers report findings in a "lesson-learned" style that imply aspects of grounded theory or thematic analysis (e.g., [54, 124]) but descriptions of the data analyzing process are vague or even absent from a noticeable number of publications. Fewer but more recent papers (n=15) use quantitative analysis methods, primarily statistical analysis and inferential statistics like correlation analysis, linear or multiple regression models (e.g., [11, 36, 86]. Some methods like network analysis for literature reviews [99] and archival analysis for coding projects [50] are more recent developments in hackathon literature that demonstrate the potential for more quantitative analysis methods given the growth of online hackathon information and code bases.

4.1.4 7 Contribution Types. We use Wobbrock and Kientz [126]'s classification system to understand the contributions in both CS and non-CS literature. We categorized publications in our sample into (1) Empirical, (2) Methodological, (3) Theoretical, (4) Artifact/System, (5) Dataset, (6) Survey, and (7) Opinion. Publications could be classified in more than 1 contribution type.

The vast majority of hackathon literature makes empirical contributions (n=94), followed by artifacts/systems, and theoretical contributions. Purpose (n=27), format (n=23), and processes (n=26) literature in empirical contributions are fairly evenly represented. Empirical studies almost exclusively study participants' experiences and what participants do in hackathons, with the exceptions of an empirical study on hackathon project code [50, 77]. These include many processes such as the role that affectual cues (or emotions) play when managing intra-team dynamics [55], experiences of minoritized participants [94, 95], collocation and social learning between hackathon teams [33, 87], the influence of mentorship and external stakeholder involvement on the outcomes of hackathon projects [17, 128], and how participants form ad-hoc teams in the traditionally short duration of hackathon [101, 104]. Nearly all disciplines from our sample contribute at least one empirical contribution.

Artifact/ System contributions (n=19) in this space take the form of intentional extensions or modifications of the hackathon format, including an evaluation on how the modified format differs from the standard hackathon or how the modified format performed with respect to its desired outcomes. Aligning with other findings, all contributions of this kind were format-related with 3 publications overlapping with the purpose focus area [10, 24, 31]. 14 of artifact/system publications were from CS and 11 from education & learning. Only 1 publication from health & medicine [122] and 2 from gender studies [24, 103] constituted an artifact/system contribution, indicating a lack of empirically evaluated modifications to hackathons for non-CS disciplines found in our sample. For theoretical contributions (n=17), the majority of theoretical publications within CS concern specifically female perspectives and participation in hackathons [23, 24, 47], which contrasts STS' focus on the purpose and impact of hackathons on society [51, 61, 117]. Another thread offered by STS and organizational studies researchers is the tension between the modern hackathon's dependency on corporate sponsor relationships, data, APIs, and hardware as materials despite hackathons' original premise of open-access, independent, and "hacker" mentality and culture [25, 61, 104, 117].

Methodological (n=4), Survey (n=12), and Opinion (n=7) contributions are less common. Among methodological contributions, most are quantitative methods published in 2020 and 2021 [50, 77, 99] like web scraping, metadata, and data mining tools which provide a starting ground for dataset contributions in hackathon literature. One publication adapts Bloom's Taxonomy of Learning to evaluate learning outcomes [1]. Survey publications, there are more recent literature review papers that indicate the growth of the field. There is only 1 publication that would be considered a dataset contribution [50], which is telling based on the difficulty to find statistics of hackathons, their growth, and projects. With more quantitative methods in recent years, we hope to see more dataset contributions in the future.

4.2 Four Core Research Areas of Hackathons

Across these 10 disciplines, we find that hackathon research focuses on 4 core areas: the purpose of the hackathon, the format of the hackathon, processes done and experienced by hackathon stakeholders, and the outcomes of the hackathon. While most papers have a single focus, some papers focus on two areas (e.g., purpose and format). We describe each core area and summarize findings below.

4.2.1 Purpose: Why organize a hackathon? Purpose is what motivates the organization of hackathons. From our sample, 38 publications focused primarily on purpose and three broad purposes emerged including innovation, learning, and participation. Additionally, we identified critical critiques of the purpose of hackathons as an common theme. We describe each purpose below.

Innovation Innovation refers to the development of products, services, and ideas with a particular emphasis on their novelty or new way of doing something. Ten publications discussed innovation as the primary purpose of hackathons. Early CS-related literature focused on innovation as purpose was typically situated in corporate settings where engineers, and later with non-engineers, would gather to innovate within the boundaries and support of their organizations [70, 105]. The interest in more sustainable outcomes for innovative products reframed hackathons as "open innovation" events which actively include knowledge, ideas, and feedback external to the organization from customers and external business partners[31]. The concept of hackathons as "open innovation" events is also mirrored in civic hackathons where participants engaged with the tools and data that could influence their way of life [54]. Due to the onset of the COVID-19 pandemic, these "open innovation" opportunities transformed specifically into "crisis innovation" to respond to the urgent challenges and needs created by crises [128]. Research on innovation in healthcare especially focuses on the value of interdisciplinary and multidisciplinary collaborations that include clinicians, medical students, engineers, business leaders, and those with lived experiences [2, 5, 13, 97]. These benefits, such as diverse and shared resources, knowledge, and perspectives, are similar to the incentives to "open innovation."

Learning Learning, the second identified purpose of hackathons, prominently features its application to CS education (9 out of 13 publications). Researchers study the direct application of programming concepts and tools from the classroom to help reinforce students' learning and provide them with a tangible project for resumés and opportunities for careers in STEM [29, 46, 114]. Hackathons in CS education were largely observed as an extracurricular activity undertaken by students on their own accord but later work sought to ingrain the benefits of hackathons directly into course curricula [35–37]. Research on hackathons for healthcare education focuses on the use of hackathons for diverse collaborations to enrich existing medical practices and health technologies [123, 127]. Across disciplines, learning in hackathons consistently found that hackathons development of soft skills to brainstorm projects, to balance ambition with feasibility, and to navigate team communication within the time pressure of a hackathon [76]. [8]'s unique study of a hackathon in the music education context focused on how hands-on interaction with people and materials (technical and nontechnical) provide opportunities to foster empathy and learn from their teammates' experiences and backgrounds.

Collaboration The third major purpose of hackathons is collaboration with diverse stakeholders (those who have something to gain from involvement with a hackathon), to inform more impactful projects (8 publications). Hackathons unite diverse stakeholders toward a common goal in a single, time-limited event. Taylor and Clarke [115] report findings from six different hackathon events that entail a range of hackathon themes (from cycling to railway codes), each with diverse groups of participants (such cyclists, politicians, and librarians) [115]. [73] study "issue-oriented hackathons" that explicitly depend on participants representing unique viewpoints so that together they can address issues in society systemically. These hackathons deviate from merely innovating new solutions, and instead focus on adequately responding to the challenge and problem space. Participatory making allows citizens the time, space, and resources to develop technologies that could be used by governments to enhance their own quality of life [32, 54]. Research on hackathons in healthcare brings healthcare professionals and subject matter experts together with participants. [17] recruited individuals who were living with systemic lupus erythematosus (SLE) to act as mentors to teams developing projects in a health hackathon. They found that participants developed better projects with the mentor feedback than without and that mentors felt hope and fulfillment from being able to participate in the design of potential solutions for their own health. Research in healthcare emphasizes the possibility of directly involving stakeholders as participants, subject matter experts, and judges in the development of health technologies and futures and see hackathons as a mechanism for participatory medicine [17, 19, 71, 79].

Critiques of Purpose Hackathons, however, have also faced substantial criticisms for its shortcomings in fulfilling their purposes (whether it be innovation, learning or collaboration). While developing innovations is an exciting prospect and hackathons have been a valuable mechanism to raise awareness of specific societal challenges in "issue-oriented" hackathons, the tangible artifacts created in hackathons often remain underdeveloped [73]. STS has observed that hackathons do not often solve the challenges felt by impacted communities and instead become theatrical displays of "social good" when celebrated in this defined space through project pitches and award ceremonies [51, 92]. One issue is the lack of impacted stakeholder groups who were largely absent from the makings of technologies that would purportedly "solve" their problems in earlier hackathons [51]. While the inclusion of people with lived experiences as subject matter experts has been highlighted in more recent research, this only addresses the conception of project ideas. A good pitch for the potential impact of a project could win a prize at a hackathon, but without the resources for follow-through after the hackathon, these projects are left behind and it is unclear who takes on responsibility [54]. Additionally, it's not always possible to rely on the creators of a winning project to carry on that labor by themselves. Perhaps unintentionally, this either places an unfair burden on participants (particularly students or lower-resourced individuals) to single-handedly direct these projects or misleads people on the responsibilities, commitment, and reality of "making an impact" in society. Instead, [73] position hackathons as sites of "material participation", reframing the events as not about "solving", but engaging with the social issue through exploration and discussion, fostering collaboration, and providing a space to articulate the problem as a community. However, with this framing of issue-oriented hackathons as events for collaboration, learning, and discussion on social issues, what participants learn is then greatly influenced by who else is present and actively part of the conversation.

Researchers also scrutinize hackathons for the lack of female and racial minority participation [23, 47]. The impact of disparate participation in hackathons results in potential losses in opportunities to explore or advance their careers in STEM and takes away the possibilities for solutions or material participation on issues experienced by marginalized communities [47, 111]. Even with their involvement, minoritized participants may not see themselves reflected in the issues advertised or data used in hackathons, creating a shallow space where they are unable to actually challenge dominant discourse despite the spirit of innovation "disruption" [117]. The question of the diversity of the collaboration in hackathons also extends into how to actively incorporate nontechnical participants in the creation and construction of projects. Hackathons in the arts have critically asked what even constitutes "hacking" for nontechnical audiences and how hackathons can be modified to better support nontechnical participants in the making of technology that can affect all of society [8, 57]. Forgotten projects, lack of sustainable impact, limited or exclusionary participation, and illusory agency–these are some realities of hackathon examined in literature. While purpose is intended, hackathon outcomes are the reality and these critiques illuminate a mismatch in expectations for what a hackathon can accomplish.

Why	**Purpose**	Learning [82, 84, 99, 127]	
		Innovation [8, 70, 105, 128]	
		Collaboration [8, 29, 46, 76, 84, 123]	
		Critiques of Purpose [23, 51, 57, 73, 92, 117]	
	Outcomes	Project Outcomes [70, 77, 86]	
		Participant Outcomes	Learning [11, 32, 80, 98, 111]
			Networking [3, 6]
			Topic Awareness [10, 16]
			Entrepreneurship [18, 85, 113]

Table 1: Purpose and outcomes are "why" we do hackathons. Purposes from literature include learning, innovation, and collaboration. There are project and participant outcomes. Examples from literature are provided.

4.2.2 Outcomes: What's the result? Outcomes refer to the results of a hackathon and inform whether people subsequently organize a hackathon again. 15 of the papers in the dataset focus on outcomes (see Table 1). Among these, 2 types of outcomes emerged: participant and project. Within the 9 publications focused on participant outcomes, we identified learning and applying practical skills [11, 32, 80, 98, 111], networking [78, 111], topic awareness [16], and entrepreneurial opportunities [18, 85, 113]. Hackathons have been seen as a way to apply skills and concepts learned in the classroom in a more fun, collaborative environment [111]. They have been found to improve students' interest in learning CS and confidence in their own programming skills through this hands-on approach [80, 125]. Corporate hackathon participants expressed similar positive benefits including networking with other employees, skill development, and career opportunities and pathways. Other participant outcomes include building awareness of the central topic of a hackathon, such as university students learning more about the economic challenges of people with systemic lupus erythematosus or dispelling misconceptions about self-harm [10, 16]. Lastly, a growing interest for participant outcomes is the use of hackathons to encourage entrepreneurship among students by using the time-limited, collaborative nature of the event to teach students how to apply business concepts, communicate effectively in teams, and practice pitching projects to stakeholders [18, 113]. Nolte [85] also finds that while there is some evidence for hackathons as the starting grounds for start-up founders, another important outcome is the resulting resources such as potential employees, business partners, and feedback that founders can benefit from.

In addition to participant outcomes, researchers consider project outcomes, like continuation after the hackathon. Research on project continuation in corporate settings emphasizes meticulous project planning post-hackathon and a fit into existing company product lines [70, 86]. Nolte et al. [86] find that in the short-term, winning a prize, using more technology, and preparation activities (e.g., discussing project ideas and setting up coding environments prior to hackathon) are correlated with project continuation but team's skill match and diversity are significantly associated with long-term continuation. McIntosh and Hardin [77] conducted a quantitative, empirical study on almost 11,900 projects affiliated with Major League Hacking hackathons from 2018-2019 and found that about 85% project changes were made within the first month of the hackathon, but only 7% of projects had any activity after 6 months. They suggest, as other work has [73, 118], that a given hackathon should be clearer in its intention and set expectations with participants about the intended goals of that specific event. Hackathons for learning should "distance the experience from the idea that [the participants'] project must change the world" (p. 84). This evidence supports criticisms about the lack of sustainable project outcomes, though there are no studies yet about the impact of projects that do end up being developed for widespread use. Of the 5 publications related to project continuation, only 1 (McIntosh and Hardin [77]'s study) was not explicitly in a corporate setting with employees as the hackathon participants. This contrasts with participant outcomes where 6 out of the 8 publications in this category were specifically about university students. Literature on project outcomes is still emerging, but have focused mostly on corporate or start-up populations, leaving room for potential insights on what could work for specific participant groups in contexts with even less infrastructure to support projects after hackathons. In addition, there are far fewer dedicated studies that examine hackathons outcomes longitudinally (more than 3 years), if changes to its format produce different outcomes, or the long-term career paths of students who participate (or excel) in hackathons [68, 84]. Outcomes-focused literature constitutes the smallest portion of literature and is more recently published compared to the other 3 core areas of research.

4.2.3 Format: What Makes a Hackathon? The format of the hackathon largely shapes the experience of the hackathon through a combination of the people, place, time, programming, and project materials (see Table 2). 34 publications focus on format. "Participants", often called "hackers," typically refer to the individuals who form teams (or work individually) to work on a project that will be submitted for judging, often for prizes. Participants and their experience in hackathons have largely been the focus of hackathon research, despite other roles present such as organizers, sponsors, and judges. 12 publications were focused on the organizers' perspective and experience (e.g., [26, 64, 107, 128]), but only 7 publications explicitly interviewed organizers (e.g., [23, 100, 115]) while 2 publications state that their future studies will directly involve organizers [78, 115]. However, researchers have considered people who provide technical or project management guidance (mentors) [87] and subject matter experts who provide knowledge of lived experiences or expertise in a particular topic relevant to the hackathon theme [10, 17]. Impacted stakeholders are often representative of the communities that may be affected by the projects produced by participants. Hackathons have traditionally taken place in-person where individuals benefit from being physically collocated but have also been observed in virtual-only or hybrid formats, particularly

What	**Format**	People	Organizers [25, 100, 109]
			Participants ("hackers") [11, 63, 125]
			Mentors [48, 87, 119]
			Judges [10, 21, 68, 129]
			Impacted Stakeholders [10, 17, 71]
			Volunteers or Staff [25, 100]
		Place	Virtual [37, 110, 124]
			Hybrid [30, 58]
			In-person (collocated) [33, 96, 120]
		Time	Duration [34, 49, 122]
			Frequency [8, 84]
			Occurrence (time, date, or day of the week) [21, 45]
		Programming	Theme [10, 103]
			Competitive vs. Noncompetitive [10, 31, 47, 84]
			Event promotion [64]
			Information sessions [8, 120, 122]
			Technology workshops or demos [100, 102, 104]
			Networking events [18, 59]
			Project pitch/presentations [104, 105, 123]
			Awards [78, 86]
		Project Materials	Technical [6, 14, 104]
			Non-technical [10, 15, 57, 118]

Table 2: Formats encompass "what" a hackathon is. Formats contain a wide variety of logistics for the hackathon event. Examples from literature are provided.

in response to the COVID-19 pandemic [37, 58, 110, 124]. Those who support the execution of the hackathon such as staff (paid) and volunteers (unpaid) with only 2 publications that involved these perspectives [25, 100]. Judges in traditional competitive hackathons are those who determine winning projects and can be representatives from corporate sponsors, university professors [129], impacted stakeholders, and domain experts [103]. The role of the "judge" in non-competitive hackathons has also seemed to move from awarding prizes to providing constructive feedback to improve projects (e.g., [10, 21, 68]) and while there is literature about judging, there are no publications explicitly focused on the perspectives of judges. "Timing" encapsulates how long the hackathon lasts (duration), how frequently it occurs (e.g., annual or monthly hackathons of the same theme, sponsor, or type), and what time of day or day of the week it is hosted (occurrence). There are no specific studies on when the hackathon is hosted, although it has been implicated as a barrier to participation for minoritized participants like returning students who are mothers, parents without access to childcare, and individuals with health concerns who cannot stay up or overnight in traditional 24- or 48-hour hackathons [23, 24, 45]. "Programming" includes the theme, whether a hackathon is competitive or noncompetitive, and a schedule of structured events and activities that are purposefully organized within the hackathon. Examples from literature include event promotion, topic presentations, technology workshops or demonstrations, and networking activities, as well as physical resources like the food or refreshments served and the available communication channels (e.g., Slack or Discord) and project repository tools (e.g., DevPost and Github) that participants must use. One strategy for broadening participation and lowering the barrier to entry for newcomers to hackathons has been to remove the competitive aspect of traditional hackathons [10, 21, 47]. "Project materials" is also an important format aspect as hackathons vary in their use and application of technical and nontechnical materials from data and application programming interfaces (APIs) to textiles and sewing machines. Materials provided by organizers and sponsors of hackathons have been suggested to influence the development of project ideas, whether to encourage nontechnical participation [57, 103] or to incentivize relevance to a sponsored technology towards corporate sponsored-awards [104]. Reasons for modifications (e.g., duration, mentorship, nontechnical materials) to the traditional in-person, 24-48 hour hackathon format were found to align with the hackathon purposes of innovation, learning, and inclusive and diverse collaboration.

4.2.4 Processes: How Do Hackathons Work? Processes explain how a hackathon works and what happens to, and between, stakeholders before, during, and after the hackathon (see Table 3). 30 publications focus on processes with at least 1 publication about processes from each discipline represented in our study except the Arts and Library & Information Science (17 in CS, 12 in Organizational Studies, and 7 in Innovation & Entrepreneurship, for more details see Table 5 in the Appendix). Pre-hackathon processes that research has highlighted include how teams form, learning about technologies or topics central to the hackathon, and motivations to participate in hackathons for participants. To a lesser extent, literature has also included how organizers plan events, find sponsors, and advertise the event and 2 publications in particular describe the planning process more in-depth (i.e., Sadovykh et al. [108] with identifying cultural heritage of participants as a challenge to collaboration in plenary meetings in Europe and Birbeck et al. [10] with navigating the sensitive domain of self-harm as a hackathon theme). Most publications about processes are concerned with what happens during the hackathon, specifically intra-team dynamics in collaboration [25, 55] and communication and project brainstorming and innovation development [30, 58]. Research on processes is heavily informed by organizational studies, primarily empirical, and often focuses on a particular demographic within hackathons to report their experiences. Much of what we know about the experience of female participants in hackathons comes from gender studies perspectives and research that focus on how participants interact with each other, their perceived involvement in project creation, and navigating their marginalized identity in predominantly white, male settings [27, 45]. One study investigates how elderly participants over the age of 50 experience and navigate the hackathon event when on teams with younger, more technical teammates [62]. Seravalli and Simeone [109] also extrapolate the dynamics between people to look more broadly at how organizations as a whole participate in hackathons and the how boundary organizations, organizations that operate in multiple domains and engage with different stakeholders, can provide starting grounds to encourage diverse participation [109].The other portion focuses on how people balance project novelty and ambition with feasibility in the time-limited context of hackathons [46, 72, 106, 107]. We found no publications that primarily studied post-hackathon activities such as post-hackathon networking or continued motivations to participate in future hackathons (despite their minor mention in many other publications). While potential factors for project continuation have been identified in outcomes-focused literature [70, 86], the granular examination of these factors and how teams can engage in the processes that promote project continuation has not yet been studied in-depth.

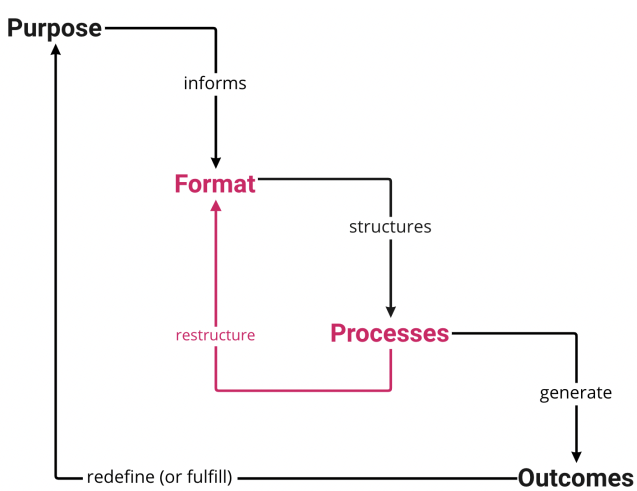

Figure 1: The 4-Core Area Framework: format structures the processes that promote the desired outcomes that fulfill or redefine the purpose of a hackathon, beginning the cycle again.

4.3 Four Core Area Framework

The emergence of 4 core areas of hackathon research illustrate important relationships that were implied across all hackathon research. The framework (see Figure 1) illustrates how research on hackathons is understood wherein the format structures the processes that generate outcomes that fulfill or redefine the purpose of a hackathon—this purpose then informs or restructures the format of the hackathon and begins the cycle again. In addition, there is a reciprocal relationship between how the desire for a preferred way that the hackathon processes be done by participants further restructures the format to achieve the desired outcomes. The interplay between the areas is also evident from the development of hackathon research found in our timeline and which of these 4 core areas research has chosen to focus on over time.

4.4 Timeline Hackathon Literature

Our construction and consequent analysis of the timeline reiterates the relationships illustrated by the 4-core framework and the progression of research over the years. Literature published about hackathons has more than doubled between 2018 to 2022 compared to its early years from 2013 to 2017. Based on the timeline, we observe a growing number of publications from non-CS disciplines and an increase in publications over time (see Figure 2). Literature published from CS venues remains prominent throughout this time period with a total of 66 publications, followed by education & learning with 39 publications, innovation & entrepreneurship with 28, and STS with 20 (see Table 4 in Appendix).

4.4.1 Driven by Purpose - The Early Years of Hackathon Research (2013 to 2016). Understanding the purpose of hackathons was the catalyst for research on hackathons. While many people were conducting hackathons in practice, researchers were slow to empirically study hackathons. The years-long delays in published empirical research on the introduction or real-world trends of socio-technical systems has been seen in other domains (e.g., Lampe et al. [67] observed the use of Facebook among college students for finding new people vs. learning more about people they meet online or Gerber and Hui [38] on participating in crowdfunding).From 2013 to 2016, purpose-focused research constitutes the majority of literature published (see Figure 3). The 4 disciplines that publish the most hackathon literature (CS, education & learning, STS, and innovation & entrepreneurship) all begin with purpose-focused literature. CS and STS may have been the first to write about hackathons as a phenomena but organizational, gender, education and learning science, and innovation disciplines soon examined the hackathon. Irani's influential critique on hackathons and their supposed premise for socially-good innovation would remain relevant throughout time [51]. An early paper published in 2015 by Jones, Semel, and Le from organizational studies examines the transitory allegiances in ad-hoc teams created by the time-limited nature of hackathons and how participants negotiate varying levels of commitment to the hackathon project at different times through verbal and nonverbal communication [55]. Their perspective, informed by linguistic anthropology, also provides interesting insights on how participants form and leave teams, highlighting a particular acceptance of temporary relationships and lack of structured obligation in the hackathon (to teammates or their projects). Despite this granular

How	**Processes**	Pre-hackathon	Organizing [26, 35, 97]
			Theme development [57, 103]
			Team formation [2, 55, 108, 112]
			Preparation activities (for participants) [33, 87]
			Motivation to participate [63, 68, 125]
		During Hackathon	Project brainstorming [27, 106, 120]
			Project development (e.g., creativity, adherence to theme) [104, 106, 107]
			Task delegation [119]
			Team communication [101, 110, 124]
			Team collaboration [45, 63, 76]
			Judging [46, 68, 91]
		Post-hackathon	Project continuation [72, 86, 88]
			Post-event networking [18, 78, 111]
			Reflection of experience [2, 17, 98]

Table 3: Processes of a hackathon constitute "how" hackathons work to generate outcomes and can be classified as pre-, during, and post-event. This table summarizes some main processes with examples from the literature.

investigation on the volatile social environment of hackathons, its perspectives and implications have remained largely unnoticed in the grand scheme of hackathon literature.

Two papers from 2015 make format modifications to improve the experience for female participants that we find to be foundational for later format-focused literature. Richard et al. [103] explicitly alter the materials, place, and theme for their StitchFest hackathon, a companion hardware hackathon within PennApps in 2014. Their use of nontechnical materials like textiles, sewing machines, and fabrics located in an open, shared space helped create an environment where nontechnical participants felt more comfortable contributing to projects and asking for help from other teams. Decker et al. [21] report findings from two Think Global Hack Local (TGHL) hackathons in 2013 that were uniquely non-competitive and actively encouraged teams to work collaboratively to create solutions for nonprofit organizations. In addition, participants also regularly received feedback from nonprofit organizers acting as mentors to projects and were also encouraged to go home to rest and return the next day. The positive reception of both participants and other stakeholders inspired new ways to think about how hackathons could be modified to improve participant experiences and better fulfill specific purposes.

4.4.2 Experimentation of Hackathon Formats (2017-2019). Informed by the discussions of purpose in the early years, hackathon literature moved to experimenting with modifications to the traditional hackathon format in a variety of settings. From 2017 to 2019, format-focused literature flourished with a wide array of proposed modifications to address shortcomings of the traditional hackathon format. These modifications were not only published from the perspectives of CS, but also education, gender studies, and the arts. In education, modifications to hackathon formats took the form of adapting the hackathon into formalized course curriculums [12, 33, 35, 49, 66]. Additionally, Bonilla, Lozano, and Granda incorporate required team parameters to promote inclusivity and diversity on teams [12]. These adaptations take into account the standard commitment and work-life boundaries of regular coursework by either scaffolding hackathons as weekend-long events after midterms [12], day-long projects [33, 66], or even week-long engagements [49]. Critical female-focused hackathon modifications were primarily hosted for university students but Hope et al. open the hackathon space to tackle challenges experienced by mothers, a group often excluded from traditional hacking [47]. They make important changes to the original format like the introduction of community standards that each participant must uphold, encouraging awards to be experiential rather than monetary or ranked, and creating an open floor, "science fair"-type exposition to share projects as peers, rather than formal "pitches". Their changes de-center hackathons as sites for singular solutions for "impact" and focus on collaborative projects that provide diverse options for care and support.

Other modifications to hackathons aim to shape more inclusive collaborative environments with nontechnical hackathon participants including primary school teachers [56] local community parents and children [116], and the elderly [62]. These community-based approaches to hackathons emphasize making technology familiar and accessible to participants and building communities' abilities to identify their own needs and how technology could address them. They explicitly turn away from the standard judging criteria of novelty and innovativeness in traditional formats in favor of this community-building work [116]. Porter et al. also suggest providing toolkits and step-by-step guidance on design processes to provide more streamlined hackathon experiences and projects for especially nontechnical participants [100]. In health literature, Wang et al. report on an extended hackathon model for medical innovation with robust preparation beginning six months prior to the 1 to 2 week-long hackathon event, need-finding with hospitals, and a small budget for diverse student teams [122]. Lee and Geller explore an alternative to the hackathon format with CodeSport in an effort to reframe participation and spectatorship in competitive STEM settings [69]. Hackathons do not have spectators—people are either participants who are creating projects or actively participating as subject matter experts or mentors. However, Lee and Geller find that Asian/Pacific Islander and especially Hispanic/Latino spectators actually considered becoming competitors after spectating

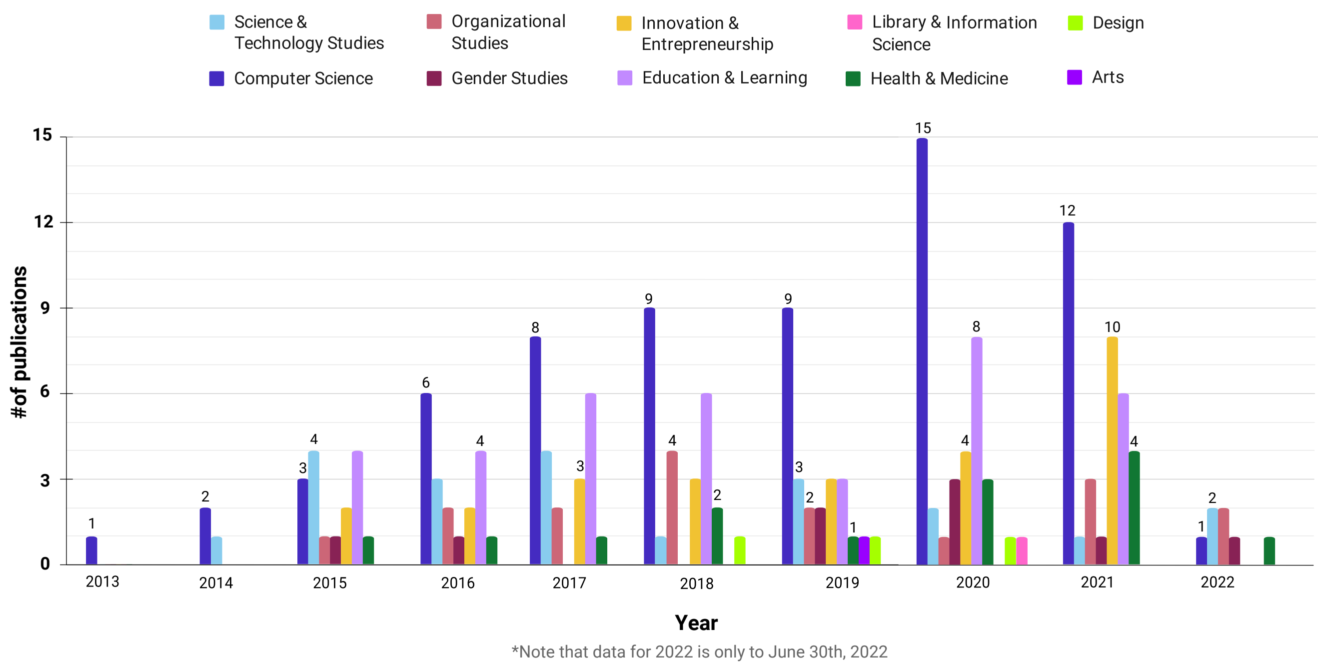

Figure 2: The number of publications and disciplines publishing about hackathons has greatly increased over time, with the majority of literature published from computer science.

the CodeSport event, suggesting that allowing non-participants to first observe what happens in coding events could encourage participation in hackathons. While not emphasized in-depth, organizational and gender studies perspectives would greatly enhance the arguments for incorporating ways that non-attendees can spectate and still be exposed to the hackathon, much like CodeSport. Also interesting to note is Suominen et al. [112]'s research from the innovation and STS perspectives that experiments with format changes for a dual-purpose hackathon in educational learning and urban issues.

4.4.3 Shifts in Understanding (2020-present). In 2020, there were nearly twice as many publications about hackathons compared to the year prior and 9 distinct disciplines represented. Purpose, format, processes, and outcome-focused literature are roughly equivalent in this year with a sizable growth in outcome-focused publications (7 total in 2020, compared to only one in 2019). Two major literature reviews about pre-pandemic hackathons were published in 2020. Based on a review of HCI research, Olesen and Halskov [90] present their paradigm of research with and research on hackathons, creating a distinction between studies that use hackathons as a methodological approach to observe another phenomenon and studies that examine hackathons as a phenomena in their own right. Medina Angarita and Nolte [78] conduct a review of literature in HCI to catalog the various outcomes of hackathons and the design aspects of hackathons that can inform more sustainable hackathon outcomes for participants and their projects. Further Nolte et al. [86] in 2020 and McIntosh and Hardin [77] in 2021 conduct two of the few quantitative studies in hackathon research to discover the lack of project development post-hackathon and factors that could facilitate project continuation.

As outcomes and processes that generated these outcomes of hackathons from prior work were being reported, the COVID-19 pandemic dramatically altered our lives and the way hackathons were run and understood by the research community. Krüger and Teuteberg [65] and Gama et al. [37] also independently report the first outcomes and repurposing of hackathons as e-learning environments for students in 2020. With this, we see a resurgence of purpose-focused literature in 2021 as researchers revisit virtual hackathons as sites for learning (e-learning) [37, 65, 101, 110] innovation (in healthcare and crisis innovation) [13, 30, 34, 124, 128], and collaboration (global civic engagement) [13, 128]. Additionally, nearly half of the articles published in 2021 (11 out of 25) were reports of the processes of hackathons, though only 3 were uniquely reporting processes of virtual hackathons. The majority of processes publications indicates a maturing and nuanced understanding of research on hackathons, enough to focus on examining the mechanisms that are produced by the hackathon format and shape the outcomes observed reported in prior work. However, the emergence of processes in virtual hackathons also demonstrates the urgent need felt by the research community to understand how hackathons could work for virtual (or hybrid) formats to retain the benefits of in-person hackathons. Researchers also needed to

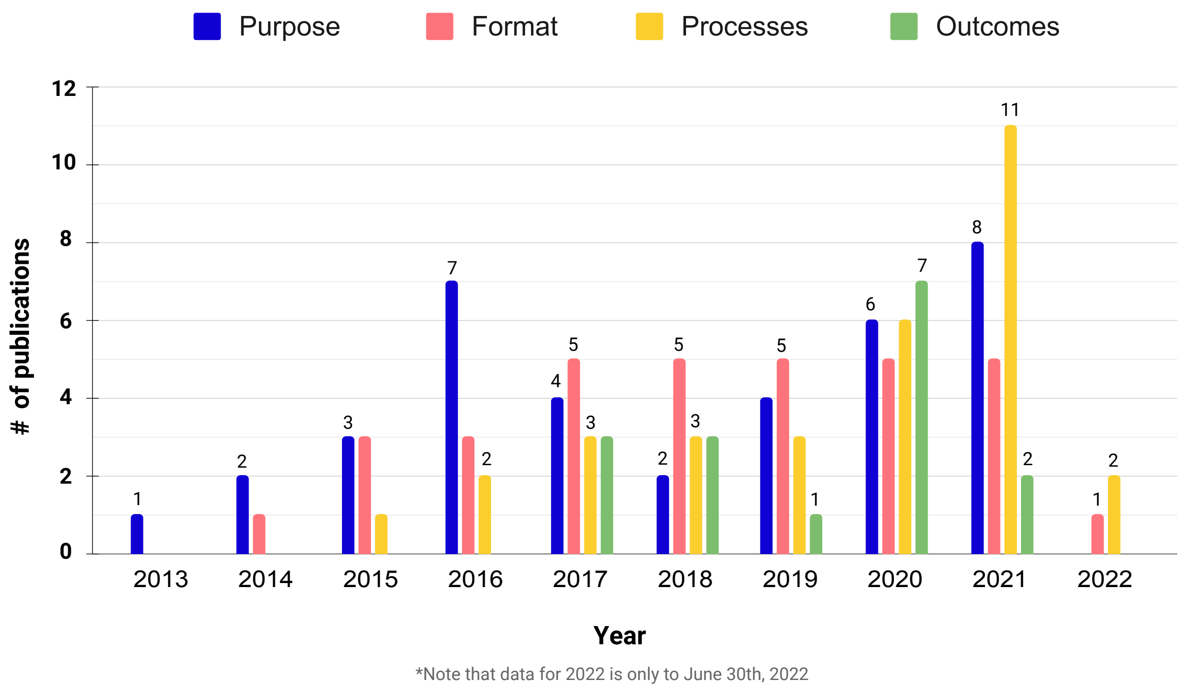

Figure 3: Early hackathon literature began with purpose literature (2013-2016), then formats became tangible ways to achieve purposes (2017-2019), and outcomes and processes publications grew as the field matured in 2020 and 2021, respectively. These reflect the changing motivations and interests of hackathon research.

devise new ways to conduct hackathon research. The resulting outcomes from these virtual hackathons prompted organizers to rethink the purpose of hackathons in this new virtual space. While the number of literature in 2022 of our sample is small, we note Kovaleva et al. [64]'s review of modifications to format towards a gender balance in modern hackathons and an emerging study on affectual engagement in hackathons from organizational studies [25]. While still in its infancy, we predict that more format- and processes-literature will be published in the future that will provide best practices for virtual hackathons and further investigate how stakeholders navigate these remote collaborations.

5 DISCUSSION

From our multidisciplinary literature review, we identify 4 core research areas of hackathon research (purpose, format, processes, and outcomes) and conceptualize how changes in hackathons across disciplines have evolved. We also see glimpses of the impact that the COVID-19 pandemic has on hackathon literature, as well as the new (and reimagined) purposes and challenges of hackathons experienced in virtual formats. We highlight that hackathon research is inherently interdisciplinary and that other disciplines have interesting and valuable insights for the HCI community's own understanding of hackathons and future research. Informed by a thorough investigation of hackathons across disciplines, our framework drives future work with hackathons while complementing program theory's defined focus on evaluating—not producing—modifications of hackathons [26]. Falk et al. describe program theory with inputs as tangible or intangible resources, process as mechanisms (principles that generate an effect) and activity (the way mechanisms are brought into action), and effect (immediate outputs, short and medium-term outcomes, and long-term impact). This coexists within our framework: inputs and activities are formats, the mechanisms are processes, and the effects are outcomes. However, our framework emphasizes the importance of purpose as the overarching catalyst for all hackathon use and modification and why other disciplines adopt hackathons, despite changes made to how hackathons are run and what participants do. Towards Medina Angarita and Nolte [78]'s end for more sustainable outcomes of hackathons, especially for participants, our framework's extends itself as a resource to orient hackathons towards desired long-term outcomes and goals, instead of just short-term changes. The framework is explicitly cyclical; outcomes inherently fulfill and redefine the purpose which suggests constant reflection and refinement in the way that we understand and organize hackathons. By doing this multidisciplinary review, we also see the nuanced iterative relationship between format and processes where each influences the other. While outcomes do indirectly influence potential changes in the design of the hackathon, targeting a specific process (e.g., how participants "hack" in a nontechnical hackathon) may provide clearer modification recommendations for the future (e.g., provide more nontechnical materials).

Unlike previous literature reviews [78, 90], our review is unique in its inclusion of non-computer science literature in the conversation about hackathons, which is critical in establishing the CHI community's knowledge and proliferation of hackathons in so many diverse domains and now in virtual space. We highlight the importance of incorporating diverse perspectives on a highly interdisciplinary topic such as hackathons as there are unexplored opportunities introduced by other disciplines. Examples include detailed behavioral studies on participant collaboration, team formation, and team commitment [55], extended models of hackathon formats for greater project continuation and fruitful innovation [122], and deeper understandings of inclusive and accessible music technologies [8]. Even library and information studies, relevant to HCI research [42], sheds light on how hackathons can build upon existing institutions like libraries that have long served as public sites for communal knowledge and learning, providing a well-known accessible area that could help broaden participation in hackathons to a wider community [74]. Other disciplines bring especially valuable insights on how other communities of people perceive hackathons and "hacking", generating meaningful future work for CHI researchers to translate the benefits of hackathons to diverse audiences like the elderly [62], social workers [118], nurses [79], filmmakers [57], musicians [8], and more. Our 4-core framework is informed by perspectives of diverse disciplines and can be used to effectively organize hackathons. We encourage more multidisciplinary reviews and research as a way to also enrich our own expertise that we can share with disciplines that are still growing in their understanding of hackathons. We contribute practical applications of our framework for those organizing hackathons to improve the iterative process of hackathon development and tangible recommendations and future research directions for hackathon researchers.

5.1 Guiding Deliberate Modifications to Hackathons

While there are broad recommendations for hackathons offered by prior work, hackathons exist in a multitude of disciplines with varying purposes and constraints. Without our proposed framework (Figure 1), the CHI community lacks a unified approach towards developing intentional modifications that are driven by real-world motivations. In addition, presenting a generalizable framework creates a more readily applicable and customizable guide for HCI researchers to bring to hackathons in other disciplines and for organizers and experts in these non-CS disciplines to leverage our communities' knowledge, experience, and expertise on hackathons. This framework helps organizers more concretely consider potential modifications to hackathons that better serve its purpose. While there are broad recommendations for hackathons offered by prior work, hackathons exist in a multitude of disciplines with varying purposes and constraints. We contextualize this framework with 2 prominent issues articulated in literature: increasing diverse participation and organizing better virtual hackathon experiences.

5.1.1 Purpose informs format. First, the framework requires organizers to reflect on the purpose of a hackathon in the chosen context. After identifying the purpose, consider what format modifications are possible based on given constraints. Literature from non-CS disciplines have especially highlighted the importance of modified hackathon formats based on purpose (e.g., Wang et al. [122] explicitly differentiates extended hackathon formats for learning and traditional weekend health hackathons for generating patents, trademarks, and commercializable solutions while organizers in Karlsen and Løvlie [57]'s study intentionally assigned teams to promote open-ended project, not "rule-based problem-solving" like in traditional CS hackathons.) **Diverse participation:** Richard et al. [103] create "Stitchfest", a smaller concurrent hackathon within PennApps, and explicitly define their purpose as broadening participation. They target changes to materials (Arduinos, fabric, sewing machines), theme ("Wear & Care"), and space (open, communal room). **Virtual hackathons:** The COVID-19 pandemic forced many interactions to be virtual. Literature has defined virtual hackathons for learning [37, 101] and also for crisis innovation [13, 128] but there is an opportunity to determine what format modifications would best suit these purposes [106]. Examples: programming (setting up Zoom break-out rooms or Slack channels with mentors learning [101, 124, 128]) or technical requirements (datasets or website repositories for projects towards innovation [101]).

5.1.2 Format structures processes. Design is an iterative process that aims to bridge the gap between the present and the desired future. For each different format aspect, ask questions that probe the current state. How does the identified format aspect shape the current processes of the hackathon? **Diverse participation:** Warner and Guo [125] noted that there were not enough mentors at their university's competitive hackathon and noticed inexperienced participants were hesitant to reach out for help. They found that 65% of female respondents who had never attended a hackathon reported "novice fears" (i.e., fears of being unable to contribute to projects or not having enough support) as the biggest reason that discouraged them from attending a hackathon. **Virtual hackathons:** Powell et al. [101] set up a specific Slack "channel" for each team and mentor; however, they found that the majority of teams only used that channel to communicate with their mentor and used separate communication tools (e.g., iMessage, Discord, and Teams) for intra-team communication. They tried to mirror spontaneous "check-ins" that mentors can do in-person, but this solution did not match the realities of teams' online communication behaviors and norms. This step can be greatly enhanced with perspectives informed by other disciplines (e.g., organizational, anthropology, and innovation & entrepreneurship studies) or with experts of the discipline in which the hackathon is being hosted in (e.g., film, music, business).

5.1.3 Processes restructure format. Findings from the previous step should answer what relationship a format aspect has with what currently happens in the hackathon. Use these findings to identify what needs to change in the format to encourage what processes are desired. **Diverse participation:** Decker et al. [21] explicitly removed the competitive aspect of their hackathon, Think Global Hack Local, which encouraged collaboration across teams and more positive interactions between participants. **Virtual hackathons:** Wang et al. [124] find that virtual hackathon teams may be more likely to form based on the perceived skill sets needed to complete a project. This may make virtual hackathon environments less welcoming and inclusive to historically minority individuals, especially those with less technical backgrounds. While we now have recommendations for female-focused in-person hackathons [64], how might we create inclusive virtual hackathons?

5.1.4 Processes generate outcomes. In this step, plan the methods that will be used to record the efficacy of modifications and gather feedback from different stakeholders. For data collection, ethnography, surveys, and semi-structured interviews are standard across disciplines. For data analysis, thematic analysis, grounded theory approach, and reflexivity are common for qualitative approaches and inferential statistics, one-way ANOVA, and network analysis as quantitative techniques.

5.1.5 Outcomes redefine & fulfill the purpose. Analyze and compare the data from the pre- and post-modification. Reflect on whether these outcomes fulfilled the intended purpose set in Step 1. Are there outcomes that are surprising or stand out? Using these outcomes, determine whether the purpose of the hackathon needs to be re-evaluated (Step 1) or return to identifying format modifications with the newfound information (Step 2). **Diverse participation:** Lara and Lockwood [68] chose learning as the purpose of the Ideas of March hackathon and incorporated feedback from the prior to include more and on-demand mentoring in 2015. **Virtual hackathons:** Within innovation during the pandemic, the challenges presented were broad in the EUVsVirus hackathon in 2020, which created many diverse solutions but the majority of projects ended with 1 or no partnerships for continuation. In the MPLabs COVID Challenge, stakeholders very clearly defined the scope that led to projects that could quickly go into production but were potentially less disruptive. Gama [34] presents a crossroads for virtual hackathons to determine to which nuanced purpose (disruptive solutions vs. tangible procurement) these events will adapt to.

5.2 Recommendations & Future Directions for Hackathon Research

Despite the importance of outcomes to organizers and researchers, it represents a smaller portion of literature. While hackathons are emphasized as participatory design activities, there is an absence of more active participant involvement in the analysis of hackathon outcomes and event feedback. Researchers could provide alternate ways to receive feedback and, especially towards the goal of increasing diverse participation, consider having a diverse team of researchers and organizers with whom minoritized participants can feel more comfortable sharing their experiences with. Interviews allow gender minority participants to recount complex emotions felt while working in hackathon environments that were not designed with their active participation in mind—critical information that may have otherwise been less apparent or absent in a survey [95]. Our multidisciplinary review also urges HCI research to adopt intersectional approaches to hackathon outcomes and not simply look at cisgender female participation, but transgender/nonbinary & gender non-conforming participants, as well as race, socioeconomic class, and ability in the context of hackathons (only bell et al. [8]'s study explicitly call out disability and hacking). Several studies suggest future work to look more closely at the relationship between participant experience and project continuation outcomes such as project scope [96], sense of ownership [87], sponsor interest and investment in a hackathon project [111], and motivations for hackathon participation [63]. The lack of longitudinal studies makes it difficult to piece together how modifications in format will impact participants and outcomes, especially those in more localized settings, like intra-university hackathons or smaller-scale civic hackathons. Hackathons that tend to host participants from a relatively similar pool of people (e.g., students, employees, transgender participants) could especially benefit from purposeful experimentation with their formats to better understand how these changes specifically impact their participants' experiences and projects, learning, and connection to the wider communities (if applicable). This framing may also be valuable for future work to uncover patterns, similarities, and differences of hackathons in non-Western contexts. Research on multiple iterations of a single hackathon series can inform what works and what doesn't to create better hackathon experiences for individuals in context. Longitudinal studies can often be challenging and require continuous effort, resources, and communication with other parties to sustain [22]. However, there are promising avenues for longitudinal studies on hackathons, especially with hackathon research's involved history with observing and modifying hackathons for university students at universities (e.g., Richard et al. [103]'s addition of StitchFest to the pre-existing PennApps) and civic engagement in local communities (e.g., Hou and Wang [48]'s study followed the same annual civic hackathon for 2 years or Taylor et al. [116]'s collaboration with a local community partnership that helped create the first series of hackathon-like events in the community).

For participants, placing community-identified problems and voices at the locus of hackathon modifications could possibly help alleviate the shortcomings of hackathons as spaces that can be performative and unwelcoming to minoritized experiences (see subsection 4.2.1). While prior literature has noticeably derived problem spaces for hackathons (e.g., systemic lupus erythematosus [17], social services [118], COVID-19 [34]), there are far fewer studies that center the hacking on issues that disproportionately impact traditionally marginalized hackathon participants (e.g., Hope et al. [47]'s female-focused hackathon revolved around redesigning the breastfeeding experience). In addition, future work could consider the relationship between where participants are geographically situated in and hackathon purposes (such as specific regional issues) and processes (impact of culture and collaboration norms) or what this means for virtual hackathons with teams situated all over the globe. For projects, project continuation has been a notable area of interest, particularly in corporate hackathon settings. However, there are opportunities for researchers to expand the evaluation and improvement of project continuation beyond corporate settings and into universities, nonprofits, and other community settings. Hackathons are often standalone, short-term collaborations but projects themselves need infrastructure to exist beyond the time-delineated event of a hackathon [30]. Innovation literature provides a framework of evaluating the "innovation ecosystem" [40] of hackathons, while our review suggests re-evaluating and suggesting modifications to improve project continuation from the perspective, circumstances, and challenges of the setting participants are tasked to hack in through purposeful modifications with our framework. The components of the framework also encourage other kinds of longitudinal studies on the processes and formats for projects, teams, individuals in future research. Further work on outcomes like project continuation would then help to determine the efficacy of hackathons—whether they serve their intended purpose—and create further discourse and improvements on hackathons.

Understandably, most literature explores hackathons from the perspective of participants with most recommendations and contributions intended for organizers of hackathons. This review catalyzes future research in hackathons that can further investigate tensions between organizers and stakeholders of different disciplines, empirical studies on recommendations for hackathons provided in prior work or related studies, the planning process for hackathons, including the perspectives of roles like volunteers or spectators, and more with greater granularity. Also, there may be an opportunity for future research to reframe contributions as not from the perspective of organizers, but that of participants to explore what recommendations they would offer to other future participants. Our multidisciplinary review also reveals the tensions within disciplines adopting the traditional hackathon format. Our analysis suggests that newer disciplines struggle with adjusting the traditional hackathon format to their intended audience—likely made more difficult in disciplines where projects may not be specifically digital or electronic creations. Karlsen and Løvlie [57]'s study on a non-technical hackathon revealed organizers' desires to use hackathons for the purpose of in innovation and collaboration, but struggled with dissociating participants' perceptions that hackathons meant "needing" digital projects despite providing numerous resources and intentionally assigning interdisciplinary teams. Similar observations have been made in CS literature about broadening participation in hackathons (e.g., [103, 115]), potentially directing future research on applying strategies for broadening participation found in CS literature to other disciplines (e.g., critiques from non-technical participants and stakeholders [10], structured brainstorming [27], information talks on the topic of the hackathon before the event happens [1], and mentoring [68].) At the same time, our review reveals opportunities for the future of hackathons with non-technical audiences through the lenses of disciplines whose primary participants are similar to those that CS hackathons aim to attract—especially with the opportunities that virtual hackathons present to those originally unable to participate due to the pressure of overnight events, transportation, and in-person interactions. For HCI researchers, fruitful longitudinal research on hackathons benefits greatly when we synergize our expertise with that of other domain experts. We also encourage future publications to include information that would help contextualize the research findings and fill in gaps in knowledge identified in this review, such as distinguishing the number of participants in the study (not just all participants of the hackathon or vice versa, when applicable), more detailed descriptions of data collection and analyses methods, and reporting the technical familiarity, skills, or background of participants, especially in research related to non-technical participation (e.g., [19, 122]). Together, multidisciplinary perspectives of hackathons could offer valuable insights on the outcomes of participants and projects (and perhaps broader impacts of hackathons).

5.3 Impact of exogenous factors on research

An important undercurrent of this work is the impact of exogenous factors on research throughout time. It is entirely possible that virtual hackathons existed before 2020, but as Grudin [42] has observed, "[w]e exercise prerogative when we use digital technology—sometimes [...and] Sometimes we have no choice" (p.32). HCI researchers must turn our attention to the technologies necessary to maintain our society and, oftentimes, sense of normalcy. COVID-19 is an exogenous shock that greatly impacts the perspectives we share of our work and future directions of research. Learning from the impacts of exogenous factors on other disciplines can also enrich our own practice in HCI. The pandemic prompted society to quickly integrate technology into our everyday lives from remote schooling to telehealth to virtual social gatherings. School teachers had to incorporate tools like Zoom and Youtube videos for early childhood education, despite reluctance to introduce technologies to children at such a young age [130]. The pandemic "broke" the teaching paradigms of medical school professors that could not substitute in-person interaction with patients [4] and also radically shifted peripheral technologies to the forefront, particularly for healthcare technologies that now needed to critically examine the infrastructure and accessibility of telehealth services [9]. In hackathon research, we have yet to explain why virtual hackathons were not in fashion despite pre-pandemic remote work and online learning. Virtual hackathons have been able to unite people worldwide but we still struggle with forging social bonds remotely. What did we do before and why, and what experiences can we (or can we not) substitute in digital space? As society finds new ways to repurpose and adopt new and old technologies for their needs, the COVID-19 pandemic has reshifted our understandings of hackathons and informs future work on what they are, how they work, and why we make them.

6 CONCLUSION

Our research reveals the evolution of hackathon research over time across diverse fields in a uniquely multidisciplinary literature review on hackathons. We find that there are 4 core areas of hackathon research (purpose, format, processes, and outcomes), reiterated across domains and across time, that we use to develop a framework to understand hackathons and orient future research towards promising directions and insights on hackathons. We emphasize the importance of an underlying purpose for hackathons to drive adoption of hackathons in other disciplines, the intentional modifications of the traditional hackathon format, and our multidisciplinary review and framework as contributions to the CHI community so that HCI researchers can lend our knowledge and expertise into other disciplines through shared comprehension on hackathons across domains. We contextualize the applications of our framework to diverse participation and virtual hackathons, as well as encourage future multidisciplinary directions for longitudinal hackathon research.

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A APPENDIX

Table 4: Categorization of publications based on discipline with the majority of literature in computer science, followed by education & learning, and innovation & entrepreneurship.

<table>
<tr><td>Computer Science (N=66)</td><td colspan="2">[90], [111], [84], [45], [103], [125], [87], [115], [82], [47], [120], [96], [119], [29], [78], [88], [65], [11], [99], [86], [14], [39], [21], [50], [128], [105], [35], [10], [108], [66], [6], [80], [98], [12], [95], [44], [3], [129], [26], [1], [49], [48], [91], [104], [85], [77], [36], [100], [121], [32], [37], [34], [56], [33], [23], [69], [27], [94], [102], [68], [46], [110], [76], [31], [101], [64]</td></tr>
<tr><td rowspan="5">Education & Learning (N=36)</td><td>Computer Science/Engineering & Data Science (n=28)</td><td>[111], [84], [45], [125], [29], [49], [110], [6], [87], [120], [119], [99], [14], [65], [12], [37], [82], [68], [36], [35], [11], [80], [98], [129], [33], [66], [1], [46]</td></tr>
<tr><td>Business (n=3)</td><td>[18], [113], [15]</td></tr>
<tr><td>Health & Medicine (n=4)</td><td>[127], [123], [122], [75]</td></tr>
<tr><td>Music (n=1)</td><td>[8]</td></tr>
<tr><td>K-12 Teacher Education (n=1)</td><td>[56]</td></tr>
<tr><td>Innovation & Entrepreneurship (N=28)</td><td colspan="2">[18], [31], [105], [88], [114], [72], [5], [128], [106], [30], [124], [113], [59], [97], [58], [107], [85], [34], [121], [61], [13], [122], [70], [2], [116], [51], [112]</td></tr>
<tr><td>Science & Technology Studies (N=20)</td><td colspan="2">[115], [96], [51], [73], [25], [23], [114], [100], [21], [55], [106], [54], [117], [10], [57], [104], [24], [116], [112], [8]</td></tr>
<tr><td>Organizational Studies (N=18)</td><td colspan="2">[63], [120], [101], [39], [98], [108], [55], [124], [109], [25], [3], [48], [107], [100], [62], [27], [76], [91]</td></tr>
<tr><td>Health & Medicine (N=15)</td><td colspan="2">[5], [2], [17], [97], [127], [123], [13], [71], [19], [92], [122], [79], [16], [118], [75]</td></tr>
<tr><td>Gender Studies (N=9)</td><td colspan="2">[63], [45], [103], [47], [94], [95], [23], [64], [24]</td></tr>
<tr><td rowspan="3">Other (N=6)</td><td>Arts</td><td>[57], [61]</td></tr>
<tr><td>Design</td><td>[20], [28], [91]</td></tr>
<tr><td>Library & Information Science</td><td>[74]</td></tr>
</table>

Table 5: Categorization of each publication's discipline and what 4 core area it represents. Publications can be in more than one discipline and more than one core area.

	Purpose **N=39**	**Outcomes** **N=28**	**Format** **N=14**	**Processes** **N=9**
Computer Science **N=66**	Raatikainen et al. 2013 [102], Rosell et al. 2014 [105], Munro 2015 [82], Fowler 2015 [29], Frey & Luks 2016 [31] (purpose & format), Nandi & Mandernach 2016 [84], Birbeck et al. 2017 [10] (purpose & format), Byrne 2017 [14], Porter et al. 2017 [100], Gama et al. 2018 [36], Taylor & Clarke 2018 [115], Hope et al. 2019 [47], Porras et al. 2019 [99], Sadovykh et al. 2019 [108] (purpose & format), D'Ignazio et al. 2020 [23], Krüger & Teuteberg 2020 [65], Olesen & Halskov 2020 [90], Falk et al. 2021 [26] (purpose & format), Gama et al. 2021 [37], Lyonnet 2021 [76], Yokoi et al. 2021 [128]	Nolte et al. 2018 [88], Porras et al. 2018 [98], Nolte 2019 [85], Gama 2017 [32], Bonilla et al. 2020 [11], Medina Angarita & Nolte 2020 [78], Mhlongo et al. 2020 [80], Nolte et al. 2020 [86], Steglich et al. 2020 [111] (outcomes & processes), McIntosh & Hardin 2021 [77]	Trainer et al. 2014 [119], Decker et al. 2015 [21], Richard et al. 2015 [103], Anslow et al. 2016 [6], Frey & Luks 2016 [31] (purpose & format), Lara & Lockwood 2016 [68], Birbeck et al. 2017 [10] (purpose & format), Hou & Wang 2017 [48], Karimi et al. 2017 [56], Gama et al. 2018 [35], Gama 2019 [33], Huppenkothen et al. 2018 [49], Kumalakov et al. 2018 [66], Bonilla et al. 2019 [12], Lee & Geller 2019 [69], Sadovykh et al. 2019 [108] (purpose & format) Affia et al. 2020 [1], Gama 2020 [34], Nolte et al. 2020 [87], Valença et al. 2020 [121], Falk et al. 2021 [26] (purpose & format), Happonen et al. 2021 [44], Yuen et al. 2021 [129], Powell et al. 2021 [101], Kovaleva et al. 2022 [64]	Trainer et al. 2016 [120], Filippova et al. 2017 [27], Warner & Guo 2017 [125], Alencar & Gama 2018 [3], Olesen et al. 2018 [91], Pe-Than & Herbsleb 2019 [96], Richterich 2019 [104], Grande et al. 2020 [39], Paganini & Gama 2020 [95], Paganini & Gama 2020 [94], Steglich et al. 2020 [111] (outcomes & processes), Hardin 2021 [45], Hardin 2021 [46], Imam et al. 2021 [50], Steglich et al. 2021 [110]
Education & Learning **N=36**	Munro 2015 [82], Fowler 2016 [29], Nandi & Mandernach 2016 [84], Byrne et al. 2017 [14], Gama et al. 2018 [36], Wang et al. 2018 [123], Porras et al. 2019 [99], bell et al. 2020 [8] (purpose & processes), Krüger & Teuteberg 2020 [65], Gama et al. 2021 [37], Yarmohammadian et al. 2021 [127]	Cobham et al. 2017 [18], Porras et al. 2018 [98], Bonilla et al. 2020[11], Mhlongo et al. 2020 [80], Steglich et al. 2020 [111] (outcomes & processes), Szymanska et al. 2020 [113]	Trainer et al. 2014 [119], Calco & Veek 2015 [15], Anslow et al. 2016 [6], Lara & Lockwood 2016 [68], Karimi et al. 2017 [56], Gama et al. 2018 [35], Huppenkothen et al. 2018 [49], Kumalakov et al. 2018 [66], Wang et al. 2018 [122], Bonilla et al. 2019 [12], Gama 2019 [33], Affia et al. 2020 [1], Nolte et al. 2020 [87], Yuen et al. 2021 [129],	Trainer et al. 2016 [120], Warner & Guo 2017 [125], bell et al. 2020 [8] (purpose & processes), Steglich et al. 2020 [111] (outcomes & processes), Hardin 2021 [45], Hardin 2021 [46], Steglich et al. 2021 [110]
Innovation & Entrepreneurship **N=28**	Rosell et al. 2014 [105], Irani 2015 [51], Söderberg & Delfanti 2015 [114], Angelidis et al. 2016 [5], Frey & Luks 2016 [31] (purpose & format), Porter et al. 2017 [100], Alamari et al. 2019 [2], Poncette et al. 2020 [97], Braune et al. 2021 [13], Yokoi et al. 2021 [128]	Cobham et al. 2017 [18], Nolte et al. 2018 [88], Nolte 2019 [85], Szymanska et al. 2020 [113], Leemet et al. 2021 [70]	Decker et al. 2015 [21], Frey & Luks 2016 [31] (purpose & format), Taylor et al. 2017 [116], Kitsios & Kamariotou 2018 [59], Wang et al. 2018 [122], Kollwitz & Dinter 2019 [61], Suominen et al. 2019 [112], Gama 2020 [34], Valença et al. 2020 [121]	Franco et al. 2021 [30], Lifshitz-Assaf et al. 2021 [72], Rys 2021 [106], Rys 2021[107], Wang 2022 [124], Khan et al. 2021 [58]
Science & Technology Studies **N=20**	Johnson & Robinson 2014 [54], Irani 2015 [51], Söderberg & Delfanti 2015 [114], D'Ignazio et al. 2016 [24] (purpose & format), Lodato & DiSalvo 2016 [73], Thornham & Gómez 2016 [117], Birbeck et al. 2017 [10] (purpose & format), Taylor & Clarke 2018 [115], bell et al. 2020 [8], D'Ignazio et al. 2020 [23], Toros et al. 2022 [118] (purpose & processes)	[None]	Decker et al. 2015 [21], D'Ignazio et al. 2016 [24] (purpose & format), Birbeck et al. 2017 [10] (purpose & format), Karlsen & Løvlie 2017 [57] (format & processes), Taylor et al. 2017 [116], Suominen et al. 2019 [112]	Jones et al. 2015 [55], Karlsen & Løvlie 2017 [57] (format & processes), Pe-Than et al. 2019 [96], Richterich 2019 [104], bell et al. 2020 [8] (purpose & processes), Rys 2021 [106], Endrissat & Islam 2022 [25], Toros et al. 2022 [118] (purpose & processes)
Organizational Studies **N=18**	Porter et al. 2017 [100], Sadovykh et al. 2019 [108] (purpose & format), Lyonnet 2021 [76]	Porras et al. 2018 [98]	Hou & Wang 2017 [48], Sadovykh et al. 2019 [108] (purpose & format), Powell et al. 2021 [101]	Jones et al. 2015 [55], Seravalli & Simeone 2016 [109], Trainer et al. 2016 [120], Filippova et al. 2017 [27], Alencar & Gama 2018 [3], Kopeć et al. 2018 [62], Olesen et al. 2018 [91], Kos 2019 [63], Grande et al. 2020 [39], Rys 2021 [107], Wang et al. 2022 [124], Endrissat & Islam 2022 [25],
Health & Medicine **N=15**	Angelidis et al. 2016 [5], Day et al. 2017 [19] , Wang et al. 2018 [123], Alamari et al. 2019 [2], Li et al. 2020 [71], Poncette et al. 2020 [97], Braune et al. 2021 [13], Cardwell et al. 2021 [17], Mevawala et al. 2021 [79], Yarmohammadian et al. 2021 [127], Toros et al. 2022 [118] (purpose & processes)	Olson et al. 2017 [92], Cardwell et al. 2020 [16]	Wang et a l. 2018 [122]	Lyndon et al. 2018 [75], Toros et al. 2022 [118],
Gender Studies **N=9**	D'Ignazio et al. 2016 [24] (purpose & format), Hope et al. 2019 [47], D'Ignazio et al. 2020 [23]	[None]	D'Ignazio et al. 2016 [24] (purpose & format), Richard et al. 2015 [103], Kovaleva et al. 2022 [64]	Kos 2019 [63], Paganini & Gama 2020 [95], Paganini & Gama 2020 [94], Lifshitz-Assaf et al. 2021 [72]
Other (Art, Design, Library & Information Science) **N=6**	bell et al. 2020 [8] (purpose & processes)	[None]	Karlsen & Løvlie 2017 [57] (format & processes), de Götzen et al. 2020 [20], Longmeier 2021 [74]	Karlsen & Løvlie 2017 [57] (format & processes), Olesen et al. 2018 [91], bell et al. 2020 [8] (purpose & processes), Flus & Hurst 2021 [28]