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Published in:
CHI'21: Proceedings of 2021 CHI Conference on Human Factors in Computing Systems

DOI (link to publication from Publisher):
10.1145/3411764.3445198

Publication date:
2021

Document Version
Accepted author manuscript, peer reviewed version

Citation for published version (APA):
Falk Olesen, J., Kannabiran, G., & Hansen, N. B. (2021). What Do Hackathons Do? Understanding Participation in Hackathons Through Program Theory Analysis. In *CHI'21: Proceedings of 2021 CHI Conference on Human Factors in Computing Systems* (pp. 1-16). Article 147 Association for Computing Machinery. https://doi.org/10.1145/3411764.3445198

What Do Hackathons Do? Understanding Participation in Hackathons Through Program Theory Analysis

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Hackathons are increasingly embraced across diverse sectors as a way of democratizing the design of technology. Several attempts have been made to redefine the format and desired end goal of hackathons in recent years thereby warranting closer methodological scrutiny. In this paper, we apply program theory to analyze the processes and effects of 16 hackathon case studies through published research literature. Building upon existing research on hackathons, our work offers a critical perspective examining the methodological validity of hackathons and exemplifies how specific processes for organizing hackathons are modified for different purposes. Our main contribution is a program theory analysis of hackathon formats that provides an exploration and juxtaposition of 16 case studies in terms of causal relations between the input, process and the effects of hackathons. Our cataloguing of examples can serve as an inspirational planning resource for future organizers of hackathons.

CCS Concepts: • **Human-centered computing → Interaction design process and methods**.

Additional Key Words and Phrases: hackathons, participatory design, research methods, program theory

ACM Reference Format:

Jeanette Falk, Gopinaath Kannabiran, and Nicolai Brodersen Hansen. 2021. What Do Hackathons Do? Understanding Participation in Hackathons Through Program Theory Analysis. In *PREPRINT FORTHCOMING AT CHI Conference on Human Factors in Computing Systems (CHI '21), May 8–13, 2021, Yokohama, Japan.* ACM, New York, NY, USA, 25 pages. https://doi.org/PREPRINT

1 INTRODUCTION

Hackathons are increasingly used for different purposes in various contexts involving technology. Even though hackathons were originally intended for and attended by software developers, in recent years hackathon events have been conducted across domains by engaging with people who do not necessarily have a software development background. As these events are increasingly embraced across diverse sectors, some hackathon organizers have sought to tailor the format in relation to their needs and context. For instance, corporate driven technology innovation has embraced hackathons for "[...] speeding-up the early phases of their innovation process up to the development and evaluation of prototypes"[16]. In contrast, hackathons in scientific communities foreground mentoring and "[...] allow community newcomers to develop technical artifacts that are perceived as useful by the community that organizes the event" [35]. In another instance, hackathon based events have been used "[...] for creating the circumstances under which grassroots innovation might flourish" [47]. These three examples show us that hackathons are organized for various contexts through modified formats with different end goals. In such instances, hackathons undergo a simultaneous change in format and desired end goal i.e. how to conduct a hackathon and towards what end are repeatedly redefined.

Studying such attempts frames our research questions: What do hackathons do? How are hackathons adapted to specific contexts and challenges? How might we conceptualize hackathons as a specific form of collaboration? Despite hackathons gaining more traction in HCI research, relatively little is understood about their methodological validity and thereby warranting closer scrutiny. In this work, we will study how hackathon processes are formatted and organized in relation to the desired end goal of a project in order to aid future research through the use of hackathons.

In general, hackathons have been commended as a way to empower a broad and diverse audience through participation in various phases of designing technology. Hackathons are often framed as a way of democratising the development of technology through participation. Though hackathons are increasingly embraced across sectors, their formats and use are not completely problem free. Criticism against hackathons include the lack of sustainable outputs in the form of prototypes as well as a lack of diversity in participation among others. Further, scholars have also argued that "'participation' is not a sufficient condition for changing power relations: forms of participation exist and presently thrive that do not question, but further, dominant power patterns around the development of IT" [2]. Exploring these tensions, we position our work as contributing to the ongoing critical dialog about hackathons in HCI [1, 12, 25, 46] by studying the processes and effects of hackathons. Falk Olesen and Halskov performed a literature review of 381 research publications and point out that "[...] the relation between how hackathons are organized and the outcomes is a valuable objective for future research" [14]. Researchers interested in utilizing hackathons as a form of participation through designing for and with specific groups can benefit from a systematic analysis of the means and intended outcomes of hackathons in their situated contexts. Building upon existing research, we offer a complimentary critical perspective by studying the processes and effects of 16 hackathon case studies selected from published research literature. While Falk Olesen and Halskov's work [14] provides an exhaustive literature review of hackathons, our work will engage with 16 case studies by applying program theory (PT) to exemplify how specific components for organizing hackathons are modified for different purposes. Our methodological approach of analysing 16 cases contrasts with and builds upon existing research on hackathons in three ways.

- First, a case study analysis "[...] focuses on understanding the dynamics present within single settings" [13] whereas a literature review is concerned with generalizing a wide range of relevant works. As Yin has argued, a case study approach is suitable for examining contextual conditions relevant to the phenomenon under study [53]. Put another way, a literature review aims to describe *what* has been said whereas a case study analysis aims to understand *how* specific cases operate in their contexts.
- Second, a case study analysis deliberately introduces a theoretical lens [31] – in our work, PT – whereas a literature review attempts to build a theoretical perspective that emerges from existing works.
- Finally, our work aims to produce a critical juxtaposition of 16 hackathon cases selected for closer analysis whereas a literature review aims to produce a systematic and exhaustive summary of existing works. We offer PT diagrams that juxtapose the modified processes and effects of 16 hackathon cases to facilitate cross case analysis. By doing so, our work critically evaluates the methodological validity of hackathons in selected cases as well as across cases through PT. Unlike a literature review, a case study analysis does not aim for an exhaustive survey.

PT comes out of the field of evaluation and offers "[...] a way to make explicit the assumed causalities of projects and programs" [7] by focusing on the "[...] underlying assumptions about how programs are expected to work" [42]. Since our work seeks to understand the processes and effects of hackathons, we apply PT to analyze 16 case studies based on existing research literature. PT has recently been used by HCI researchers to "[...] make evaluations more precise and increase learning, since making processes explicit enables investigation into why a project or program did or did not work" [22]. Hackathons are increasingly embraced in HCI both as part of conferences such as CHI4Good but also as ways to generate research data and explore new research endeavours [32, 40, 45]. We offer our work as a methodological inquiry about hackathons by pursuing our research question – what do hackathons do in their contexts? Through a PT analysis of 16 case studies, we provide a cross case analysis where "[...] mobilization of case knowledge occurs when researchers accumulate case knowledge, compare and contrast cases, and in doing so, produce new knowledge" [27]. Based on our case study analysis, we discuss the formats of hackathons and offer suggestions for researchers interested in organizing hackathons. In line with Falk Olesen and Halskov's work [14], we are interested in developing a more systematic approach for organizing and using hackathons as part of research.

Our contributions include: a catalog of examples on hackathon formats modified for specific purposes, see Table 2 for an overview. Each example is analyzed according to PT and provides structuring about how the hackathon was organized as well as explicating assumptions of a range of adaptions to the formats. We furthermore identify three main motivations for modifying the hackathon formats, see Tables 3, 4, and 5 for overviews of PT diagrams for each motivation. Based on our cross case analysis of 16 case studies, we provide suggestions for researchers who are interested in using modified hackathons for further knowledge production.

The rest of the paper is structured as follows: First, we introduce related work on hackathon formats, and the theoretical framework of PT. Secondly, we describe the method for selecting papers for the PT analysis, and the analysis procedure. Thirdly, we analyze the selected papers based on PT. The analysis section is structured into three categories: Participation, Sustainable Outcomes, and Learning, which represents the main motivations for modifying hackathon formats. Finally, we discuss retrospective insights on analyzing modified hackathon formats using PT. We also discuss some prospective considerations for organizers and HCI researchers.

1.1 Limitations

We selected our cases for modified hackathon formats using the ACM Digital Library for our search query. By doing this, we have restricted our scope of analysis to research literature that is published through ACM. This precludes any research about hackathon formats that may have been published outside of ACM in other related fields such as healthcare, where there is an increased use of hackathons. Therefore, our analysis and claims must be understood within the limited scope of our research and not as universal claims about hackathons. As mentioned earlier, our aim with this paper is not to conduct an exhaustive analysis of all the ways hackathon format have been adapted to specific formats. Rather, we want to highlight cases which may be particularly relevant for the HCI community and provide closer analysis of the selected cases through PT. Further, we have analyzed the 16 cases solely based on published research literature which may not include all the relevant details of a project.

2 RELATED WORK

In this section, we introduce related HCI research to our research interest in hackathon formats and how they may be organized for specific purposes. Then, we present the theoretical framework of PT.

2.1 Conceptualizing Hackathon Formats

There is no strict definition of what exactly constitutes a hackathon as such. Although hackathon formats are varied, there is a commonality of elements which often occur in hackathons and the formats often share a very similar structure [11]. Research literature describe hackathons in very similar ways, such as: "Hackathons are events where people who are not normally collocated converge for a few days to write code together." [50]; "Hackathons bring together participants from different backgrounds to address a problem through the creation of a computational intervention over the course of a day or two." [40]; "In general, hackathons are time-bounded events, typically of two to five days, during which people gather together and form teams, each of which attempts to complete a project of interest to them." [38]; On a general level, we subscribe to these ways of describing hackathon formats, which we frame as typically intensive and accelerated design processes where participants explore and design ideas for design cases or challenges during a short time-frame.

In recent years, there have been some contributions which systematically conceptualize the elements which generally constitute hackathon formats in order to support the design and organization of hackathons in different contexts. Based on empirical studies of 10 hackathons and a review of published literature, Pe-Than et. al. contributes with a discussion on how hackathons can be organised by listing design choices which organisers may consider in order to meet particular purposes [38]. Their contribution focus on corporate hackathons, and while there may be relevance for non-corporate hackathons as well, the discussed design decisions and the purposes which the design decisions support are specifically oriented towards creating commercial advantage in a corporate context. In this paper, we explore how hackathon formats have been modified and organized for several different contexts.

In extension of Pe-Than et. al.'s study [38], Nolte et. al. have recently developed a kit for supporting the organisation of hackathons. They outline 12 general decisions which a hackathon organizer should consider [36]. We share a research interest with Nolte et. al. who focus on hackathons which aim: "[...] to foster a specific goal for a specific audience in a specific domain." [36]. We diverge from Nolte et. al.'s focus on how to organize hackathons on a couple of perspectives: We conduct a retrospective case study on 16 particular hackathons, and scaffold our analysis using PT. We thereby focus on the experiences and insights from organizing hackathon formats for specific purposes, and seek to explicate as well as juxtapose the assumptions underlying how the specific hackathons were organized. We further argue that PT can be used prospectively for organizers as a tool to structure how to evaluate specific attempts at organizing hackathon formats.

Porras et. al. seek to: "[...] explore the various approaches to implementing hackathons and their outcomes for different stakeholders [...]" [39]. Based on the authors' own experiences with hackathons, a review of literature as well as empirical data from students and industry participants, the authors sum up their insights from organising hackathons over the years in a taxonomy of seven different hackathon formats, mostly organized in educational contexts. Though we are also interested in the various approaches of implementing hackathons, we do not delimit our study to educational contexts.

Taylor and Clarke frame hackathons as participatory design activities which designers and HCI researchers can learn from [46]. Taylor and Clarke engage in better understanding: "[...] how hackathons are being appropriated for different audiences and what we might learn from these events to inform the configuration of our own participatory activities." [46]. In order to accomplish this, they participated in and studied six hackathons which specifically invited non-technical participants. The hackathons which they study can be seen as being organized towards accommodating this non-technical audience. Therefore, there are overlaps between our study and theirs: Similar to Taylor and Clarke, we also study for instance the hackathon Self-Harmony by Birbeck et.al. [4]. However, we do not only look at hackathon formats which have been modified for a non-technical audience, though these are part of our study, but we are interested in cases which in general pursue tailoring hackathon formats for a specific purpose.

Motivated by an aim to systematically conceptualize the phenomenon of hackathons, Kollwitz and Dinter developed a taxonomy based on a systematic literature review of 189 publications [28]. The taxonomy cover ten dimensions which each contain a spectrum of characteristics of the different ways in which a hackathon format is typically organised.

Table 1. A recreation of the Program Theory representations used by Hansen et al. [22].

Input	Process		Effect		
	Mechanism	*Activity*	*Output*	*Outcome*	*Impact*
Tangible and intangible resources needed	The fundamental principle generating an effect	The medium or way in which the mechanism is brought into action	Immediate tangible and intangible product emerging from the process	Short- and medium term consequences derived from the output	Long term effects of the program or project

While Kollwitz and Dinter seek to conceptualize the characteristics of hackathon formats on different dimensions, we seek to explore the hackathon formats which are explicitly organized for a particular purpose. Such a modified hackathon format may share characteristics as described in Kollwitz and Dinter's taxonomy, however, they introduce and explore often novel ways of organizing hackathons tailored for specific purposes.

Another literature review which we draw upon, is the aforementioned work of Falk Olesen and Halskov [14]. Based on a comprehensive literature review of how researchers conduct research with and on hackathons, they identify three overarching motivations for organizing hackathons in this context: Learning, structuring processes, and enabling participation. While these overlap with our findings, they elaborate the motivations for structuring processes and enabling participation with several sub-categories based on multiple examples from the review. As mentioned before, our study contrasts with theirs by focusing on a few select cases in order to provide detailed analysis and comparison.

Based on five hackathons which de Götzen et. al. themselves participated in or organized, the authors explore how the hackathons: "[...] were prepared and run and how their different formats affected both the selection of participants and the outcomes of the hackathons." [11]. We share the research interest in how hackathon formats can take on different forms, but we differ from their focus on hackathons in service design.

We see the contributions in this section as important steps towards more systematic research on hackathons, where insights on different kinds of formats and how to organize these formats are synthesized and structured, which furthermore enable comparison of the formats. The systematization of hackathon organizers' accumulated experience can inform how other organizers may choose to organize as well as evaluate their particular hackathon format. We believe the latter in particular can contribute with intermediate level knowledge contributions [23], which can further support HCI researchers using modified hackathon formats as part of their research methods. In our paper we contribute to this line of hackathon research.

2.2 Program Theory

PT is originally intended for the field of evaluation, and is not a theory as such, but an approach which can be used for understanding processes and making clear how to evaluate a program [3, 22]. The aim is to make evaluations of programs more precise, and thereby contribute to knowledge on how different programs work. Recently, PT have been applied in the field of participatory design [22], playful and participatory city-making [44] and has also been discussed as a way to approach and contribute to research on hackathons [14]. Hansen et al. [22] build on PT to conceptualize how participatory design can be viewed as a specific set of programs that uses certain mechanisms (such as for instance mutual learning or shared reflections) and aims at specific effects such as quality of life, workplace democracy or emancipation [22]. They visualize the relationships between inputs, processes and effects in a tabular format (see Table 1) that we also draws on in the analysis. PT operates with the notions of inputs, process and effects [22]:

- *Inputs* to a program are the provided resources which are needed to initiate and complete a program. This could for instance be provided design materials or tools in a hackathon, or a design challenge.

- The *process* of a program consists of the *activities* which are conducted during the program by the participants. These activities support *mechanisms*, which are the general principles that generate effects. An example from a hackathon setting could be workshops during the hackathon to improve participants' proficiency in prototyping, which may lead to better quality prototypes.
- The program can generate *effects*, which are distinguished into *outputs*, *outcomes*, and *impacts*: Outputs are the immediate tangible and intangible products of the process, for example prototypes developed during a hackathon. Outcomes are short and midterm effects, such as consequences, benefits or drawbacks of the program. In the context of hackathons, this could be a startup company which started as an idea in a hackathon. Impacts are long term effects which are often "[...] achieved in conjunction with other programs." [22]. Impacts are, however, difficult to determine whether it was caused by a certain program. A long term impact of hackathons could for example be the production of "[...] new imaginaries of place, belonging, and hope in the performance of citizenship." [12].

In terms of inputs, process, and effects, PT can be used to make explicit "[...] the underlying assumptions about how programs are expected to work." [42].

In the participatory design context, Bossen, Dindler and Iversen argue that more explicit, systematic evaluations of participatory design, such as in applying PT, can: "[...] enhance accountability, learning and knowledge building.´´ [6]. Similarly, we argue that this can be obtained by applying PT for the study of hackathon formats. PT can be used to structure and articulating evaluations of these modified hackathon formats, and explicate assumptions of why a format was designed in the way it was. This, in turn, make way for comparing hackathon formats, and can contribute towards more formative research on hackathon formats [17].

3 METHODOLOGY

In this section we describe our method for selecting and analyzing the papers using PT.

3.1 Selecting the Papers

We searched for "hackathon" in the abstract, title and author keywords of publications, divided by the boolean operator OR, in the ACM Digital Library (ACM DL), published in the year range of 01/01/2010 to 23/07/2020, the last date representing when we conducted the latest search. There were no hits before the year 2010 with this search query. All items which were not either a journal paper, conference paper, book or book chapter were filtered from the sample. This resulted in 78 publications from the ACM DL.

Before reading the 78 abstracts, the three authors discussed and agreed on a set of guidelines for filtering the sample of abstracts. We based the development of the guidelines on our interest in finding papers which intentionally and clearly adapt a hackathon format for a specific purpose. The following guidelines supported us in filtering out publications which:

- Only made cursory mentions of hackathons, such as when a hackathon was used to produce an outcome, with the outcome being the focus of the publication.
- Only used a hackathon as a method to evaluate a prototype. In these cases the hackathon format was not modified for a specific purpose as such, but would often follow a "typical" hackathon format.
- Reported on only the participant perspective of hackathons, such as motivations and experiences of participating in a hackathon.

Table 2. An overview of the selected 16 papers which organize hackathon formats for specific purposes. They are categorized after three main motivations for modifying the formats: Participation, Sustainable Outcomes, and Learning.

Category	Paper
Participation	Hackathons as Participatory Design: Iterating Feminist Utopias [24]
	Self Harmony: Rethinking Hackathons to Design and Critique Digital Technologies for Those Affected by Self-Harm [4]
	StitchFest: Diversifying a College Hackathon to Broaden Participation and Perceptions in Computing[41]
	Strategies for Engaging Communities in Creating Physical Civic Technologies[48]
	MUDAMOS: a civil society initiative on collaborative lawmaking in Brazil[29]
	Older adults and hackathons: a qualitative study[30]
	ATHack: Co-Design and Education in Assistive Technology Development [33]
	How to Support Newcomers in Scientific Hackathons - An Action Research Study on Expert Mentoring [35]
	Co-designing Scientific Software: Hackathons for Participatory Interface Design [49]
Sustainable outcome	Mapathons and Hackathons to Crowdsource the Generation and Usage of Geographic Data [20]
	Lab Hackathons to Overcome Laboratory Equipment Shortages in Africa: Opportunities and Challenges [52]
	Post-Hackathon Learning Circles: Supporting Lean Startup Development [9]
Learning	Short datathon for the interdisciplinary development of data analysis and visualization skills [43]
	Experience Report: Thinkathon – Countering an "I Got It Working" Mentality with Pencil-and-Paper Exercises [10]
	Developing Course Projects in a Hack Day: An Experience Report [19]
	The community garden hack: participatory experiments in facilitating primary school teacher's appropriation of technology [26]

- Described the organization of a hackathon, but did not organize the format for a specific purpose.
- Did not revolve around the organization and facilitation of a hackathon.

Following the above guidelines, two authors read the 78 abstracts of the papers. During this reading, the two authors compared and discussed insights in order to align the filtering process. This resulted in 41 papers chosen for further reading.

We iterated our reading process, and read the full paper closely. During the reading of the 41 papers, we filtered out papers which for instance included too little detail about the organization of the hackathon, or turned out to not live up to our focus on papers that described how a hackathon format was organized for a specific purpose.

In some cases, the paper authors themselves clearly indicated that the conducted hackathon was modified, by writing for example: "However, we also recognised inclusivity challenges with the hackathon format and made significant changes to cater to a wider audience." [48]; or "[...] a novel initiative that adapts the conventional hackathon [...]" [52]; or "[...] we present a reimagining of the hackathon model [...]" [24]. In these cases, we included the papers.

In one case, two papers referred to the same hackathon [47, 48], so we included the more recently published paper [48] which also described the hackathon in enough details for us to analyze the format according to PT. This resulted in 16 papers chosen for further analysis, see Table 2.

As described in the introduction, we approach the 16 papers as case studies, in the sense that we focus on understanding the dynamics within the single settings. In the next subsection we describe our analysis procedure.

3.2 Analysis Procedure

Our analysis of the 16 papers was driven by PT. We coordinated the analysis of the 16 papers by identifying the following focus points for each paper:

- The domain which the hackathon was conducted in, for example education, research, or civic engagement.
- The main approach used for organizing a hackathon format for a specific situation, for example through choice of material.
- The reason for why the format was modified.

- The input elements for the hackathon format.
- The process elements for the hackathon format, including activities and mechanisms.
- The output elements for the hackathon format, both intended and described.

For each paper, we filled in these focus points in a collaborative online spreadsheet. These focus points helped us in terms of identifying overarching domains and research contexts in which the hackathons were organised. Two authors both analysed all 16 papers using the focus points. During the analysis of the papers, the authors kept an ongoing discussion of insights.

In order to identify potential patterns across the 16 papers, we used an online collaborative whiteboard tool to visually group the papers into categories. We identified three purposes for which the hackathons were modified: Participation, Sustainable Outcomes, and Learning.

These three categories are not mutually exclusive, but reflect the main purpose for which the hackathon was modified. A paper could still reflect intentions for for example broadening participation, while the main purpose for the hackathon adaptions were based on supporting learning.

4 ANALYSIS

In a PT perspective, the intended effect of a program is pursued through planned inputs, and mechanisms facilitated by activities during the process. In the following subsections, we describe the motivations and considerations for how the hackathon formats were tailored for a specific purpose, and how the tailored hackathon format was evaluated, if it was evaluated. This analysis forms the point of departure for the discussion where we discuss the patterns found in the analysis. To make it easier to follow how PT informed our analysis we use the schema from Table 1 to visualise the relationships between inputs, processes and effects of the many different hackathons.

4.1 Participation

We identified nine papers which aimed at broadening participation through tailoring hackathon formats [4, 24, 29, 30, 33, 35, 41, 48, 49]. Two of the papers used a co-design approach with end-users [4, 24], where hackathon participants were either end-users themselves or worked closely together with end-users to co-design prototypes, while Richard et.al. [41] are more focused on empowering the hackathon participants by inviting them to partake in the development of technology. Taylor et.al. [48] also focus on empowering the participants of the hackathons, but do this by specifically engaging the participants with their own neighbourhood community. The case of Konopacki et. al.'s hackathon did not involve technology development, but used the hackathon format to structure the participants' engagement with a platform for engaging citizens in lawmaking [29]. In Kopeć et. al.'s hackathon end-users, older adults, were invited to partake in the hackathon with developers [30]. Similarly in Narain et. al.'s hackathon, end-users were invited to participate, and were additionally carefully matched with developers [33]. The participation of newcomers in a scientific hackathon was the focus in Nolte et. al.'s case [35], where mentors supported the novice participants during the hackathon. A focus in Thomer et. al.'s hackathon for co-designing with end-users was the choice of design material as a way to support non-designers [49].

In the following sections, we analyse these cases in detail according to PT. Table 3 provide an overview of the salient elements of the cases in terms of input, process and effects.

4.1.1 *Co-Designing with end-users.*

The hackathons in two of the papers concern designing and developing technology both for and with those affected by the theme of the hackathon: self-harm [4], and breastfeeding [24]. The authors

Table 3. A comparative overview of selected elements which contributed to modifying hackathon formats for specific purposes in terms of broadening participation.

	Input	Process		Effect		
		Mechanism	*Activity*	*Output*	*Outcome*	*Impact*
Co-Designing with end-users [4, 24]	Sense-checking activities Prioritised participant recruitment Welcoming venue space Inspiration sources	Centering marginalized voices of participants	Volunteers supporting participants with tools and materials Microphone	Designs presented at science fair	Raising awareness of theme Press and media Collaborations Community Policy Personal	Reimagining breastfeeding in the US Making hackathons more inclusive and accesible
	Sense-checking activities Participant recruitment Safe space Three challenges	Continuous sense-checking Facilitating later discussion	Mentors Process documentation	Seven designs Stakeholder discussion	Raising awareness of theme	
Broadening Partici-pation in Computation [41]	Targeted rectruitment Theme: Wear & Care Venue Design materials: LilyPad Arduino Hack boxes Recommendations [34]	Cross-team social interactions and collaboration Helping novice participants with technology development	Sharing content from hack boxes Mentors	Wearable designs	Changed perceptions on coding and computation	Broadening female participation in computation
Empowering Communities [48]	Participant recruitment through local events Makers recruited through makerspace	Allowing families and parents to participate	Three events of six hours Slow introduction of technology	Three prototypes	Relationships between residents and makers Creating excitement around technology possibilitites Confidence with technology	Empowerment of citizens
Engaging Citizens in Lawmaking [29]	Mobile app Mudamos	Collaboration Diversity of participants strengthen bill proposal	Multistakeholder panel Fishbowl converstion Draft bill creation in three steps	Test of bill Publication on Mudamos	Engaging citizens in lawmaking	
Inviting End-User Participants [30]	Targeted invitation of older adult participants Meeting prior to hackathon between organizers and participants			19 designs	Reflections on challenges regarding participation of end-users	
Matching End-Users and Participants [33]	Recruitment of co-designers (end-users) Proposal of projects by co-designers Presentation of projects at social event Project preferences submitted Documentation prize			Assistive technology prototypes	Knowledge about accessible product design	
Mentoring Newcomers [35]	Mentors Presentation on problem space by mentor	Mentors as experts assisting newcomers	Mentors helping with problem scoping and technical support	3 projects		
Design Materials for Co-Designing with End-Users [49]	Materials for paper prototyping Workshop on prototyping Workbooks	Capturing work practices	Filling out workbooks	Completed workbooks Interface designs	Sharing with broader community	

of the two papers [4, 24] share a motivation for raising awareness about their hackathon themes by conducting the hackathons. The way in which the authors modify the two different hackathons in order to achieve this motivation differ from each other.

Input: The organisers of both hackathons undertook *sense-checking activities*: In Birbeck et. al.'s hackathon [4], it was important to consult frequently with local mental health organizations to ensure the creation of a sensitive and tactful space. For Hope et. al.'s hackathon [24], it was important for the organisers to work with their own biases, since the majority of the organizers were white, college-educated, cis-gendered, and heterosexual, and the target audience of the hackathon were mothers and parents who face the most challenges regarding breastfeeding: "[...] mothers of color, low-wage workers, and/or LGBTQ+ parents." [24].

The two hackathons diverge in how *participants were recruited*. In Birbeck et. al.'s hackathon [4], participants were recruited through channels such as mailing lists. Their recruitment operated after a first-come-first-served principle. The hackathon attracted a wide range of participants, including a target audience of end-users with lived experience of self-harm [4]. In an earlier version of their hackathon format, Hope et. al. used a similar participant recruitment as Birbeck et. al, however for the hackathon described in [24], they made a prioritised recruitment of participants in order to reach their target audience, by using channels such as: "[...] personal outreach through our partners, specific recruitment at Historically Black Colleges & Universities (HBCUs), and outreach to community organizations." [24].

Both hackathons reflected on the *venue* and how the location could support specific needs during the hackathons. In the case of Birbeck et. al.'s hackathon [4], they needed a space for participants who would need to withdraw if they for example became upset because of the particular hackathon theme (self-harm). In the case of Hope et. al.'s hackathon, the venue space was designed in order to: "[...] make the space more welcoming to a wider spectrum of people." [24]. This included spaces which imitated living rooms, an art exhibition, a zine library, and a "Baby Village" [24].

Inspiration sources in different forms were also offered to the participants of both hackathons. Birbeck et. al. offered inspiration packs with three challenges (in the form of questions) to guide the initial idea generation [4], while Hope et. al. created and distributed a book with narratives and innovations from parents to the hackathon participants[24]. Additionally, quotes from these books were hung up on the walls of the venue.

Process: During the process, Birbeck et. al strived for a continuous sense-checking of the participants' ideas, and did this by having mentors at the hackathon who could provide critique and ensure that participants engaged sensitively with the topic. These mentors were both people with lived experience of self-harm, as well as professionals working with mental health. Additionally, participants were asked to document their process, so that this process documentation could be used to later engage stakeholders in critical dialogue about the design outputs of the hackathon and whether the outputs engage with the topic of self-harm in a sensitive way [4]. During the process, Hope et. al. focused on centering the marginalized voices of the participants, and had volunteers to help the participants with the provided tools and materials of the hackathon. The organisers also provided a microphone, which the participants at all times could use during the hackathons, in order to make requests and: "[...] leverage expertise in the room and provide a way for people to take ownership over the process [...]" [24].

Effect: The output of Birbeck et. al.'s hackathon [4] was seven different designs developed by the participants, as well as the post-hackathon stakeholder discussion about these designs. The authors reflect that, while it is important to engage end-users in the design process, it is equally important to ensure objective and expert perspectives on the outcomes of the design processes, as these stakeholder discussions: "[...] can be seen as integral to how these design outcomes could be successfully integrated into self-harm care pathways."[4]. In order to build relationships and meaningful dialogue around the output, in form of the designs, Hope et. al. held a science fair. They furthermore report five different kinds of impact of the hackathons: Press and media, collaborations, community, policy, and personal. A research related output are five design principles for organizing an event for centering marginalized voices.

Though the two papers both strive for similar outcomes of their programs, facilitating co-design with end-users, the planned inputs and activities facilitating these outcomes are quite different. This emphasises how the *theory* of the program, (hackathons can be settings for co-designing with end-users, and furthermore be a meaningful setting where respectively sensitive topics can be explored and marginalized voices are centered), can potentially be pursued through a range of different activities.

4.1.2 Broadening Participation in Computation. Like the two above-mentioned cases, the format of Richard et. al.'s hackathon, called StitchFest, was carefully and comprehensively organized to "[...] broaden not only participation in computing by reaching larger numbers of female participants but also perceptions of computing through the event composition and theme." [41].

Input: In order to accomplish this, Richard et.al. designed StitchFest based on a set of recommendations released from the National Center for Women and Information Technology [34]. Additionally, the authors drew on research that indicate that the use of design materials, themes and spaces can influence participation and perception [21]. As the main design material or platform for the StitchFest, the authors chose the LilyPad Arduino, which combines computation with crafting and sewing. The authors continued the theme of crafting, by developing a design challenge called "Wear and Care". Another input to the hackathon, was the distribution of "hack boxes" for each team. The hack boxes each contained the same primary components, but had different sensors and actuators in them. The reason behind the different content of the boxes, was based on the authors' assumption that this would prompt the participants to interact with each other, exchanging both materials and experiences with using the materials.

Process: During the hackathon, the hack boxes contributed to an activity of sharing materials between participants, and in that way support cross-team and collaborative interactions, rather than isolated teamwork. Mentors were also present during the hackathon, assisting the participants with the technology development.

Effect: The immediate outputs of the hackathon were wearable designs and longer term outcomes were how the participants, who were interviewed a few weeks after the hackathon, reflected on how the hackathon broadened their perceptions regarding coding and computation [41].

However, despite the hackathon being carefully designed and followed recommendations and research meant to support a broader participation in computation, the authors reflect: "[...] a list of recommendations alone is no guarantee for success." [41]. In conducting a second iteration of the hackathon the authors reflected: "While the second iteration of StitchFest benefitted from our experiences in setting up the Spring 2014 [...] we found that this was not sufficient to bring in larger number of female participants as we did in the Fall." [41]. Despite some seemingly positive effects from the hackathon, this reflection points towards the need for further exploring and evaluating the assumed relations between planned inputs and intended effects of hackathons. However, the StitchFest suggest some interesting future endeavours for research on hackathon organization modified for broadening participation, in terms of: targeted recruitment, thematic framing, space arrangements, kinds of materials and material distribution [41].

4.1.3 Empowering Communities. The hackathon of Taylor et. al. was organized to accommodate the needs of families and parents, who did not have much experience with technology development [48]. This was done through rethinking the program of the hackathon, introducing technology slowly, and facilitate the creation of inventor kits after the hackathon, meant to enable the residents to build new civic technologies. They motivate the choice of conducting a hackathon for this purpose because of hackathon formats': "[...] intensive nature and their focus on active participation and creative thinking, as opposed to more discursive consultations." [48]. However, at the same time, the authors are aware of inclusivity challenges with hackathon formats, and therefore modified their hackathon to: "[...] cater to a wider audience." [48].

Input: Neighbourhood residents were recruited through local events in the city where the hackathon would take place. Makers were also recruited through the city's makerspace and personal connections.

Process: One significant activity of Taylor et.al.'s hackathon was dividing the hackathon program into a series of three events of six hours, as they assumed this would allow parents and families to participate, contrary to a single weekend-long event. The authors introduced technology slowly: At the first event, participants mainly worked with craft materials which were easy to work with for all the participants. The second event: "[...] followed a more conventional hackathon model," [48], where teams built prototypes using both craft materials and simple electronics. The last event made use of the digital fabrication equipment at the city's makerspace in order to finalise prototypes.

Effect: The immediate output of the hackathon was three prototypes. The intended outcome of the three events was building relationships between residents and makers, which could potentially facilitate future learning and collaboration between the two groups. An outcome of the hackathon was the residents becoming more comfortable with technology, and being able to see technology as something they could employ for local needs in the neighbourhood. An assumption was that the residents would become comfortable with technology, because participating in developing technology would provide them insights into this process and demystify it. Following the hackathon, the authors held several informal and formal gatherings and events in order to among other things maintain a sense of community for the residents.

The authors reflect that it is important that the participants' feeling of ownership of being able to develop civic technology for local needs extends beyond the prototypes to the process itself. For that purpose, the authors suggest making activities more open, and supporting lightweight, drop-in engagement [48].

4.1.4 Engaging Citizens in Lawmaking. Konopacki et.al.'s hackathon is an example on a hackathon format which was specifically tailored towards engaging citizens in drafting bills.

Input: Their case took point of departure in an app, Mudamos, developed to enable citizens to: "[...] participate in lawmaking and express their support for draft bill proposals introduced in the legislature using electronic signatures." [29]. To start supporting citizens in drafting bills through the app (the intended outcome of the hackathon) the authors organized a hackathon to: "[...] draft bills collectively addressing a single issue and within a timeframe." [29].

Process: During the hackathon the authors organized a range of activities to support this outcome, including a multistakeholder panel, and a "fishbowl conversation" with the audience. Next, the hackathon was structured into three steps: "[...] address the draft bill main objective, write down general definitions and, finally, draft bill devices." [29]. Participants worked in groups during this process, and were supported by mentors. These activities were driven by an assumption that the more diverse sectors who participate during the hackathon, the stronger the bill proposal.

Effect: An immediate output of this modified hackathon is a test of the bill and its publication on the Mudamos app. The test is presentations of the proposals to consultants in order to improve the bill. Finally, the bill is published on Mudamos, and signatures for the bill can be collected through the app.

The Mudamos hackathon is the only example in our sample where the output does not as such involve technology development. Instead, a specific technology, the app, is the input and platform around which the process revolves. The hackathon format is then organized around activities which drives discussion and content creation for the technology.

4.1.5 Inviting End-User Participants. Kopéc et. al. organized a hackathon where older adults were invited to participate in teams of young programmers [30]. They argue that: "[...] it is important to optimize the process of developing solutions that would suit the needs of this demographic [the older adults]." [30].

Input: The main way in which the hackathon format was organized for this purpose, focus on the targeted invitation of older adult participants. Prior to the event the hackathon organizers met with the older adult participants in order to explain the hackathon to them, as well as discuss any concerns from the older adult participants regarding participation. The main concern from the older adult participants was about their own technical aptitude, whereto the organisers assured them that the their technical skills were less important than: "[...] their willingness to share their personal insights and experience with the programmers." [30].

Effect: In evaluating the case of Kopéc et. al.'s hackathon, the authors observed a number of issues regarding the participation dynamic between the young programmers and older adult participants. In one scenario the programmers did not make contact with the older adult participants, whose insights were oftentimes disregarded as non-representative for the older adult population. In a second scenario, the older adults were only consulted sporadically by the young programmers, and here the older adults' experiences were oftentimes also deemed as non-representative. In a third scenario, the older adult participants played an active role in the development teams, like the organisers had envisioned.

Kopéc et. al. reflect that it is not enough to only invite a target group to participate in a hackathon, as it cannot be assumed that all participants, whether they are part of the target group or the developers, can participate on equal terms [30]. End-users needs to not only be invited as an input to the hackathon, but to be actively supported and perceived as participants with valid insights during the process of a hackathon, if full collaboration and participatory design is envisioned.

4.1.6 Matching End-Users and Participants. An intended outcome of the hackathon organised by Narain et. al. [33] is educating student participants about designing accessible products. The outcome is facilitated by conducting a hackathon which include a rather elaborate matching process between the student participants and the co-designers, who live with a disability.

Input: We see the elaborate matching process as an important input for this case. The co-designers were recruited from interest lists at rehabilitation facilities, schools, and disability service centers at universities. Then, the co-designers proposed potential projects, and were encouraged to consider among other things the feasibility and scope of the projects. The projects were then presented to all the hackathon attendees at a social dinner event two weeks prior to the "build day" of the hackathon. During the event, the co-designers and participants mingled and discussed ideas. After the social event, the participants submitted project preferences, and matched co-designers and participants were encouraged to get to know each other before the build day. Another interesting input to Narain et. al.'s hackathons is the inclusion of a documentation prize, which can potentially facilitate outputs which are more easily shared. The authors report that, as a result of including the prize: "[...] many teams created high-quality instructions and drawings to help others understand their work." [33]. However, the authors note that their hackathon format still lack: "[...] support for the continuation of projects after the event." [33].

Effect: An immediate output of the hackathon was assistive technology prototypes.

Despite the careful matching process, some end-user participants did not feel that their perspectives were perceived as valid, quite similar to Kopéc et. al.'s older adult participants [30]. One participant reflected: "Two of my friends participated in the event and had very negative experiences because the hackers did not take any of their input. It wasn't collaborative at all. They were not open to the co-designer's suggestions and went off and did things without including the co-designer at all. In fact, they did the exact opposite of what the co-designer wanted and something he knew would not work." [33].This further suggest that it is not enough to only invite participants, such as end-users, there needs to be activities during the process which can support mechanisms of collaboration between participants and end-users.

4.1.7 Mentoring Newcomers. Nolte et al. [35] presents a study on how adding *mentors* might be needed in scientific hackathons, that aim to support scientific communities by developing technical artefacts useful to the research being conducted. In short, while a person might be competent to participate in a hackathon in general, the scientific hackathons can often be excluding to newcomers because of the large amount of lingo, complex challenges and especially existing technical infrastructure and requirements.

Input: Nolte et al. [35] ran a study where they introduced mentors, that is domain experts already working on research problems and using tools related to them, to help the hackathon newcomer groups out before, during and after the hackathon. The mentors for example would provide a short webinar on the problem space before the hackathon and be available during the hackathon to help with problem scoping and support on technical issues related to the domain.

Process: Nolte et al.[35] highlights how the mentors were not meant to be stakeholders owning the problem, but rather experts assisting, and in the case where these two roles were confused this seemed detrimental to the progress of the hackathon. This is ascribed to one of the strengths of hackathons, in allowing hackathon teams to take ownership over their work and so, care should be taken to ensure that this is allowed while mentors act in a more outside and neutral role.

Effect: As an output of the hackathon, three projects were developed.

In a PT perspective the mentors contributed both with inputs (in the sense of domain knowledge, webinars, logins and tools), and participated in activities (by helping scope, discuss and assist during the hackathon) and also interestingly with sustaining the effort beyond the scope of the actual hackathon. As the members were community members, they were well-positioned to help take a next step with the projects.

4.1.8 Design Materials for Co-Designing with End-Users. The choice of design material can in the hackathon of Thomer et. al. be seen as a way to modify the hackathon format to be more welcoming for non-designers. The hackathon of Thomer et.al. is conducted in the research field of taxonomy, which often operate with niche UX/UI needs and underdeveloped GUI's [49]. These GUI's can act as barriers for entry of researchers with less computational backgrounds [49]. In order to develop better GUI's which accommodate for those niche needs, Thomer et. al. organised a three day hackathon around co-designing interfaces by inviting people with expertise in either taxonomy, information science or software development.

Input: The participants were provided with materials for creating paper prototypes and digital wireframe tools, and were introduced to prototyping methods. Thomer et. al. reported that despite the participants not having prior design experience, the participants easily created interface designs with the provided materials for paper prototyping. The participants, however, struggled with the tools provided for creating digital wireframes. Another input were the workbooks provided to the participants [49].

Process: These workbooks were intended to support the capture of the participants' work practices as well as storing the interface designs during the hackathon process. The completed workbooks would then serve as an output, which could: "[...] be shared with the broader development community, and act as a blueprint for future software design." [49].

Effect: The motivation behind including the workbooks, creating more shareable outputs, is similar to the motivation for the input of a documentation prize in Narain et. al.'s hackathon [33].

We see this design material choice as a way of tailoring the hackathon format to invite non-designers to partake in design, as materials for especially paper prototyping does not require a certain expertise, such as a design or computation background, in order to be used. This is similar to the case of the above-mentioned Stitchfest hackathon [41].

4.2 Sustainable Outcomes

The three papers in this category, revolved around the theme of creating more sustainable outputs and outcomes of hackathons. Two papers modified the hackathon format as a vital part in a circular process, and sought to make

Table 4. A comparative overview of highlighted elements which contributed to modifying hackathon formats for specific purposes in terms of facilitating more sustainable outcomes.

	Input	**Process**		**Effect**		
		Mechanism	Activity	*Output*	Outcome	*Impact*
Rethinking the Hackathon Format as Part of Circular Processes [20, 52]	Unmapped geographic data	Improving geographic data	Mapping unmapped geographic data	Mapped geographic data	Improving and prolonging hackathon outcomes	Supporting growth of sustainable Blue Economy
	Improved geographic data from previous mapathon		Developing applications using mapped data	Applications		
			Improving mapped data using feedback from hackathon	Evaluations of mapped geographic data		
	Need for laboratory equipment	Educational opportunity	Learning sessions and workshops	11 frugal and reproducible designs	Contributing to Open Hardware movement	Addressing equipment shortage which undermine STEM education in Africa
	Arduino kits for teams	Skill development	Elaborate preparation and prototype creation phase before physical event			
	Open Hardware resources					
Post-Hackathon Activity [9]		Improving connection between output and stakeholders	Learning circles	Four solution suggestions		

the formats, and particularly the outcomes, more sustainable in each their way: [20, 52]. One paper implemented a post-hackathon activity intended to support advancing the immediate hackathon outputs and consider business models for the outputs: [9]. Table 4 provide an overview of the salient elements of the three cases in terms of PT.

4.2.1 Rethinking the Hackathon Format as Part of Circular Processes. The two hackathon formats by Gama et. al. [20] and Webb et. al. [52] can be seen as formats that address the critique point of hackathons as producing only short lived outputs, often in the form of the immediate output of prototypes.

Input: Gama et. al. conducted a circular process of hackathons and mapathons exploring the Blue Economy, which is: "[...] the sustainable use of marine and ocean resources for economic growth and improved livelihoods in coastal areas." [20]. The input for the mapathons, which are hackathons for generating map data through remote mapping, was unmapped geographic data, while the input for the hackathons was the outcome of these mapathons: mapped geographic data.

Process: During the mapathons, geographic data of unmapped areas was generated and improved. During the subsequent hackathons, prototypes based on this generated geographic data were developed, and the geographic data was evaluated[20].

Effect: The output of the hackathons were the prototypes as well as feedback for improving the geographic data, which was then collected and used as input for the next mapathon [20].

Webb et. al.'s hackathon format, the LabHack, is a case on modifying a hackathon by addressing an issue particularly relevant for the participants themselves. Emphasising that hackathons have become: "[...] a valuable educational and practical tool across the CHI community [...]" [52], Webb et. al. motivate their modified hackathon format by focusing on laboratory equipment shortages in STEM education in Africa. The goal, and thereby the intended outcome, with the modified hackathon format was to: "[...] motivat[e] and challeng[e] students to design and build their own frugal, reproducible pieces of laboratory equipment." [52].

Input: In order to approach this issue, Webb et. al. tailored a hackathon format based on the Open Hardware movement,where laboratory equipment plans are disseminated through online resources [37]. University students and technical club hobbyists were invited to the hackathon, and were encouraged to draw on these already available resources and make their own design plans available.

Process: One process element for Webb et. al.'s modified hackathon, was the preparation phase, where participants did most of the design and development of the equipment prototypes before the actual hackathon event, which were mainly dedicated to learning sessions. According to the authors, the longer preparation phase for example enable design iterations and thereby improved quality of the designs [52]. In addition, participants have more time for developing skills necessary for building their prototype [52].

Effect: Eleven prototypes were developed, and additionally contributions to the Open Hardware movement were made. Like Gama et. al. [20], Webb et. al. [52] rethought the hackathon format into a circular process, in the sense that the LabHack is meant to be applied whenever there is a need for laboratory equipment and thereby the hackathon can potentially contribute to the shared repository of equipment plans.

Summarizing, the two hackathon formats analyzed in this section each explore how to potentially improve the longevity and quality of hackathon outputs and outcomes. In Gama et. al.'s case, they organized mapathon and hackathon formats into a circular process where each conducted format is used to build on and improve outcomes from a previous format. This presents an interesting approach to potentially improve the quality, as well as prolong the lifetime of hackathon outcomes. Webb et. al.'s case deliberately aims at contributing with *reproducible* outputs, in the form of design plans that can be shared beyond the immediate hackathon event in a central repository, hence potentially facilitating an "[...] ongoing and self-sustaining process to be applied whenever there is some equipment need [...]" [52].

4.2.2 Post-Hackathon Activity. We identified one paper which explored an activity that mainly concerned the output of a hackathon, and how to advance the outputs towards realization and practice, for instance by transitioning a hackathon team into a startup [9]. Chan et. al. introduce the concept of post-hackathon *learning circles*, to: "[...] connect hackathon teams with key stakeholders, reflect on prototypes and consider business models." [9].

In terms of PT, the learning circle activity can be described as having potential for supporting a mechanism for improving the connection between the designed outputs and stakeholders, hence improving the chances that the immediate outputs could have an impact on end-users.

4.3 Learning

This section shows how hackathons activities and mechanisms have also been found useful in educational settings, primarily to solve issues faced by more traditional instructional approaches. In a PT perspective this could be construed as experimenting with alternative programs in the form of inputs, mechanisms and activities to either strengthen existing approaches and tools for instruction or enabling students to engage with new types of technology they have not encountered before. Table 5 provide an overview of the identified PT elements.

While all the papers in this category are concerned with learning, they also generally take different approaches both in terms of inputs, mechanisms and activities. Salinas et al. [43] discuss how to use the specialized "Datathon" format in an adapted shorter and more intensive version, while Cutts et al. [10] transform a traditionally digital programming introductory class into a shorter paper-based hackathon format that enables students to grasp fundamental concepts. Similarly, Gama [19] adapted the hackathon format into a full day of solving challenges in groups, thus aiding student motivation and hands-on experience with topics in a course on web technologies. Last, Karimi et. al. [26] used a modified hackathon format to allow teachers to better understand the possibilities that technology might offer.

Table 5. A comparative overview of highlighted elements which contributed to modified hackathon formats for specific purposes in terms of facilitating learning.

	Input	Process		Effect		
		Mechanism	*Activity*	*Output*	*Outcome*	*Impact*
Shortening timeframes to build skill [43]	Setup with computers Userfriendly software	Enable participants to gain basic data analysis and visualization skills	Six hour time frame		Basic literacy skills	
Alternative educational program [10, 19]	Pen and paper	Mastery-based learning Peer-learning	Collaborative group activities solving code exercises Tutor assistance	Improved code comprehension		
	Challenge Data files	Challenge-based learning	10 hour timeframe	Prototypes	Higher motivation	
Demystifying design materials [26]	non-entry level design materials Familiar setting	Demystifying technology	Setup and troubleshooting of prototyping technology			

4.3.1 Shortening Timeframes to Build Skill. While hackathons draw on time constraints for some of their power, there is also potentially excluding aspects or new potentials in even further constraining or expanding the timeframe in which the hackathon is executed in.

One example of this is the 'Short Datathon' format presented by Salinas et al. [43]. Salinas et. al. observed that with the rise of Big Data, so-called 'Datathons', that is hackathons that focus on a particular set of data, are becoming increasingly popular, yet it is difficult for newcomers to participate as they do not possess the basic data literacy skills.

Input: Salinas et al. [43] adapted the Datathon format for an educational setting running as part of an "Internet Week" focusing on new technologies. The outset consisted of creating an initial infrastructure with existing computers, an easy to use piece of software and a series of vetted data sources to ensure participants do not have to spend time on setting up for getting started.

Process: Rather than trying to tweak a larger Datathon, the authors created a six hour hackathon that enabled participants to gain basic data analysis and visualization skills, thus allowing them to participate in larger Datathons. The chief means of this is a shortening of the timeframe: it can be daunting to participate in a full weekend event if one does not feel confident about being able to participate. This in turn hurts the diversity of existing datathons. With the infrastructure ready and a set schedule for the six hours long Datathon, collaboration between participants on the actual data exploration and visualisation could begin.

Effect: In terms of PT, the intended outcome, basic literacy skills for newcomers, shaped both the inputs and process. The authors shortened the format to six hours as well took on a more structured form, to achieve their goal of supporting newcomers. We consider this paper an example of how it might not be enough to do recruitment to achieve the necessary inputs for a given program: rather, we might need to run other programs first.

4.3.2 Alternative Educational Program. One example of transforming an educational program is the 'Thinkathon' discussed and developed by Cutts et al. [10]. While students were able to solve programming problems at home using assistance from the internet or their development software, they would struggle with 'code comprehension' in the final exams and further in their studies.

Input: To enable students to strengthen their understanding of the core concepts of programming, the authors developed the 'Think-a-Thon': three evenings where students in groups would, using only pen and paper, work their way through 200 exercises.

Process: The designed activities were, in PT terms, the collaborative group activities with tutor assistance as students worked their way through the exercises with pen and paper. The employed PT mechanisms are referred to by Cutts et al. [10] as Mastery-Based learning by way of exposure and practice with one problem-set that challenges students and builds upon the previous one. The ability to be co-located and work on similar problems with tutor assistance established a mechanism of peer-learning in the sense that students would discuss informally between groups how to solve certain issues. This mechanism, a novel coupling of reading and lab exercises in a hackathon-like format using pen and paper, allowed the students to ignore scaffolding such as code editors and frameworks, focusing purely on the code and the fundamental concepts such as statements, expressions or variables.

Effect: Cutts et al. [10] report how the outcomes and impact of this approach was meant to both prepare them for the coming exams but also develop confidence and understanding in their own ability to solve programming problems without external assistance.

A second example is provided by Gama [19] who reports on how they transformed the final part of an introductory distributed systems course for undergraduates as an elective in an education on Information Systems. Gama [19] focuses on how adapting a hackathon model might establish 'Challenge-based Learning'.

Input: Students received data of the geolocation of taxis and busses, and would use this to simulate the real-time streaming of the data to create a system using distributed technologies.

Process: A 10 hour 'hack day' was organized where the students would turn up and in groups start developing a system using the data and series of distributed web technologies. The idea was to put into practice what the students had learned during the semester, and this idea was motivated by the reflection among staff at the education that assigning such projects as homework seemed less efficient due to creating a disconnect between concepts and technologies, and the actual project work. This was accomplished by means of an activity where students were tasked with developing a prototype of an urban mobility system. Throughout the activity the students had the chance to receive feedback on their design choices. The core mechanism of Challenge-Based learning can be considered driven partly by this challenge and intense teamwork by means of being co-located, receiving support and discussing with other students.

Gama [19] reflects that the setup might have benefited from an even more careful structuring of the data the students received and also that there tended to be a quick division of labour among students that meant that not every student got to work on all parts of the projects. The latter is suggested to be solved by a forced task rotation thus making the format proposed by Gama [19] even more structured.

Analysing these these two examples in a PT perspective is closely linked to the two core mechanisms, Mastery Based Learning and Challenge-Based Learning, discussed by Cutts et al. [10] and Gama [19] respectively. What hackathons do in these two education-based examples is to establish intense time-constrained activities that are a) *co-located* b) *framed in terms of specific tech and challenges* c) *and with ample in-room support for students.*

4.3.3 Demystifying Design Materials. Another example on a modified hackathon for supporting learning, was the hackathon organized by Karimi et. al. [26].

Input: They specifically selected design materials which were not entry-level 'plug and play' materials as input for a short hackathon lasting five hours [26]. In addition to the choice of material, Karimi et. al. designed the overall challenge and theme for the hackathon to be about augmenting a community garden with technology, a setting meant to be familiar to the teachers.

Process: The choice of design material was motivated by Karimi et. al's objective of "demystifying technology", so that teachers could develop experience with the technology in order to be able to apply the technology into their own classrooms as part of their teaching.

Effect: Karimi et. al. believe that this approach is more sustainable and has longer-term impact compared to if the teachers were only presented for the 'plug and play' types of technology. However, despite this motivation, the authors conclude that the: "[...] oneday hackathon workshop did not provide sufficient background to allow teachers to gain the confidence needed to implement their own digital technology project in a classroom." [26]. They still reflect on the hackathon as a potential format for providing teachers with experiences with technology that move beyond only appropriating 'plug and play' technologies into their classrooms, and note that, in general, appropriating technology into their teaching will unlikely ever be straightforward for teachers, given their constraints [26].

Though the hackathon was only partially successful [26], we see the attempt of providing experience with the "mysterious" and unfamiliar (the technology) in a familiar setting (a community garden) as an interesting approach to balancing the input for a hackathon format, where the goal is to expose non-designer participants to the messy reality of designing with technology that is not 'plug and play'.

5 DISCUSSION

What do hackathons do in their specific contexts? To engage with this question, we have performed a PT analysis on 16 case studies studying the processes and effects of hackathons. We have sought to explicate the underlying assumptions of 16 case studies that modify hackathon formats for specific purposes through our analysis in the previous section. We have offered our case study analysis as a critical effort to prepare the grounds for researching and evaluating hackathons formatively [17] by investigating which adaptions worked well under which conditions, what kind of problems were faced, and how the overall process for organizing hackathon can be improved. Carrying forth insights gained from our analysis, we now turn to discussing the role of hackathons and how they may be modified for future HCI research.

First, we discuss the retrospective insights on modified hackathon formats, in terms of the three categories: Participation, Sustainable Outcomes, and Learning. Following this, we discuss prospective considerations for future research and organization regarding hackathon formats.

5.1 Retrospectives on the Modified Hackathons

Researchers have noted that it is "difficult in particular for novice organizers to decide how to run an event that fits their needs" [36]. We have provided a catalogue of 16 case studies and presented a PT analysis of these cases studying their modified processes and effects. By juxtaposing and comparing these cases, we hope that future research with and on hackathons can systematically build on the knowledge and experiences in relation to organizing hackathon formats for specific purposes. Oftentimes, modifying a hackathon format was motivated by general criticism of hackathon formats, such as the lack of sustainable long-term outcomes and lack of diversity in participation. The analyzed cases illustrate steps towards exploring formats which may accommodate these critique points.

5.1.1 Participation. As mentioned in the introduction, the HCI community has an ongoing critical dialog about hackathons. Lodato, Gregg and DiSalvo noted that though hackathons can produce new imaginaries in the performance of citizenship, hackathons risk reinforcing specifically a technological citizenship, while neglecting to ask who do not participate, who are not able to participate or is not represented in hackathons [12]. Or in the words of Irani: "There was no time to care by drawing in those who have been silenced [...] There was only time for the entrepreneurial spirit." [25]. Through analyzing the nine cases which broadly revolved around the topic of participation, we noticed several different ways of modifying hackathons to invite a broader audience to partake in technology development, see [4, 24, 29, 30, 33, 35, 41, 48, 49].

An input used to invite a broader audience to take part in developing technology was the choice of which design material to provide for participants. This reflect the findings from the related work of Taylor and Clarke [46], who studied how non-technical participants can participate in hackathons appropriated for a non-technical audience. While the choice of design material in hackathon formats can be used to lower the barrier for developing technology for non-technical participants, design material can also be used because it is a barrier. This was illustrated in the hackathon of Karimi et.al. [26].

An often-mentioned suggestion for broadening participation in hackathons, is inviting or recruiting specific people who may not normally participate in hackathons. However, the authors from [30, 33] illustrate that it may not suffice with targeted recruitment. From the perspective of PT, in order to move towards an intended impact of a broader and more diverse participation in hackathons, for example by minorities or end-users, there needs to be carefully designed activities and mechanisms during the process which can support their participation.

In their guidelines for organizing corporate hackathons, Pe-Than et.al. reflect that teams with mixed skilled participants most likely will consist of novices and experts [38]. In order to bridge the gap between novices and experts, Pe-Than et.al. suggest for example brainstorming as a useful technique: "[...] that allows everyone to feel their ideas are heard and seems particularly effective in helping those who identify as minorities." [38]. Brainstorming is, however, a technique which is used for generating ideas, which is usually needed in the *beginning* of a design process. To keep bridging the gap between different groups of people during the process of hackathons, a range of different and synergetic activities throughout the process may be necessary. As illustrated in the analysis of the hackathons of Birbeck et.al. and Hope et. al. [4, 24], a range of different activities and mechanisms may accomplish similar intended effects, such as facilitating communication and collaboration between different groups of people. Therefore it is important to evaluate experiences with modifying hackathons for specific purposes, to explicate whether assumptions behind initiatives hold water, and share these insights.

5.1.2 Sustainable Outcomes. The output of hackathon formats have been criticized on several dimensions, for example of being of poor quality, lacking in utility and usability [18].

Through PT, we can juxtapose and compare the different approaches to creating more sustainable outcomes. These approaches were particularly pronounced in the cases of [9, 20, 52]. However, we noticed other initiatives which were motivated with contributing to more shareable outcomes, for example the workbooks in [49], and the documentation prize in [33]. Making outcomes of hackathons shareable could potentially help improve some of the issues surrounding hackathon outcomes. The inputs of the workbooks and the documentation prize aim at making the design processes more transparent in two different ways: The workbooks were intended to capture *work practices* and make them shareable, while the documentation prize was intended to motivate participants to make high-quality instructions so others could understand their work. In that way, the captured work practices become a form of shareable output. Even though an immediate output in itself is not good quality, shareable outcomes can be more valueable for longer term effects, such as contributing to a shared knowledge repository, as was the case by Webb et.al. [52].

In line with the approach in Chan et. al.'s hackathon [9], the hackathon by Birbeck et. al. offer inspiration for how to support the output of hackathons. In the case of Birbeck et. al. this was done through post-hackathon stakeholder discussion about the hackathon prototypes. They argue that involving stakeholders in post-hackathon discussion like these, can make way for potentially integrating the design outcomes into "self-harm care pathways." [4].

While these concrete examples may potentially contribute towards more sustainable hackathon outcomes, we need more studies to explore these initiatives and their effects. Furthermore, while these initiatives aim at making work practices transparent and outcomes shareable, sustainable outcomes should also be considered in terms of participation. In a participatory design context, involving end-users as participants carefully and meaningfully in design processes is essential for ensuring outcomes which authentically meet end-users needs [5]. Therefore, the question of how sustainable outcomes are may also depend on who participates and how they participate. As we observed from the cases, the participation of people has to be thoroughly considered in order to go beyond participants as only inputs towards employing activities and mechanisms which support their participation throughout the hackathon.

5.1.3 Learning. Learning and developing skills has been one of the major promises of hackathons [51] and given the focus of education on novel ways of engaging with difficult topics it was unsurprising that we found a set of papers on education such as [10, 19]. We consider such efforts attempts at using alternative *programs*, where classical homework, classroom instruction and exercises would be the normal way of doing it. However, the studies also show that hackathons are no silver bullet in this area. Rather, the examined corpus show how the positive learning outcomes reported is the result of a careful tweaking of both input and activities to ensure that the vital mechanisms of Mastery Based Learning and Challenge-Based Learning become effective and leads to outcomes appropriate for the teaching goals outlined in the papers. What PT offers in this case is a way of being precise about the interplay between inputs, activities, mechanisms and outcomes.

5.2 Considerations for Organizing Hackathons

Even though there are several problems with using hackathons as a research method, based on our analysis we believe that hackathons offer unique strengths and advantages that can be carefully leveraged for future HCI research. While we are in agreement with several of the existing critiques on hackathons, we argue that modified hackathons can and should be utilized as a part of future HCI research since they can offer a form of methodological democracy in the face of epistemological hegemony. Epistemological hegemony "represents a concern for the domination of one view of knowledge and the subordination of all other forms" [8]. By modifying the processes and desired end goal of hackathons, researchers have the opportunity to include those who have been historically marginalized when considering the design of technology mediated futures. Through our PT analysis and comparison of 16 cases studies, we have foregrounded the researchers' point of view who have attempted to explore and add various dimensions to the democratic aims of participation through modified hackathons.

Pushing our argument further, we argue that modified hackathon formats for research should be understood and evaluated as exercising methodological democracy by both researchers and partcipants, albeit not without problems. Based on our cross-case analysis, we proposition that modified hackathon formats should aspire to make two types of contribution for HCI research. One type of contribution is concerned with the desired end goal of the research project while the other type of contribution is about exercising methodological democracy by redefining hackathon formats for further knowledge production. The latter contribution extends beyond the scope of the individual project and can only be made sense of in relation to how other researchers are utilizing hackathons in their specific contexts over a period of time. Since researchers are often, though not always, positioned as the driving and defining force of hackathon activities and formats, exercising methodological democracy is attributed to the researchers' agency by default. However, participants' contributions towards methodological democracy in the face of epistemological hegemony is currently underexplored and requires further engagement in future HCI research utilizing modified hackathons.

Understanding modified hackathons as exercising methodological democracy involves acknowledgement of participant contributions beyond individual project outcomes towards the development of broader HCI methodology and theory related processes and mechanisms. Because participants' contributions towards methodological democracy may not always be immediately evident and most likely evolve beyond a specific project, we speculate that this aspect is often overlooked and/or overshadowed by insights that are circumscribed within the scope of individual projects through research writing. However, there are a few research works that have critically foregrounded participants point of view thereby questioning, re-ordering, and expanding the processes and outcomes of hackathons. For instance, DiSalvo et al have argued that "civic hackathons produce new imaginaries of place, belonging, and hope in the performance of citizenship [wherein] these imaginaries provide crucial affective mechanisms for mobilizing energy and ultimately resources to secure political outcomes in local communities"[12]. Similarly, exploring feminist hackerspaces, Fox et al have noted that "designing how the space should look, feel, and run, members reframe activities seldom associated with technical work as forms of hacking [thereby] shift concerns for women in technology from questions of access (who is included) to questions of recognition (who is visible) while grappling with productive ambiguities in between" [15]. In both these cases, participants' points of view are intentionally foregrounded as driving methodological decisions with respect to the research project but also towards the development of broader HCI methodology and theory related to hackathons.

For researchers who are interested in using modified hackathon formats, based on our cross case analysis, we recommend framing their work and claiming contributions in relation to exercising methodological democracy. Research utilizing modified hackathon formats for further knowledge production should be evaluated beyond individual project goals and aim to push back on epistemological hegemony by exercising methodological democracy. This does not mean that all modified hackathon formats are necessarily problem free but should rather be treated as critical attempts at questioning and rearranging existing power relationships with respect to research knowledge production.

ACKNOWLEDGMENTS

We thank our anonymous reviewers and Midas Nouwens for helpful feedback. This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 740548).

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