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PERSPECTIVE

The Future of Hackathon Research and Practice

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ABSTRACT Hackathons are time-bounded collaborative events that have become a global phenomenon and are adopted by researchers and practitioners in a plethora of contexts. Hackathon events generally accelerate the development of scientific results and collaborations, communities, and innovative prototypes that address urgent challenges. As hackathons have been adopted in numerous different contexts, the events have also been adapted in numerous ways that correspond to the unique needs and situations of organizers, participants, and other stakeholders. While these interdisciplinary adaptions, in general, afford numerous advantages—such as tailoring the format to specific needs—they also entail certain challenges: limited exchange of best practices, limited exchange of research findings, and larger overarching questions that require interdisciplinary collaboration are not discovered and remain unanswered. To address these challenges, we call for interdisciplinary collaborations. As an initial initiative toward this, we performed an interdisciplinary collaborative analysis in the context of a workshop at the Lorentz Center, Leiden. In this paper, we report the results of this analysis in terms of six important areas that we envision will contribute to deepening hackathon research and practice: (1) hackathons for different purposes, (2) socio-technical event design, (3) scaling up, (4) making hackathons equitable, (5) studying hackathons, and (6) establishing hackathon goals and determining how to achieve them. We present these areas with respect to the state-of-the-art research proposals and conclude the paper by suggesting the next steps required for advancing hackathon research and practice.

INDEX TERMS Future, hackathon, interdisciplinary collaboration, perspective, state of the art.

I. INTRODUCTION

Time-bounded collaborative events have become a global phenomenon. In this paper, we refer to them as hackathons but also as hack weeks, hack days, data dives, codefests, sprints, etc. They began as niche competitive events in the early 2000s. Most junior developers formed small ad-hoc teams to work on a software project for pizza and occasionally the prospect of a future job. Since then, they have moved into a plethora of contexts, including science [1], industry [2], entrepreneurship [3], government institutions [4], non-profit organizations [5], education [6], civic engagement [7], and libraries [8], involving fields such as design [9], computer science [10], arts [11], health [12], and marketing [13], to mention a few. The largest hackathon database[1] lists over 1000 annual events, with many of them running under the umbrella of Major League Hacking (MLH)[2]—the largest

The associate editor coordinating the review of this manuscript and approving it for publication was Derek Abbott.

[1]https://devpost.com/hackathons
[2]https://mlh.io/

supporter of collegiate hackathons. However, since MLH only focuses on collegiate events, only registers a few of their hackathons on Devpost, and mainly focuses on North America and Europe, it can be expected that the actual number of annual hackathon events across the globe is likely much larger.

Most hackathon events share commonalities—like being collaborative, time-bounded, and motivated by an overarching theme—that participants aim to address. Consequently, the adoption of hackathons in different domains has led to formats evolving in various directions to suit specific needs or foster specific goals [14]. Therefore, apart from the commonalities mentioned above, there are many different approaches to almost any other aspect of the format, including, but not limited to, the duration and size of events, how participants are recruited, how their collaboration is structured, what kind of support they receive, which tools and materials they work with and have access to, how these tools and materials are introduced to them, and so on.

We observe a similar variety and specialization in the scientific literature that covers hackathons. Research that focuses on these events has developed in various disciplines and domains, including computer science [10], high-performance computing [15], astrophysics [16], and others. However, research on such events has also been initiated somewhat late. The term ''hackathon'' first emerged in the early 2000s, while research on these events — taking the ACM Digital Library as a case in point — only started to become more prevalent five to ten years later [17]. This is also observed in our quantitative analysis in 1, which investigated the term ''hackathon'' more broadly in academic publishing venues.

While we acknowledge the advantages of interdisciplinarity when organizing and studying hackathon events, we observe that research around hackathons is *siloed*. This observation originally stemmed from our experience in reviewing hackathon research. However, we quantitatively confirm this aspect for this paper using bibliometric tools (section III).

Advancing theory and practice for interdisciplinary researchers who study the hackathon phenomenon is challenging if awareness of relevant and prior theories is lacking because of siloed research. This can create problems that ''diminish the effectiveness of the research products'' [18] if an appropriate alignment between the research question, prior work, research design, and contribution to literature is missing [18].

Similarly, hackathon organizers we collaborate with and are affiliated with report that hackathon practice is often siloed as well. This reflects our own experience as organizers often seek inspiration from existing guidelines such as the MLH Hackathon organizer guide[3] and other organizers. Still, they typically seek advice about events in the same domain and with a similar focus. Organizers of corporate hackathons that focus on software innovation would, for example, likely seek information about similar hackathons they are aware of. This considerably limits the exchange of best practices, which poses significant risks, such as repeating poor or, in worst cases, even harmful practices, thereby leading to sub-optimal experiences and outcomes not only for researchers but also for participants, organizers, and connected stakeholders, such as sponsors, challenge or design case providers, mentors, and volunteers. These poor practices include repeating and amplifying not only superficial but also technosolutionist approaches to complex social and societal issues [14] or inadvertently contributing to bad experiences or limited access for minority populations who wish to participate in hackathons [19].

We argue that *siloing* and the resulting poor methodological fit of hackathon research and practice inhibits progress in both areas. We further argue that this siloing results in the following challenges:

1) **Limited exchange of best practices**, which leads to organizers having to rediscover the same things, repeating mistakes, and the overall format drifting into different directions without critical reflection.
2) **Limited exchange of research findings** leads to repeating studies that discover the same or similar things, thereby stagnating research progress.
3) **Significant research and practice challenges** that require interdisciplinary collaboration are not discovered and **remain unaddressed**.

To address these three challenges, we organized a workshop at the Lorentz Center.[4] We brought together hackathon researchers and practitioners from various disciplines, including software engineering, high-performance computing, information systems, astronomy, geology, physics, and organizational sciences. During the five-day workshop, the participants engaged in in-depth open discussion formats similar to interdisciplinary discussion formats, such as the World Cafe [20], regarding event organization and under-researched areas. The workshop participants collected issues and shared resources, then prioritized these topics based on research potential and interdisciplinary collaboration. They continued collaborating online after the workshop to refine these areas and research directions. This paper presents the result of the multidisciplinary analysis of these discussions on hackathon research and practice.

In the following account, we first outline existing studies that have attempted to review and structure previous work on hackathon research and practice (section II). We use these as a point of departure for continuing the improvement of understanding hackathons and as motivation for our focus on an interdisciplinary perspective on unified problem formulations, sharing of methods, and creating new research questions [21], [22]. In section II-A, we subsequently define hackathons; in section II-B, we outline several disciplines that the context of hackathons is related to. Second, to support our observation that hackathon research is indeed siloed,

[3]https://guide.mlh.io/

[4]https://bit.ly/3gtv4Gl

we present results from a network analysis on the distribution of hackathon research in section III. Third, since research on hackathons is closely connected to the practical sphere of hackathon organizations, we discuss the logistics and facilitation related to hackathons based on our experience of hackathon practice in section IV. This section is particularly suited to readers who wish to organize hackathons. Fourth, we outline the methodological approach that we followed (section V) to arrive at the six areas that we envision as directions for future hackathon research and practice; we discuss this in greater detail in section VI:

(1) Hackathons for different purposes (2) Socio-technical event design (3) Scaling up (4) Making hackathons equitable (5) Studying hackathons (6) Hackathon goals and how to achieve them

This paper makes the following three key contributions:

First, we define hackathon formats that are sufficiently flexible to embrace numerous variations of hackathons while describing characteristics that differentiate hackathons from similar events. Second, we help practitioners identify areas in hackathon organizations to explore and further develop the format and improve participation in diversity and inclusion, mentoring, and support for participants. Third, we provide directions for future research on hackathons.

II. BACKGROUND

A few publications have synthesized insights on hackathon research and practice, including literature reviews and case studies:

Overviews of hackathon practice include Rys' [23] evaluation of 14 hackathons as an invention development method compared to brainstorming, in which they explore how hackathons may mitigate a few of the drawbacks of brainstorming. Pe-Than et al. [24] review 10 hackathons and research literature to discuss the design choices that hackathon organizers should consider. Nolte et al. [25] extend this work and develop an online kit to support the organizing of hackathons.

These papers are notable contributions to developing an ontology of hackathons and uncovering best practices for organizing hackathons. While they are important for understanding hackathons and how they can be organized in different contexts, the studies have generally been conducted *as part of* various disciplines.

Literature reviews include the one by Flus and Horst [26], who focus on characterizing the design activity in hackathons and discussing future design research on hackathons. In their review, Falk Olesen and Halskov [17] use the Association for Computing Machinery Digital Library to study the relationship between research and hackathons and provide an overview of challenges and opportunities. In addition, Kollwitz and Dinter systematically review 189 research publications with a focus on the information system research domain at "the crossroads of digital innovation and OI (open innovation)" [27] and, on this basis, develop a taxonomy of hackathon dimensions.

Moreover, Chau and Gerber conducted a multidisciplinary literature review of 111 publications across 10 diverse disciplines [28]. While their main intended audience is focused on the human–computer interaction community and what this community can learn from other disciplines that research hackathons, they contribute with a much-needed multidisciplinary perspective on hackathon research. They offer an in-depth overview of the development of hackathon research in multiple disciplines. In addition, related to our paper, they discuss a set of recommendations and future directions for hackathon research, including the adoption of human–computer interaction (HCI) research employing intersectional approaches to hackathon outcomes and a call for longitudinal studies on hackathons; the consideration of the relationship between participants' geographical situations and the hackathon's purposes and processes; shifting the focus of project continuation beyond corporate settings into universities, non-profits, and other community settings; and framing contributions as not only originating from the organizer's perspective but also from the participant's perspective, as also discussed in [14].

While we share a multidisciplinary perspective on hackathon research, our contribution both differs from and triangulates with Chau and Gerber's method and findings in different ways: By drawing on our extensive and practical experience with and research knowledge on hackathons, we do not frame our findings for a single discipline. Furthermore, we highlight future directions for both hackathon researchers and practitioners. Where a literature review often relies on a few authors summarizing existing studies, we conducted in-depth and interactive discussions. We analyzed our findings collaboratively, contributing diverse perspectives, methodologies, and insights from a multidisciplinary group of experienced practitioners and researchers. To address the challenges described in the introduction—that is, limited exchange of best practices, limited exchange of research findings, and unaddressed research and practice challenges—we need to foster interdisciplinary collaborations to deepen not only hackathon theory but also practice in general. Current related research, which synthesizes insights on hackathon research and practice, has mainly been conducted within disciplines and does not identify and address the overarching challenges of hackathon research and practice across disciplines.

Our aim with this paper is somewhat similar to the aims of researchers and practitioners developing "maturity models," such as the capability maturity model (CMM) [29]. However, our proposed approach toward reaching maturity in the research and practice of hackathons is different. Maturity models assume that "predictable patterns exist" [30], which can be conceptualized in distinctive stages and progressed in a step-by-step manner [31]. Furthermore, the models may provide criteria "that need to be fulfilled to reach a particular maturity level" [31]. While we address one distinct phenomenon—hackathon events—these formats exist in multiple contexts and forms. Rather than describing distinctive stages and success criteria, our initial analysis and envisioning of different interdisciplinary areas, including state-of-the-art and research proposals, offer flexible and multiple paths for inspiring future interdisciplinary hackathon research and practice, which can be applied to numerous contexts of hackathons.

Identifying and addressing challenges of hackathon research and practice across disciplines is essential to sharing best practices and mature theory on hackathons—for example, research methods—and our paper is a call to action in this direction. In summary, we offer an interdisciplinary perspective on hackathon research and practice and outline possible paths for formulating unified problems across disciplines, sharing methods, and developing new research questions [21], [22].

A. DEFINING HACKATHONS

First, we need a definition of hackathons to place them in an interdisciplinary context. As we established earlier in this paper and explained in more depth in the next section, hackathons are conducted in numerous contexts and fields with different purposes. This suggests that identifying a unified, interdisciplinary definition may be a complex problem. We initially attempted this definition at the workshop and refined it among the authors afterwards. What we present below represents our collective understanding of what constitutes a hackathon.

We aim to propose a framework that is inclusive rather than exclusive. Many existing works define hackathons too narrowly, excluding how and why some hackathons are organized and run today. As a case in point, Komssi et al. define hackathons as "an intense, uninterrupted period of programming " [32]. Another highly cited paper on hackathons by Nandi and Mandernach similarly defines hackathons based on their origin in software development environments [33]. These definitions reflect a time where hackathons were mostly organized for technical innovation, however, today, hackathons are organized in much broader contexts, and a definition should reflect and embrace that development. A previous attempt in this direction is the definition proposed by Pe-Than et al. [24], who define hackathons as "time-bounded events [...] during which people gather together and form teams, each of which attempts to complete a project of interest to them" without specifying the nature of the project. Their definition, however, lacks other important characteristics of hackathons, such as organizer and participant incentives. Our goal thus was to provide a definition that should include any event that can conceivably be perceived as a hackathon. Simultaneously, it should not be so broad that it could include any event where people come together, such as concerts, conventions, workshops, or similar events. The traits we describe in the definition below are common traits for many, if not most, relevant hackathon events but might differ for specific hackathons designed for a specific purpose.

We **define hackathons** as time-bounded participant-driven events that are organized to foster specific goals or objectives. A team of organizers plans the scaffolding of a hackathon event to support its goals or objectives. People who participate in an event often (but not necessarily) have different backgrounds and bring different expertise. Their primary motivation to join an event is to work on a shared team project that interests them, although there might be additional incentives, such as prizes and networking opportunities. During the event, teams attempt to create an artifact (e.g. software or hardware prototypes, slides, videos, and documents) that can be shared with other participants. It is also acceptable, and occasionally even desirable, if they do not manage to create anything. Participants are often encouraged to be bold and work on things beyond their area of expertise.

In the next subsection, we outline a few fields of study related to hackathon research and practice.

B. HACKATHONS IN CONTEXT

At their core, hackathons are collaborative events. Collaboration in these events mainly takes place in small teams that work independently [34]. Much work in different domains — including psychology, education, organizational sciences, volunteer engagement, and entrepreneurship — focuses on how (small) teams communicate and collaborate. This work is deeply relevant to the study of hackathons, as we expect teams to face similar communication, organization, leadership, and equity challenges. However, two major defining factors in hackathons are their time-bounded nature and the feature that team members might meet each other at the event for the first time. Consequently, teams have to establish how they collaborate in a short period of time—which is related to what Edmondson termed "teaming" [35]—as this has been described as a key characteristic of hackathon participation [36].

Collaboration in teams during a hackathon revolves around a project selected by the teams themselves [37]. These projects often focus on creating a (technical) artifact, such as a website, mobile application, robot, or software. Our understanding of how teams engage with this task can be informed by work related to project management, agile software engineering, design, and others. The differences between such work and hackathons relate, for example, to how teams approach their projects. In hackathons, team members often select tasks within their projects that they are interested in rather than tasks that correspond to their individual skill sets [38]—often they might even choose a task they have no prior knowledge in, as they use the hackathon as a learning opportunity. Teams also often approach projects without any or limited prior planning and engage in a form of rapid prototyping.

While teams mainly work independently and are self-directed, their collaboration still occurs in the context of a specific event. Consequently, the planning of the overall

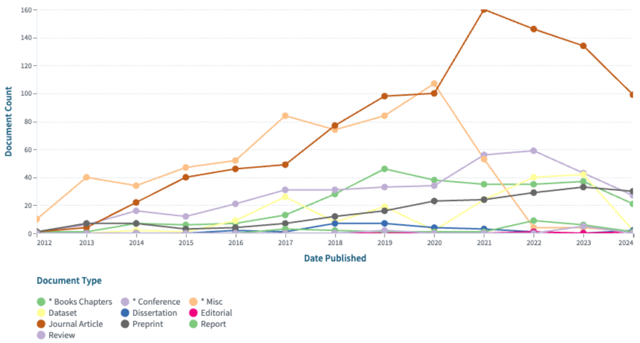

FIGURE 1. **Publications over time from 2012 to 2024. The figure shows a continuing rise in journal articles and conference proceedings on hackathons. We used groupings that combine categories of other publications, e.g., unknowns, reports, etc., and conference proceedings, books, and chapters.**

event influences teams, particularly in the context of team formation and project ideation [39]. Organizers often deploy facilitation means to keep teams on track [7]. Related works on other collaborative settings—such as game jams, workshops, classrooms, and teamwork—may support our understanding of how teams engage in such environments. A key difference between hackathons and other events is that hackathons have a much looser scaffolding on which fewer rules are enforced.

III. DISTRIBUTION OF RESEARCH ON HACKATHONS

We analyzed research outputs around hackathons to obtain an overview of which research disciplines are involved and how authors collaborate to illustrate the siloed effect we discussed in the introduction. For this purpose, we used bibliometric tools, which are employed to analyze the impact of a research area [40]. We used the Lens Scholarly Analysis tool [41], which utilizes global public resources like PubMed, MAG, and Crossref for science and innovation assessment. Using the search: (title:(Hackathon*) OR abstract:(Hackathon*) OR keyword:(Hackathon*) OR field-of-study:(Hackathon*)) yielded 2682 scholarly works and 873 scholarly works cited by other literary works.[5] While this provides a good overall trend of the rise of hackathon numbers, it does not measure, for example, papers studying adjacent collaborative events. It may misrepresent certain papers that examine hackathons referred to by different names, such as "codefest". However, experimenting with different search strings did not change the result of the initial search query much. For example, the search string:(title:(hackathon) OR abstract:(hackathon) OR keyword:(hackathon) OR field_of_study:(hackathon)) OR (title:(codefest) OR abstract:(codefest) OR keyword:(codefest) OR field_of_study:(codefest)) OR (title:(hackweek) OR abstract:(hackweek) OR keyword:(hackweek) OR field_of_study:(hackweek)) OR (title:(hackday) OR abstract:(hackday) OR keyword:(hackday) OR field_of_study:(hackday)) resulted in 2630 papers, compared to 2682 for using only "hackathon" as a search query.

[5]We performed the search on June 4, 2024. The full current dataset is available here: https://link.lens.org/Cqcv3yIs8Yk, which when accessed will reflect new additions, visualizations, and the scholarly works

FIGURE 2. **Word-cloud of fields of study.**

Our findings indicate that interest in hackathons has steadily risen over the last 11 years. In particular, Fig. 1 reveals a continuing rise in journal articles and conference proceedings on hackathons.

Additionally, the figure shows that non-peer-reviewed articles on hackathons began to spring up a few years before journal articles and conference proceedings and were the most common form of publication on hackathons until 2020. Since then, non-peer-reviewed forms have begun to decline while other forms of publication continue to grow, thereby indicating that the field is maturing.

To reveal the diversity of fields that organize and study hackathons, we constructed a word cloud (Fig. 2) based on a service provided by Microsoft Academic through the Lens Scholarly Analysis tool (retrieved June 4, 2024) that uses machine learning to parse all accessible text in the record (title, abstract, and keywords). It illustrates that computer science is mentioned most frequently (1245 articles), followed by political science (463), and engineering in the third place (411). We also analyzed the citation metrics for the papers in our corpus and found that the most highly cited paper is in computer science (215 citations). The second and third most cited papers are a paper on informal learning (158 citations) and a paper focusing on collocation and collaboration (113 citations). The next field of study is political science, and the most cited paper is related to open innovation in the face of COVID-19 (79 citations) and the mainstreaming of hackathons (62) citations). Further, the most cited paper in engineering is on what hackathons are for (144 citations).

Finally, we also conducted a co-authorship analysis. For this, we used VOSview [42] with a RIS export from Lens Scholarly Analysis with a minimum number of documents of an author set to two, with fractional counting (weighted), which set a threshold from the 6790 authors to 1420 that meet the threshold. We grouped these 211 co-authors into clusters, as depicted in Fig. 3. The figure illustrates that the research in this area is isolated into separate clusters. Although some connections exist between these clusters, the clustering is more prominent than the inter-cluster connections. The links between clusters are usually linear and not centralized. Researchers collaborate individually, which results in links between the clusters.

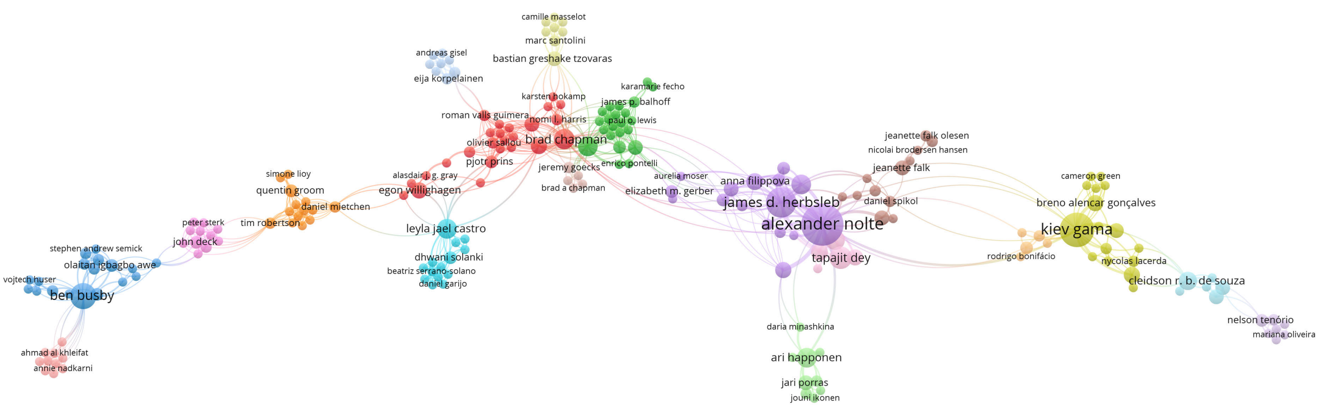

FIGURE 3. **Author map of contributors to hackathon research as defined in the text. This reveals that this research area is siloed, as the clusters are poorly connected.**

IV. HACKATHON ORGANIZATION

As described in the previous section, hackathons began as collaborative, hands-on events, and researchers took a while to take an interest in them. Therefore, our paper's foundation is informed not only by the emerging research on hackathons but also, to a great extent, by the practice of hackathon organization and participation. This section establishes the foundations that we are starting from by summarizing the key aspects of logistics and facilitation of organizing hackathons. Most of these aspects are experience-based and anecdotal rather than based on studies. The next section touches on some of this, indicates where formal studies might be beneficial, and provides insights that can improve the organizing of hackathons.

A key element of hackathons is getting people out of their "day jobs," so the event format must differ from what participants use in their day-to-day work. This is often achieved by creating a relatively informal atmosphere, allowing spontaneity and bringing in unexpected ideas. Thus, the organizers and participants need to be prepared to constantly adjust their plans to what is happening at the event. The community-developed online resource called the "Hackathon Planning Kit[6]" [25] is useful to get started with organizing a hackathon and to ensure that no important aspect is forgotten.

Further, hackathons are inherently experimental. The participants are allowed and encouraged to experiment and fail rather than following a set step-by-step tutorial to complete a given task. Thus, hackathon organizers should allow themselves to experiment and try new things.

A. LOGISTICS OF HACKATHON SETTINGS

Due to the agile nature of hackathons, flexible spaces are required that can be adjusted to the needs of participants. For in-person events, adjustable rooms, movable tables and chairs, a large number of boards and screens, a sufficient number of power plugs and extension cables, Wi-Fi, and plenty of space are required, depending on the number of participants. An example of flexible spaces is the University of Washington Active Learning Classroom,[7] while setups like traditional lecture theatres should be avoided. For online hackathons, the flexibility needs to be reflected in the range of tools used—for example, Zoom for plenary events, Zoom breakout rooms for hackathon work, and a persistent chat tool with configurable channels—such as Slack or Discord—for asynchronous communication. In addition, a central notice board or shared documents with links and all necessary information that tells participants where they have to be, where things are, who is in which group, etc., can be helpful and avoid people getting lost in the multitudes of material and spaces. Furthermore, breaks should be centrally scheduled to keep teams together and ensure participants do not forget to look after themselves, and food should be provided in-house at in-person events. This is also an opportunity to provide networking opportunities. Participants can also be brought together for tutorials or talks, in which methods and technologies relevant to the hackathon are taught or insight into an overarching theme is provided.

Hackathons are often evaluated in-depth to ensure that, despite or because of all the flexibility, the organizers do not get carried away and lose touch with the participants. For example, in addition to post-event surveys, a few hackathons have physical or virtual feedback walls during the entire event. While it is not possible to use this evaluation to do "everything right next time," it is an important tool for reflecting on what worked and what did not and to make more informed decisions for future events.

B. FACILITATION OF HACKATHON PARTICIPATION

Generally, hackathons are spontaneous and do not have too much of a strict schedule; therefore, they also require increased flexibility from organizers and the ability to

[6]https://hackathon-planning-kit.org/

[7]See an example online here https://www.washington.edu/classroom/OUG+136

adjust and adapt quickly. However, designing facilitation plans for use throughout the event reduces the mental load on organizers during the hackathon. This is not to say that there is necessarily only a low, upfront effort before the event: organizers who, for example, emphasize inclusivity in their hackathons may also spend considerable time and energy planning appropriate physical and digital spaces and processes. For example, considering the latter, certain hackathons implement active participant selection processes to create a diverse cohort in terms of background and experience; this requires designing and implementing selection processes. One online resource that may assist hackathon organizers in participant selection processes is *entrofy* [43], specifically developed to help select a diverse cohort from a set of candidates.

While the difference between a hackathon's format and participants' ''day job'' can help them engage in the event, this difference also makes increased facilitation necessary. In general, the amount of advanced planning and organization required from participants varies depending on the purpose of the hackathon, the communities that participate in it, and the amount of knowledge or field-specific language participants share. For example, a hackathon designed around a single purpose with one stakeholder providing the problem description and data may require less upfront effort from participants than a more open-ended design in which participants can pitch their projects. However, such single-stakeholder approaches may also limit the participants' creativity and may, therefore, reduce the value of these approaches to certain participants whose interests may differ from the stakeholders'.

Designing a short time-bounded project with a measurable outcome, forming a team, and implementing teamwork structures on the extremely compressed timeline of a hackathon are often not aspects that all participants have much experience with. Before the event, facilitation typically includes guidance for the participants' preparation for the event: preparing project pitches, acquiring and cleaning any relevant data sets, and identifying crucial project tasks and team member roles. Similarly, significant effort is spent on forming and facilitating project teams throughout the event. In particular, this includes mechanisms for team formation, for participants to change teams, and for that change to occur gracefully. For numerous hackathons, where networking and learning are core goals, framing team formation and teamwork is crucial to creating a positive learning environment. In particular, in larger groups, it is easy for participants to get ''lost.'' In response, organizers are often present in the space, listening to teams and helping where needed, along with scheduled check-in procedures.

V. METHOD

To address the challenges outlined in the introduction, we brought together hackathon researchers and practitioners in the context of a workshop at the Lorentz Center, Leiden, The Netherlands. We chose the Lorentz Center as a venue because it supports collaboration beyond disciplinary boundaries by ''providing a platform and infrastructure to discuss scientific developments, ideas and plans in an open and interactive atmosphere'' [44]. The workshop was attended by 33 participants (18 female, 15 male) from 13 countries across 3 continents. Five of the 23 practitioners who attended the workshop came from different for-profit organizations, 2 came from organizations focusing on civic engagement, and 16 came from research institutions and universities. The participants brought expertise from various domains, including astronomy, geology, oceanography, biology, biophysics, psychology, creativity, library science, education and workforce development, citizen science and civic engagement, software engineering, data science, IT security, high-performance computing, and human-computer interaction and collaboration. They have experience organizing a variety of events, including innovation—and technology-focused events, as well as events that focus on recruitment, education, engagement, and networking.

The participating researchers and practitioners facilitated several in-depth open discussions during the five-day workshop, inspired by interdisciplinary discussion methods, such as the World Cafe [20]. First, we, the workshop participants, engaged in brainstorming sessions and collated different issues faced when organizing events and areas of research identified as being under-researched. These discussions included sharing different resources, such as best practices and related research publications from different disciplines. Next, we engaged in ''World Cafe'' discussions to further explore and refine the above-mentioned issues related to organizing and under-researched research areas and develop a common understanding of each issue and research area. Subsequently, these issues and areas were clustered into larger groups (the six described areas in section VI). They were prioritized based on the following criteria: potential for future research, fruitfulness for interdisciplinary collaboration, and improvement in organizing events. For each area, we discussed the current state of the art and identified open questions and potential research directions. After the workshop, we frequently communicated via online meetings and emails to continue collaborating on refining these areas, their respective state-of-the-art, open questions, and research directions.

In the following sections, we discuss what we collaboratively identified as the six most important areas of hackathon research and practice. The six areas are enumerated below: (1) Hackathons for different purposes (2) Socio-technical event design (3) Scaling up (4) Making hackathons equitable (5) Studying hackathons (6) Hackathon goals and how to achieve them. While the six areas listed above represent a synthesis of our discussions at the workshop, they are not exhaustive. Instead, we perceive these areas as an invitation to begin tackling the issues we have observed in hackathon research and practice—that is, limited exchange of best practices, limited exchange of research findings, and unaddressed large interdisciplinary challenges. We also acknowledge that they are not independent but rather intertwined. When — for example — discussing about hackathon goals and how they can be achieved (section VI-F) one could reasonably consider the context in which a hackathon takes place (section VI-A) and how to study events (section VI-E) as well.

VI. ENVISIONING THE FUTURE OF HACKATHON RESEARCH AND PRACTICE

In this section, we discuss the six areas we identified as important for future hackathon research and practice. For each area, we discuss the current state of the art and propose directions for future research.

A. HACKATHONS FOR DIFFERENT PURPOSES

A good starting point for framing hackathons for different purposes is Briscoe and Mulligan's [4] definition that loosely groups hackathons as tech-centric or focus-centric. Tech-centric hackathon events focus on developing software and hardware using a specific technology (e.g., a hackathon that aims to promote the usage of an existing API and develop a new one).

Focus-centric hackathons involve creating prototypes to address a specific social issue or business objective—for example, improving city transit systems. Briscoe and Mulligan's classification may be further expanded into including three categories of hackathons: corporate, educational, and civic hackathons [45]. In addition to these categories, we may also consider research-focused hackathons—see, for example, [17]. In the next subsection, we will use this categorization as a starting point for discussing the state of the art.

1) STATE OF THE ART

Corporate hackathons aim at broadening innovation, with participants typically motivated by learning and networking. Information technology (IT) companies of all sizes have commonly organized hackathons, integrating these events into their research and development activities. These hackathons aim to generate new ideas, early prototypes, and even business plans and can be internal or external to the organization [49], [52]. **Internal hackathons** are designed to stimulate creative thinking for the organization and generate new ideas. **External hackathons** are open to participants outside the organization and are motivated by the open-innovation paradigm by introducing new resources in crafting unique solutions. Internal and external hackathons can alternate between a tech-centric or focus-centric approach or combine the two. These mixed events represent a strategy to support ecosystem evolution by offering a software platform and hardware for third parties to develop new products or services and encouraging outsiders to become network complementors. Additionally, hackathons are a means to attract and build a community of experts [46], which help to foster a broader innovation ecosystem.

Educational hackathons are performed in association with teaching and learning activities, either as an initiative of a teacher or as cooperation between academia and industry, which is sponsoring the event [33], [47], [53]. These hackathons are often tech-centric and can bring focus-centric approaches as well. For example, in IT or design courses, the hackathons become a contest for graduating students to address real-life issues in an engaging scenario that enables them to collaborate and enhance their abilities intensively [47].

Civic hackathons address public and societal issues organized by the public sector or non-governmental organizations. These hackathons focus on more socially oriented innovation [4], [51]. These events are typically focus-centric hackathons. However, government institutions have also been using such events to generate value from open data and APIs (a more tech-centric perspective), which different players explore (e.g., citizens, different types of companies, universities, etc.). These contests generally leverage the idea of the government as a platform [50].

Research-focused hackathons are hackathons used as a kind of research method. In line with academia embracing research on hackathons (see section *Studying hackathons* below), researchers have also organized hackathons for various research purposes (see e.g., [17], [37], [48], [54]). To mention a few examples, these purposes could be for producing and studying specific hackathon outcomes, increasing collaboration among stakeholders, and evaluating prototypes [17]. It is common for numerous publications to use hackathons as research methods to emphasize how hackathons enhance and accelerate scientific collaboration—see, for example, [48].

2) RESEARCH PROPOSAL

While hackathons are evolving events, classifications can play a valuable role in analyzing these events. However, understanding the different motivations and the "why" for event organizers and participants remains an open question, as current evaluations and research are primarily tied to the specific type of events and their specific goals. Only a few studies combine the different aims and types [4], [26] and do so primarily from a design perspective. Generally, organizers from the different categories of hackathons highlighted above often mention *collaboration* as the main benefit of hackathons. Exploring this aspect from a macro perspective across different hackathons and focusing on motivations, expectations, and stakeholders can aid in better understanding and organizing of hackathon events. Furthermore, it will likely provide insights into how collaboration unfolds across research, industry, and education.

B. SOCIO-TECHNICAL EVENT DESIGN

Technology is a key component of hackathons, which are often tech-focused as they revolve around *creating* technology [4]. In this section, we will not focus on the technologies that participants develop during an event, e.g., as part of their projects. Instead, we focus on the technologies that organizers, mentors, participants, and other

TABLE 1. This is an overview of the six areas involved in envisioning future hackathon research and practice and is the result of the collaborative analysis effort during and after the interdisciplinary workshop. The table lists the six areas, a description, and references to related literature for each area.

Area	Summary	References
Hackathons for different purposes	Hackathons are evolving events and understanding motivations, expectations, and collaborations across different types and goals can lead to better event organization and insights across research areas, industry, and education.	[4], [17], [26], [33], [37], [45]–[54]
Socio-technical event design	In response to the current trend toward online and hybrid hackathons, we suggest exploring the effect of organizers prescribing technology for participants, identifying suitable communication technologies, aligning them with the organizational structure of the event they are organizing, and improving technology support for organizers.	[4], [7], [17], [25], [34], [55]–[64]
Scaling up	The lack of rigorous research on scaling up in terms of time and participants, offline and online, calls for a significant effort to examine tradeoffs, including investigating the impact of hackathon durations on participants' perception of pace and exploring the benefits and challenges of small-scale hackathons with two-person teams and shorter schedules.	[1], [27], [57], [62], [65]–[72]
Making hackathons equitable	The current research on equity in hackathons lacks exploration in various axes of diversity—such as ethnicity, culture, socioeconomic background, gender, sexuality, and neurodiversity. Further investigation into participants' contributions to methodological democracy and tailored facilitation of participation in hackathons is required. The shift to virtual and hybrid hackathons due to the COVID-19 pandemic poses opportunities and challenges for equitable participation, prompting questions regarding the role of anonymity in virtual hackathons and the potential collaboration with sociology and psychology fields for insights on equitable participant selection and team dynamics.	[14], [19], [24], [51], [52], [70], [72]–[82]
Studying hackathons	We propose the following paths for future research and practice: (1) Utilizing a mix of quantitative and qualitative data for developing mature theories in the study of hackathons. (2) Topics for future studies on hackathons include supporting participants' creativity, the role of temporality, and the perspective of organizers. (3) Sharing data using the Findability, Accessibility, Interoperability, and Reusability (FAIR) Data Principles and developing shared survey instruments to ensure meaningful comparisons across studies. (4) Organizers can use a formative research methodology to improve their hackathon practices, considering effectiveness, efficiency, and appeal as evaluation dimensions.	[14], [17], [18], [60], [61], [83]–[91]
Hackathon goals and how to achieve them	Future research should expand studies beyond the immediate outputs of hackathons and consider short, mid-term, and long-term impacts while developing instruments to assess actual impact rather than relying solely on individuals' perceptions. Attention should be paid to studying the goals of individuals involved in preparing and running hackathons, including goal alignment and considering goals beyond those of organizers and participants. There is a lack of studies that consider hackathons in their larger context, as events are often studied as one-off occurrences with limited connections to other activities of communities or corporations. Advancing the format and unlocking its full potential necessitates considering hackathons in their broader context during their study and organization.	[1], [3], [7], [14], [34], [37]–[39], [45], [47], [51], [52], [60], [61], [66], [83], [92]–[97]

stakeholders utilize to communicate and collaborate in the social context of a hackathon. We thus perceive hackathons as socio-technical systems [98] which are co-designed by the aforementioned groups in that organizers and participants have to decide which technologies to use for which purpose(s) during a hackathon [25]. The importance of technology is exacerbated by the growing popularity of online and hybrid formats; technology forms the foundation of organizing such formats, and participation and interactions might be facilitated entirely through technological means for virtual participants [62]. Online and hybrid events require reliable platforms for simultaneous and asynchronous interaction, such as video calls and text-based chat features, virtual versions of whiteboards and note-taking facilities, and virtual spaces designed for unstructured interactions, such as coffee breaks and networking events.

Technology often plays a vital role in in-person events as well—for example, it is used to publicize events, support registration, foster the development and sharing of ideas ahead of and during the hackathon, support team formation, serve as a means to communicate and/or collaborate on artifacts, and submit projects. Various platforms—such as Devpost,[8] Hackbox,[9] and Eventornado[10]—offer a few of these functionalities. While different event formats and sizes afford the use of different technologies, it is evident that choices need to be aligned with the organizational structure of an event.

In particular, online hackathons have witnessed a steep rise during the global COVID-19 pandemic [55], [58]. Although they require a more rigid organizational structure and pose unique challenges e.g. related to organizers retaining an overview of how their event is going and managing a multitude of different technologies [62], they also provide new opportunities such as limiting the carbon footprint of travel [56] and provide the possibility of participating online for individuals who cannot travel due to visa, funding, or other issues. Thus, even as in-person events become more prevalent again, online events or online components of in-person events will remain, and with them, the requirement for reliable and accessible technological solutions that facilitate hackathon organization and participation will also remain.

1) STATE OF THE ART

A large variety of technologies have been proposed to prepare for and run hackathons like the ones mentioned earlier. Organizers often utilize a variety of technologies for different purposes. There are tools that are commonly used to facilitate live (Zoom, Teams, etc.) [57] and asynchronous interaction

[8] https://devpost.com/
[9] https://formidable.com/work/hackbox/
[10] https://eventornado.com/

(Slack, Discord, etc.) [58], [59] as well as sharing artifacts (Github, GDrive, etc.) [60], [61]. In addition, organizers often utilize websites to share the agenda or structure of an event. Most of our current knowledge regarding the use of technology in hackathons stems from studying in-person events [7], [17], [34]. This work has established thus far that the technologies used and how they are used can affect participants' experience during an event, particularly in an online context. However, there can also be a difference between the technologies that organizers propose and the technologies that participants ultimately utilize. This discrepancy is driven by participants' preferences and the strength of those preferences (i.e., technologies that a participant "likes" vs. a technology that other participants "do not mind" using). Even when the same technology is used, teams differ in the extent and purposes for which they utilize a specific technology [62]. The extent to which participants can choose technology can also vary between events. Organizers that run hackathons within a specific context (e.g. corporate hackathons) might require participants to utilize specialized infrastructure.

Studies on the use of technology in hackathons are often limited to post-event reports of individuals that collaborated during a single or few events [58], [62]. Large-scale studies of how teams utilize technology to communicate and collaborate using, for example, trace data from communication tools are missing (one notable exception is [63]). Thus, it is unclear whether the reported findings can be expected to hold across different events and event designs. However, studies on online events remain rare [58], [62], [64], and reports on hybrid hackathons are largely non-existent at this point.

2) RESEARCH PROPOSAL

From the current trend regarding online and hybrid hackathons and the current state of research in this area, we propose a number of open questions that future research should address. In particular, it is important to know the extent to which hackathon organizers can and should prescribe the technology that participants utilize during an event. Participants may be able to spot accessibility issues with platforms that organizers do not, but increased flexibility may also lead to additional confusion and fatigue in virtual participation. Second, it is currently unclear which technologies are particularly suited for the affordances of the hackathon format. Most technological tools are designed for commercial applications with a narrower focus than the wide variety of modes and purposes of communication that commonly occur at hackathons, and there may be no single solution that can provide all the necessary functionality. Finally, it is an open question how technology can better support organizers of online and hybrid events. Identifying and addressing these technological issues is difficult, and implementing technological solutions on such platforms can add significant overhead to organizations.

C. SCALING UP

Given the time, effort, and costs involved in hackathon preparations, some organizers might aim to maximize the impact by scaling it up in time (longer events) and/or size (more participants). The common hackathon format is often short, usually 24 or 48 hours, and the number of participants for most events varies between 20 and 100. According to Kollwitz and Dinter [27], a short hackathon is defined as one that lasts less than 24 hours, medium as one that lasts between 24 hours and 72 hours, and long as one that last over 72 hours. The hackathon portal Devpost lists that out of 6149 hackathons on that page, 72 had over 1000 participants, 197 had between 500 and 1000, 1787 between 100 and 500, 1290 between 50 and 500, and 2803 had less than 50 participants.

Examining the time dimension reveals that there can be additional reasons for having longer hackathons. For example, long-term goals or larger projects require more time to be achieved and, thus, lend themselves to hack weeks or similar events; for more complex or ill-defined projects, time for scoping and requirements analysis needs to be factored in. Other hackathon projects might require asynchronous upfront work or work between hackathon days, lending themselves to short but repeating events on the same topic. Certain hackathons bring together communities with somewhat different customs, language, and background knowledge, where significant time must be devoted during the hackathon to create common ground. The team formation process in hackathons adds significant overhead in terms of building a shared language among the participants and organizing the team structure. From an equity and inclusion perspective, organising a hackathon over multiple working days rather than a continuous 24- or 48-hour event can be beneficial, as participation outside of business hours and long, sustained participation can be tricky for certain people—for example, for those with caring responsibilities. In certain contexts, such as in hackathons that address social innovation, a wider time span may be required; this is because methodologies adapted from social sciences require more time to provide a better understanding of social contexts [65]. In other contexts — such as corporate events — scaling up might not be feasible because of organizational constraints.

1) STATE OF THE ART

When a hackathon is scaled up in the size dimension, more people usually implies a larger number of teams rather than bigger ones. This can lead to less collaboration and exchange between teams if the organizers do not put explicit effort into facilitating this exchange. The overall facilitation of the event becomes more difficult and time-consuming for organizers. However, certain communities have successfully experimented with distributed events over several time zones and hackathons comprising regional pods embedded in a global organization [66]. In particular, for virtual hackathons, this might provide a fruitful avenue for addressing issues around time zones. During social distancing times in the pandemic, numerous hackathons that aimed to crowdsource a generation of solutions to problems around COVID-19 took advantage of the online format, involving hundreds (and occasionally thousands) of participants in the same virtual event [57], [67].

When scaling up in terms of duration, organizers have to consider whether they want to run a single event spanning multiple consecutive days or a series of smaller events over a longer period of time. Over a few consecutive days, a single event might lend itself to hackathons designed for community building, sparking innovation, and networking (e.g. [1]). Examples include hackathons as a team-building activity, a student event during term breaks, or a way to advance a software project significantly. Conversely, a regular schedule of short hack days may be beneficial for problems that require sustained effort within the same teams over months or years, thereby taking advantage of the opportunity for asynchronous work in between to prepare these hack days and drive their projects forward. Creativity research reveals [68] that this distribution also gives participants the time to ''mull over'' their ideas and might lead to more creative outcomes.

For example, Basden et al. [69] describe a hackathon run over seven months, with one hack day per month and asynchronous work done between hack days. On each hack day, a new performance analysis tool was introduced that the participants, who were already part of existing teams, applied to their research codes. The time between hackdays was used by the teams to continue their work, asynchronously discuss problems with tool experts, and set up tasks for the next session. The feedback for this format was positive, and a few teams achieved significant insights and speedups for their codes.

Research on online [62] hackathons has revealed their advantages and disadvantages. However, whether and in which situations they are beneficial for scaling up is still an open question. While it is relatively easy to accommodate more people in an online environment in terms of logistics, as space considerations do not play a significant role, more care has to be taken to facilitate interactions among teams and a larger number of mentors, organizers, and instructors might be required. Hackathon organizers must be careful not to underestimate this shift in effort for scaling up online.

2) RESEARCH PROPOSAL

To the best of our knowledge, no rigorous research has been conducted thus far on the effects and limitations of scaling up in terms of time and number of people and how this differs between offline and online events. Therefore, we suggest that significant research efforts be dedicated to examining the inherent trade-offs in these choices. As discussed by Falk et al., reducing or increasing the duration of hackathon events may determine how people participate in them [70]. Longer or shorter durations of hackathons may change how *pace* is perceived by participants during designing and prototyping and, thus, ''influence which strategies participants pursue'' [70] citing [71]. As argued in the section above, we may ask how scaling up hackathons by organizing—for example, a series of regular schedules of short hack days—may influence how participants perceive the pace of designing and prototyping.

Another interesting question to examine is scaling down: Are hackathons with teams of two persons beneficial? Which aspects of hackathons can be retained in small-scale hackathons? What effects, benefits, and challenges could short hackathons of one or two hours entail, for example, in terms of participation, accessibility, creativity, and outcome? For example, shorter schedules have been proposed to ensure broader participation of older adults [72].

D. MAKING HACKATHONS EQUITABLE

As events that thrive on social interactions, hackathons tend to reproduce the power structures and discrimination of the society they are embedded in unless they are carefully facilitated. Hackathons are typically perceived as non-inclusive events [73]. They are, for example, not frequented much by female participants [74] as they are often subjected to different forms of discrimination involving misogyny, rudeness, sexist and inappropriate behavior [19].

Hackathons that explicitly welcome transgender, non-binary, and gender non-conforming people are rare and represent a small fraction of these events [75]. A lack of inclusion at these events implies that underrepresented groups (e.g., women, LGBTQIA+) might receive fewer opportunities (e.g., learning, skill development, networking, jobs) that are characteristic of hackathons [79]. Therefore, a hackathon cannot be considered a successful event unless it ensures equitable participation for all participants.

Hackathons have also often been criticized for their tendency toward technological solutionism. Thus, any hackathon in which the outcomes affect human lives—particularly those of traditionally minoritized groups—must ensure that stakeholders can engage with the planning and the hackathon itself [76]. However, representation is only the first step, and the organizers must design a hackathon in which participants from historically underrepresented groups are welcome.

1) STATE OF THE ART

Equitable participation includes both logistical aspects (e.g., wheelchair access, gender-neutral bathrooms, food that respects dietary restrictions, and quiet rooms) and facilitation aspects (e.g., a code of conduct and facilitation structures that mitigate power dynamics in teamwork).

Before the event, gender-neutral communication to and advertisements for specific audiences are important to attract underrepresented groups [77]; during the event, nuances such as allowing participants to specify their preferred pronouns in identification badges can improve the sense of belonging [81]. A core goal is to ensure that participants feel welcome, that their experiences and skills are valued, and that they belong at the hackathon.

Further, the logistical aspects of hackathon participation often depend directly on the selected venue, and organizers should carefully evaluate whether a venue provides equitable access. This includes building-related features, such as wheelchair accessibility or—in the case of age-inclusive hackathons for older participants—simple room layouts on the ground floor [72]. It also includes much broader questions around, for example, visa restrictions on travelling to the country where the hackathon is held, local laws, and disparities in travel funding among institutions and countries for participants. For a series of workshops like certain hack weeks, shifting the country and venue where the workshop is located has facilitated broader access, combined with dedicated fundraising activities to enable travel for those participants who would otherwise not be able to attend. Further, the emergence of fully virtual hackathons during the global pandemic provided opportunities to address logistical issues of travel funding and equitable access around the space the hackathon is held in. At the same time, virtual hackathons have introduced and increased other issues (e.g., participants may not have adequate access to electricity and the necessary technology for participation, key technologies may be censored in certain countries, and participants may be located in very different time zones).

As a safeguarding measure, introducing codes of conduct can be one means of making hackathons more equitable. They should clearly state what constitutes unacceptable types of conduct at the event and delineate (and carry out) enforcement procedures that have emerged as a key element of setting a baseline for enabling equitable participation free of discrimination and harassment [81]. However, codes of conduct (e.g., hack code of conduct[11]) can only provide a baseline, and, as is the case in other teamwork environments, by necessity leave a large grey area of behaviour that does not strictly rise to the level of a violation, but will nevertheless make the event unwelcoming for certain participants (e.g., repeatedly talking over a team member, in-group jokes, extreme competitiveness, and exclusion of team members based on disparities in technical skills).

Then, proactive strategies for mitigation hinge on organizers setting the event's tone and leading by example. In an analysis of 16 hackathons described in the research literature, Falk et al. [14] identified nine hackathons which were specifically tailored toward broadening participation. According to them, "By modifying the processes and desired end goal of hackathons, researchers [and hackathon organizers] have the opportunity to include those who have been historically marginalized when considering the design of technology-mediated futures" [14]. Related to this, it has been discussed how hackathons [70] can facilitate participation in design processes with low investment to include vulnerable people [78].

[11]https://hackcodeofconduct.org/

Further, hackathons often involve a sexist competitive environment that is not very welcoming for underrepresented groups [79]. Fostering a competitive or collaborative ambiance is a design choice made by the organizers [24]. The traditional competitive hackathon format is common, with incentives being offered, such as rewards. A hackathon event can be a cooperative one when social elements are introduced—for example, stimulating participants to pitch project ideas or to wander around the premises and discuss with other teams—thereby helping participants from different teams to collaborate and network [52]. This also supports how students belonging to traditionally marginalised computer science groups tend to participate in hackathons—by embracing collaboration and non-competitive goals [80]. Different collaboration strategies should also be considered to include older hackathon participants, such as consulting or validation [72]. Prado et al. [81] interviewed transgender and gender-nonconforming hackathon participants to draw the following set of recommendations for more trans-inclusive hackathons: begin with a gender-inclusive organizing team, foster inclusive communication, make safety visible, and showcase trans people in the event. Other recommendations for making events more equitable: focus more on collaboration and less on competition, stimulate the development of technical and transferable skills, promote healthier habits, define an inclusive code of conduct, and include women in the organization team [82].

Successful facilitation also rests on mentors and leads to be ready to facilitate their teams in a manner that respects every team member (see also the vision of a feminist hackathon in [51]). This can involve explicitly embracing failure as part of the hackathon, thereby recognizing that many hacks fail and participants may not feel sufficiently competent. In certain events, this has also included co-creating a value statement for the hackathon with participants to generate a buy-in. In addition to tailoring hackathons toward broadening participation, there are also examples of hackathons in which the topic of equity is deeply embedded into the theme of the hackathon itself, thereby inviting participants to develop ideas and prototypes that engage with the concept of *safe spaces*[12]—that is, a place where people can feel confident that they will not be exposed to discrimination, criticism, harassment, or any other emotional or physical harm.

No hackathon will be perfectly equitable. Thus, it is crucial that organizers 1) identify and recognize what went wrong at any given event and 2) learn from those mistakes for future events.[13] This includes critical questions regarding recruitment: who was invited and solicited? Of these, who participated? Why did those who did not attend decline attendance? How did those who attend experience the hackathon event? Post-attendance surveys

[12]https://www.unwomenuk.org/safespacesnow-hackathon

[13]for an example, see also https://github.com/MarionBWeinzierl/RS-EDI/blob/main/HackathonEDI.md

that include demographic questions can capture how experiences might have differed for participants from different backgrounds.

2) RESEARCH PROPOSAL

Despite a number of studies on equity in hackathons, this space remains underexplored regarding numerous axes of diversity and equity, such as ethnicity, culture, socioeconomic background, gender, sexuality, and neurodiversity. According to Falk et al. [14]: ''[P]articipants' contributions toward methodological democracy in the face of epistemological hegemony is currently underexplored and requires further engagement in future HCI research utilizing modified hackathons.'' In other words, what are, for example, ways in which participants have tailored and facilitated their own and others' participation according to their specific situations?

The rapid shift toward virtual and hybrid meetings in response to the COVID-19 pandemic opens up opportunities and challenges regarding equitable participation in hackathons that should be the focus of future work. In this context, one might ask whether virtual hackathons in which participants are anonymous facilitate or hinder equitable participation. In the study of equity in hackathons, closer collaboration with related fields in sociology and psychology that explore equitable participant selection and teamwork, diversity in competitive environments, and anonymity in other virtual spaces may provide valuable insights and starting points for future research.

E. STUDYING HACKATHONS

We need to study hackathon formats and participation to improve how hackathons are generally organized and run. Studying hackathons may be valuable not only for researchers but also for organizers who seek to evaluate and re-iterate the manner in which they organized a hackathon.

In this section, we address the aspect of siloed research and practice by discussing how we may improve what we observe as a poor methodological fit—that is, how we may begin developing and implementing the methodology for studying hackathons by considering relevant and prior theory and thereby move toward a more mature state of theory. A diverse range of multiple methods may help not only to generate new knowledge but also advance prior theory and thereby mitigate the risk of repeating known insights related to hackathons as a consequence of repeating what we observe in the form of rather similar studies with merely a few changes that cannot be compared or built on.

1) STATE OF THE ART

When reviewing the research on hackathons conducted thus far, it becomes evident that most studies focus on analyzing participants' experiences using qualitative methods such as post-event interviews and surveys. Few studies also report on in-depth observations of teams during an event or focus on studying the projects that teams work on. These studies focus on various aspects of the participant experience, including their satisfaction with the event, the individuals involved in organizing it, their project, and their team.

For qualitative research, *program theory* has been discussed as a valuable concept for studying the relationship between hackathon format and outcome [17]; one example in this context is the work presented in [14] Some studies utilize quantitative methods—for example, those that have investigated the usage of software repositories [60], [61], [83]. Other researchers have also included social network analysis [84]. Methods such as sensor-based analytics and tools like smart badges—which could foster the investigation of hackathons on a large scale and that have been successfully used in an educational context—have not yet been utilized to extensively study hackathons [85], with only very few exceptions like [86].

We interpret this wide variety of aspects being studied as pointing toward a lack of agreement in the research community regarding what is worth studying and what can be studied. Related to this, there is also a lack of ''standardization'' regarding the instruments used to study hackathons, which can further complicate, for example, the replicability of studies. Most studies utilize instruments specifically developed to study one event or a single aspect of an event.

In our experience, organizers rarely focus on ''studying'' their event when planning it, with a few exceptions, such as [87]. Instead, they often mainly focus on event logistics and funding. Often, they will do what they have seen before—for example, attending a hackathon themselves or following others' example. Some hackathons are also ''inherited,'' —that is, passed on from organizer to organizer, so the ''senior'' will pass down their knowledge to the ''junior.'' Having said that, there is always some development that is usually underway—that is, small changes are made if something was found not to work, an exciting new tool is just launched, or an organizer has experienced something at another hackathon that worked well [88].

2) RESEARCH PROPOSAL

Moving toward mature theory generally benefits ''from a mix of quantitative and qualitative data'' [18]. Based on discussions from the Lorentz Center workshop, we provide an overview of several possible qualitative and quantitative methods that readers can consider in Table 2. The overview should be seen as a developing repertoire of methods for studying hackathons; we invite readers to discuss and develop methods for studying hackathons.

Future studies of hackathons could focus on topics such as how to support participants' creativity—individually or collaboratively—through tools, materials, or physical venue surroundings and the role of temporality in participation, design decision-making, and design thinking, including how different kinds of bias may be introduced, enhanced, or mitigated.

To avoid replication of mistakes, data from hackathon research could be shared using, for example, the FAIR

TABLE 2. A synthesis of proposed methods for studying hackathons compiled by the workshop participants. The provided references are a mix of literature that describes a method in a general context and literature that has applied the related method in the context of hackathons.

Methods category	Methods	Hackathon stage			Perspective studied		References
		Before	*During*	*After*	*Participants*	*Organizers*	
Qualitative							
	Interviews (Contextual, structured, semi-structured, etc.)	x	x	x	x	x	[99], [100]
	Observations		x		x	x	[101]
	Analysis (e.g. thematic)			x	x	x	[102]
Quantitative							
	Output (Code, product, prototype etc)			x	x		[83], [103]
	RFID badges (sensor based technologies)		x		x	x	[104], [105]
	Surveys (incl. demographics of returning participants)	x	x	x	x	x	[106]
	Audio/video recordings of discussions		x	x	x	x	[39]
	Experience sampling method		x	x	x	x	[107]
	Social media content and online chats	x	x	x	x	x	[108]

Data Principles, which researchers can use to "enhance the reusability of their data holdings." [89].

In addition to these suggested methods, topics, and data sharing for studying hackathons, we call for developing shared survey instruments used by as many organizers and participants as possible. Generally, such shared survey instruments aim to "ensure that observed differences are real differences and not an artefact of differences in how the data were collected" [90]. Developing such instruments requires interdisciplinary collaboration to explore topics that are "universally" interesting for all fields (e.g., making hackathons equitable) but may be expressed differently across fields and contexts.

Further, as a point of departure for organizers for such an instrument, we make the following suggestions: For hackathon organizers who wish to study hackathons to improve their practice, we are inspired by a methodology described by Frick and Reigeluth as *formative research*—that is, a research methodology intended to improve theory for "designing instructional practices or processes" [91]. How do organizers decide to organize their hackathons, and how do they tailor the format to support the participation of specific groups of non-technical or even vulnerable people? The major concern for evaluating a certain practice is *preferability*—for example, how a hackathon practice is better than other practices—and consists of at least three dimensions that may be valued differently depending on the situation [91]: 1) *Effectiveness*: How well did the practice attain the goal in the given situation? 2) *Efficiency*: How effective is the practice in relation to the cost (e.g., time, money, and energy)? 3) *Appeal*: How enjoyable is the practice for everyone involved?

F. HACKATHON GOALS AND HOW TO ACHIEVE THEM

Organizing a hackathon takes substantial time and resources, particularly on the part of the organizers. Thus, as discussed earlier, they commonly organize an event to attain specific goals. Certain goals can be achieved at an event, while others might require preparation and/or follow-up activity. To discuss this difference, we utilize the differentiation proposed by Falk et al. [14] using program theory described by Hansen et al. [92]. The program theory describes how goals can relate to *immediate outputs*, such as artifacts that are created during hackathon events [37], *short or mid-term outcomes*, such as a startup that is created after an event [3], or *long-term impacts* such as establishing or growing a community [51]. Often, hackathons focus on multiple goals simultaneously, such as fostering the development of innovative technology that can subsequently be turned into products [38], [95] or fostering the integration of individuals into a community while teaching them related skills [66], [94].

We also note that organizers are not the only ones who invest time and resources into preparing for and running an event. Other individuals such as participants, mentors, jurors, support staff, or external stakeholders (such as sponsors and supporters) put equal time and effort into organizing a hackathon. However, these individuals might have very different goals than the organizers of an event. Their goals might or might not be compatible or aligned with those of other individuals involved in a hackathon [97]. Individuals might also have goals that contradict those of others involved in the same event. Thus, certain individuals might achieve their goals while others might not, even if involved in the same hackathon.

1) STATE OF THE ART

Most current research and practice on hackathons focuses on *immediate outputs*. These outputs can be varied and include allowing participation [7], raising awareness regarding specific issues [93], sharing information, teaching specific subjects and practices [1], [66], and creating an artifact, such as a piece of (innovative) technology [38]. Studies in this regard mainly report on how the design of an event can influence immediate outputs. This includes the time that is allocated for a hackathon and the space it takes place in [34], who is invited [3], and how the design processes are supported [39], [45]. However, most work related to immediate outputs relies on the perception of participants [94] or the perception of researchers who observe an event [37]. Whether and what participants learned during an event or the quality of the artifacts they created during an event has not been extensively studied.

Further, a few studies discuss *short or mid-term outcomes*. These mainly focus on hackathon projects [60], [83]. Existing studies report that few projects become continued [83], [96] and that continuation is often left to individual participants who might or might not be in the position to carry a project forward [38], [95]. Prior work also reports on the difference between continuation intentions and continuation activity. Despite positive continuation intentions, projects are often abandoned [96], only continued in the short term [83], or handed over to others after an event [38], [52]. A few studies focus on short or mid-term outcomes other than projects. These include individual career gains [38], [52] and learning [47].

Certain studies also discuss *long-term impacts*. Existing research in this area mainly focuses on hackathon projects, particularly in relation to open source. They report that long-term project continuation is predicated by aspects such as skill diversity within a team and the intention of team members to expand the reach of their project [83]. Moreover, there are studies on the reuse of code created during an event. The findings from these studies indicate that approximately one-third of such code is reused in other open-source projects and that the number of hackathon team members increases reuse probability [61]. Other long-term impacts, such as community integration and addressing larger environmental and public health issues, have not been extensively studied.

Finally, few studies focus on goal alignment between organizers and participants. They report that organizers and participants might not share the same goals and provide an indication that the hackathon format itself might enable the attainment of certain goals, such as networking and learning [97]. The goals of other individuals involved in a hackathon, such as mentors, jurors, support staff, or external stakeholders, such as sponsors and supporters, have not been studied extensively thus far.

2) RESEARCH PROPOSAL

There is existing work on fostering specific goals through hackathons, and future research could address a few areas. First, studies must expand beyond immediate outputs and focus on short—or mid-term and long-term impacts. Moreover, future research could focus on developing instruments that help assess actual impact rather than relying on individuals' perceptions.

Another area that requires attention is studying individuals' goals in preparing for and running hackathons. This relates to goal alignment and includes goals beyond those of organizers and participants.

Finally, there is a lack of studies considering hackathons in the specific context in which they have been organized.

Events are often studied out of context and organized as one-off events that are only marginally connected to other activities that a community or corporation undertakes. To advance the format and unlock its full potential, hackathons must be considered in their larger context both when organized and studied.

VII. CONCLUSION

To facilitate more interdisciplinary sharing of best practices and collaboration on hackathon research, we need to create *awareness* that both research and practice are siloed. This paper's purpose is to create awareness across disciplines, and we do this first and foremost by targeting a broad audience. We presented our best practices based on our combined experiences with organizing hackathons and discussed six important areas and research proposals for the future of hackathon research and practice:

How can we then begin sharing best practices, establishing interdisciplinary research collaborations, and thereby addressing grander challenges that require interdisciplinary approaches? A first step toward this was the Lorentz workshop in 2021, which was the starting point of the current paper. Several researchers and organizers from multiple disciplines initiated the conversation on the future of hackathon research and practice.

With this paper, we call for more interdisciplinary collaboration to address the three challenges identified in the Introduction section; we envision the paper as a point of departure for such collaboration. In particular, the sections "Hackathons in context" (section II-B) and "Envisioning the future of hackathon research and practice" (section VI) including table 1 should serve as a solid foundation for guiding the deepening of future hackathon research and practice. Our next concrete step toward breaking down the silos is to establish and nurture an interdisciplinary community around hackathons by organizing workshops, open to both researchers and organizers, centered on hackathon research and practice.

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