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Does It Make Sense to Hack Online? – A Multiple Case Study on Team Collaboration in Remote Hackathons

Master's Thesis (20 ECTS)

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Abstract:

Hackathons are rapid design and development events used by organisations to maintain their competitive advantage, create innovations, and explore new business opportunities. Until lately, hackathons have been primarily in-person events where collocated teams solve challenges of interest to them. However, due to the global COVID-19 pandemics and work shifting online, remote hackathons have become the norm. The research around the remote hackathon phenomena is still being developed. Thus, this study contributes to exploring the remote hackathon topic from a collaborative aspect. More specifically, the way teams collaborate in a remote setting and the effect of the hackathon setting on collaboration. The findings indicate that some characteristics of in-person hackathons, such as preparing for the hackathon and extensive mentoring, could also be identified in the remote setting. However, other affordances, like networking and interaction with other teams, have noticeably diminished. The contribution of the thesis is a set of guidelines for hackathon participants and organizers to better cope with the online format of hackathons.

Keywords:

Hackathon, online hackathons, collaboration, remote work, innovation

CERCS: P170 - Computer science, numerical analysis, systems, control

Kuidas toimivad virtuaalsed häkatonid? – Meeskonnatöö juhtumiuuring kahel virtuaalsel häkatonil

Lühikokkuvõte:

Häkatonid on arendussündmused, mida erinevad organisatsioonid kasutavad konkurentsieelise tagamiseks, innovaatiliste ideede loomiseks ja uute ärivõimaluste avastamiseks. Kuni eelmise aastani, olid häkatonid peamiselt koosviibimisel põhinevad sündmused, kus ühises asukohas olevad meeskonnad lahendasid endale meelpäraseid väljakutseid. Kuid COVID-19 pandeemia tõttu on populaarsust kogunud kaugtöö ning ka häkatonid on muutunud virtuaalseks. Kuivõrd virtuaalsete häkatonide kohta on teadustööd tehtud vähe, on käesoleva töö eesmärk uut formaati uurida tiimide koostöö aspektist. Täpsemalt uuritakse, kuidas häkatoni tiimid kaugtöö formaadis koostööd teevad ning kuidas häkatoni disain ja korraldus koostööd mõjutavad. Töö tulemused näitavad et, mitmed tavapäraste häkatonide omadused nagu tiimide ettevalmistavad tegevused ja mentorluse oluline roll, on säilinud ka virtuaalses formaadis. Kuid mõned aspektid, nagu uute inimeste kohtamine ja suhtlus teiste meeskondadega, on oluliselt vähenenud. Töö väljundiks on soovitused häkatoni osalejatele ja korraldajatele, et virtuaalses formaadis paremini toime tulla.

Võtmesõnad: Häkaton, virtuaalne häkaton, koostöö, kaugtöö, innovatsioon

CERCS: P170 - Arvutiteadus, arvutusmeetodid, süsteemid, juhtimine

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1 Introduction

"The only way to win is to learn faster than anyone else." a quote by Eric Ries describes the ideal mindset in today's fast-paced world [1]. This mentality guides an increasing number of organisations, who, in order to maintain their competitive advantage, create innovations, and explore new business opportunities, have found their way to hackathons [2]. Hackathons are rapid design and development events that traditionally occur in a restricted timeframe, over the span of one to two days [3]. During this time, hackathon participants, who are often grouped into smaller teams, work on completing projects of interest to them [4]. The main objective of a hackathon depends on its theme, and although hackathons are often perceived as events meant only for software development, hardware solutions and other domains should not be excluded [5]. The solutions can be produced for various industries such as education [6], [7], information technology [8], [9], healthcare [10], [11], biotechnology [12], non-profits [13], large corporations [8], [14] and others. Therefore, the objectives of an event can, for example, include developing innovative ideas [5], [14], solving civic issues [13], [15], or building a community [6], [16].

Hackathon as a term is a combination of the words *hack* and *marathon*, and according to Briscoe and Mulligan [5], it was first used in June 1999 by the employees of Sun Microsystems (later acquired by Oracle) and OpenBSD. Soon after that, starting from the early 2000s, hackathons began to gain popularity and became known as an effective approach to developing new technologies and locating funding quickly. By their origin, hackathons are in-person events where the work is conducted by a collocated team of 3-5 people who, in some cases, such as corporate hackathons, might be acquainted. However, it often happens that the participants do not know each other, and hackathons also serve as networking events. Furthermore, meeting new people is one of the main features next to learning that motivates people to participate in these rapid development gatherings [5]. Another common characteristic of in-person hackathons is that the communication between organisers, teams and team members takes place face-to-face [12]. This has been the most popular format for organising hackathons since the concept emerged in the early 2000s. However, due to the COVID-19 pandemic, there has been a rise in online events. It is reported that over 30% of work is being pursued remotely since the beginning of the pandemics [17], and the same is happening with hackathons. Only the pandemic-focused *#hackthecrisis* movement alone reported that 68 different COVID-19 related remote hackathons were held in the first half of 2020 [18]. On the contrary to collocated events, the remote hackathon format is characterised by distributed yet synchronous collaboration, meaning that the participants are in separate locations but work together at the same time [19]. The collaboration is realised with the help of different remote working tools such as Slack, Zoom, Devpost and Menortnity [10], [15].

Most research until this point, however, has focused on in-person hackathons, which have been studied in regard to their design [20], participants [8], [12], mentoring [21], and project continuation [9]. For example, Trainer et al. [12] were looking into how brief collocation influences team development at in-person hackathons and if and how do team members form close ties with each other during these events [12]. Moreover, as hackathons can be

meant for different audiences, Pe-Than et al. [8] studied corporate hackathons and looked at the aspects that affect project sustainability and the impact that the hackathon process has on participants. Furthermore, the effects of mentoring at a hackathon were researched by Nolte et al. [21]. Additionally, the design of hackathons has been previously studied because, depending on the goals and opportunities, hackathons can be organised in different ways. Nolte et al. [20] have identified 12 main aspects, which have an essential role to play in a design of a hackathon, including topics such as the goal of the hackathon, participant recruitment, stakeholder involvement, and others [20]. The hackathon topic is summarised by overarching literature reviews from Medina Angarita et al. [22] and Porras et al. [7], analysing the outcomes of hackathons and opportunities to use these events in the educational context respectively.

However, there is a gap in research on remote hackathons. Although some work does exist on the topic, for example, the pandemic-focused EUvsVirus remote hackathon was analysed by Bertello et al. [23] from the perspective of using Open Innovation and concluded as a case study by Brereton [15]. The existing studies focus only on single events, and the general perspective of teams collaborating in an online setting has not been explored. Thus, this study aims to decrease the gap in the research and create an understanding of distributed collaboration in a hackathon setting.

The focus of this research is particularly on how teams collaborate during an event because it will help to understand how teams adapt to an online setting and cope with the challenge to collaborate remotely. The choice of the research focus is further motivated by the fact that collaboration within teams is at the core of each hackathon, the lack of studies on the topic, and findings from previous studies, which have discovered dependencies between the hackathon outcomes and the characteristics of the participating teams [22]. Thus, the primary research question is formed: *How do different teams collaborate during an online hackathon? (RQ1).* The question specifically tackles aspects of team formation, project selection, and task division, which are the typical activities of hackathon teams [20]. Furthermore, it will cover the asynchronous (collaboration happening at a different time) and synchronous (collaboration happening at the same time) collaboration styles within teams and tools used for online communication, as those aspects are relevant in the context of distributed collaboration [24].

Furthermore, it has been found that the success of the collaboration could depend on the setting it takes place in [22]. Moreover, the novel remote environment is expected to have its influence on hackathon design and, therefore, the collaboration. Hence, the second research question is formed: *How does the hackathon setting impact team collaboration? (RQ2)*. The work around this question will concentrate on how hackathon organisers arranged the event structure, team formation, mentoring and tool selection for collaborating in an online setting. Additionally, these aspects are expected to be influenced by the remote setting. Based on the findings of the two research questions, the contribution of this thesis is a set of guidelines both for hackathon participants and organisers that will help the latter to structure their events and participants to mitigate potential risks in an online hackathon setting.

The previously presented research questions are answered by conducting a mixed-methods multiple case study of six hackathon teams from two different remote events – the PEARC20 hackathon in the US and 48 for the Future event in Estonia. The PEARC20 hackathon took place adjacent to the Conference on Practice and Experience in Advanced Research Computing (PEARC) and was organised by members of the high-performance computing (HPC) community [25]. The aim of the event was to attract students to the HPC community. In comparison, the 48 for the Future hackathon was organised by an Estonian foundation, Garage 48, with a focus on finding solutions to the issues caused by the COVID-19 pandemic both locally and globally [26]. Altogether 15 team leads, and members were interviewed, and a post-hackathon survey was conducted amongst them.

The findings of this study provide an insight into the impact of being locally distributed on synchronous collaboration in the context of hackathon teams. The results are structured according to the four key concepts of distributed collaboration - common ground, coupling, collaboration readiness, and collaboration technology readiness, by Olson and Olson [24] with an additional section around hackathon specific findings. Consequently, the contribution of this study is twofold. Firstly, providing an understanding of the affordances of synchronous collaboration in a non-collocated setting and, secondly, presenting suggestions to hackathon participants and organisers on how to collaborate in an online context successfully.

The remainder of the thesis is structured as follows - chapter 2 discusses the background of hackathons to provide a context for the thesis. It will uncover the history of hackathons, introducing different understandings, methods and looking into previous research that has been done in the field. In chapter 3, the research setting and methodology are introduced in further detail. Chapter 4 will give a precise overview of the findings that were discovered during the research and analysis. Furthermore, chapter 5 will include a discussion on research questions and thesis contribution in the form of practical implications. In chapter 6, the conclusion of the study will be presented. Part of this thesis' findings are published in a paper currently under review - "Socio-technical Constraints and Affordances of Radical Virtual Collocation in Online Hackathons", submitted for the 24th ACM Conference on Computer-Supported Cooperative Work and Social Computing on October 23–27, 2021.

2 Background

In todays' rapidly changing world where customers' needs constantly change, and the competitors are breathing down each other's necks, businesses are pressured to stay on top of changes and innovate. The fast enough pace could be held by engaging in product innovation and technological strategies [27]. Creating innovations can be approached either from an external or internal perspective. However, the latter has become almost obsolete due to the increase in external knowledge creation and talent mobility and has been overtaken by Open Innovation (OI). Chesbrough defines Open Innovation as *"Utilizing external as well as internal ideas as inputs to the innovation process, combined with employing internal and external paths to market for the results of innovative activities."* [28]. In order to maintain their competitive advantage, create innovations and explore new business opportunities, companies and organisations combine the principles of OI and rapid learning and have found their way to hackathons [2]. However, innovation is not the only driver for hackathons. The format has also been found to suit well for social and educational events, as it enables participants to experiment, learn and meet new people [2].

Hence, hackathons are an increasingly popular approach for creating innovative solutions and building communities. According to the hackathon.com database, in 2018, 5636 hackathons were held, which was a 26% increase from 2017 [29]. Moreover, the areas in which hackathons are conducted have expanded from technology-centric topics [8], [9] to fields such as education [6], [7], healthcare [10], [11], biotechnology [12], non-profits [13], large corporations [8], [14] and others. With that, also the target audience of hackathons has become more diverse and is now ranging from students [6], [30], corporate [8] and SME employees [2], industry-specific personnel [11] to community members [30].

To uncover the background of hackathons and provide a context for the study, the following sub-sections will give an overview of the historical perspective of hackathons (section 2.1), the hackathon format (section 2.2), and previous work conducted on the topic (section 2.3).

2.1 The historical perspective of hackathons

As mentioned above, according to Briscoe and Mulligan [5], the first hackathons took place in 1999 amongst the employees of Sun Microsystems and OpenBSD. Although hackathon is the most popular term for such kinds of events, then depending on the characteristics, hackathons could also be named as code day, referring to a daylong event, sprint, when talking about technologically focused events or codefest, aiming to avoid the negative term of hacking [5]. The first hackathons, which took place in the late '90s, were utterly technology-oriented and tackled cryptographic development and Java programming. Briscoe and Mulligan [5] suggest that the main elements of a hackathon derive from LAN (local area network) parties. The common aspects identified between LAN parties and early hackathons are the timeframe for gathering so that activities are pursued overnight and the fact that the people who have come together are technology enthusiasts. Starting from the early 2000s, these intense and effective events began to gain popularity and became known as a fast-paced approach to developing new technologies, locating funding, and recruiting talent. Since then, hackathons have spread from gatherings meant mainly for young

technology enthusiasts and coding to a cross-industry tool for coming up with innovative approaches [5].

2.2 The hackathon format

According to Komssi et al. [2], there are three phases to every hackathon – the pre-hackathon phase, the hacking itself, and the post-hackathon phase. Each of those has its specific activities (Table 1). There are two main objectives in the pre-hackathon phase: coming up with the ideas and forming teams. Coming up with and collecting ideas before the hackathon is essential so that time at the event could be used as effectively as possible. However, in some cases, the challenges or ideas are proposed in the early phases of the hackathon itself. Regarding the team formation, the hackathon type should be considered, so whether the event is more internally or externally focused [2]. In the case of external hackathons, the participants can be anyone interested in the topic, whereas internal hackathons are meant for employees or members of a specific company or organisation [20]. When the ideas are selected and teams formed, participants can prepare for the hackathon by doing further research on the topic, planning the tasks, and their distribution amongst team members [14].

The hackathon itself generally lasts around 2 or 3 days. However, some concepts extend to 5 days in length [2]. The event usually starts with presenting the main objectives and incentives, if available. Some final team formation could be done at the beginning of a hackathon, for example, when there is a need to recruit additional members with specific skills. Once the introductions are completed, the hacking within the teams starts [20]. During this time, teams work on completing the projects of interest to them [4], and the common activities include ideation, if not done beforehand, further project scoping, and developing the idea [14]. In order to get an overview of how different teams are doing and allocate additional support to the teams in need, it is suggested that the organisers include checkpoints throughout the hackathon [20]. Additionally, the core part of hackathons could include mentoring sessions for additional feedback and guidance, talks or training sessions to provide domain knowledge, and different social activities for relaxing and networking [20].

Hackathons traditionally end with teams presenting their solutions and, if available, showcasing the prototypes created during the event. In the case of competitive hackathons, a jury will evaluate the ideas presented, and the winning ideas might receive further funding or other prizes [5]. In the post-hackathon phase, it is essential to distinguish whether the idea will be worked on further or not. It is common practice that the ideas which receive additional funding will be continued, as both the team and the idea were assessed to be viable by the jury. However, when no definitive decision is made either by the team itself or the judges, then the participants often separate, and the ideas are abandoned [2]. According to recent research by Nolte et al. [9], around 65% of hackathon projects are discontinued, and after a week has passed from the hackathon, only 17% of projects are being pursued. Table 1 presents an overview of previously described hackathon phases and activities that are pursued.

Table 1. Overview of hackathon activities in different phases

Hackathon phase	**Activities**
Pre-hackathon phase	Idea selection, team formation
Hackathon phase	Introducing event objectives; team formation; project scoping; work on the idea; checkpoints; mentoring; talks and trainings; social activities; showcasing solutions; choosing winners
Post-hackathon phase	Project continuation

Recently, however, online hackathons have increased in popularity. This can be associated with the emergence of COVID-19 pandemics, which has shifted over 30% of work to be done remotely [17]. Although little research has been published on remote hackathons, the studies around EUvsVirus event [23], [15], and EasterHack [10] create an understanding of the virtual and distributed hackathon format. In contrast to in-person hackathons, where the teams are collocated and communicating face-to-face [12], the remote format is characterised by distributed yet synchronous collaboration, meaning that the participants are in separate locations but work together at the same time [19]. The collaboration is realised with the help of different remote working tools such as Slack, Zoom, Devpost and Menortnity [10], [15]. Similar to collocated hackathons, mentors are included via mentioned channels to facilitate the rapid work better. Another similarity is that for structuring the hackathon, organisers set up checkpoints and pitch deadlines for the teams to follow. However, the opening and closing of remote events differ from physical ones. The ceremonies consist of pre-recorded interviews and keynotes or are carried out from special filming studios and via streaming solutions such as Facebook or YouTube Live [15], [10]. As online hackathons are a recent phenomenon and have not been researched thoroughly, they are associated with challenges, which could be further studied.

2.3 Related work

On the contrary to remote hackathons, a considerable amount of literature has been published on in-person events. The research varies along several dimensions: the build-up of hackathons [20], the focus of hackathons [8], how different hackathon teams perform [12], [31], and how the design and outcomes of a hackathon are connected [22]. As the current work aims at understanding how hackathon teams collaborate in a remote environment and how the hackathon setting affects that, the existing literature will be explored from the same perspective.

In their study about hackathon outcomes, Medina et al. [22] found that the organisation of a hackathon in many cases contributes to the event's outcomes. The importance of hackathon setting is furthermore confirmed by the "Planning Kit" developed by Nolte et al. [20] and several other resources published around organising a hackathon [32], [33]. The "Planning Kit" describes 12 key decisions that a hackathon organiser must think of, such as participant recruitment, agenda, and mentoring. Meaning that the organisers should plan how and via which channels the participants are recruited and whether everyone registered

can participate or a preliminary selection of participants must be made. Regarding the agenda, organisers should consider details such as communicating the organisational details, scheduling checkpoints, thematical trainings and final presentations. When it comes to mentoring, it should be decided which kind of mentors (e.g., technology, design, marketing, business development mentors) are available by which means, and how much they will be able to communicate with the participants. For example, it has been found that mentors should form a personal connection rather than a remote one [21]. Although the mentioned aspects of hackathon organisation have been developed for physical events, the current study aims to discover their relevance regarding the remote hackathon format.

When the organisational side is settled and the hackathon starts, the focus shifts to hackathon participants and teams. Multiple existing studies explore hackathons teams and their dynamics [8], [12], [22], [31]. For example, Trainer et al. [12] were looking into how hackathon teams make use of the collocation and situated co-worker familiarity, Nolte et al. [8] studied how corporate teams approach hacking, and Medina et al. [22] discovered several team characteristics, such as teams skillset and size, that contribute to the outcomes of hackathons. During a hackathon, a team goes through multiple phases where its characteristics are of importance. At the beginning of hackathons, teams face a coordination challenge because when the team members do not know each other, they need to build trust before they can start hacking [8]. Furthermore, it has been found that trust is relatively harder to create in an online environment [34]. Therefore it is somewhat easier for teams where members are previously acquainted, as they can build upon their existing relationships, whether in online or offline environments [8]. Another influencing factor of teams' performance is the skillset of members and how the work is divided between those skills [9], [14]. A variety of skills have been found to produce diverse results [35] and help teams when solving creative and innovative tasks [9]. In addition, the diversity of participants enables collocated knowledge exchange and provides learning opportunities, especially as the participants are working side-by-side and have the possibility of spontaneous discussions [31]. The previously mentioned aspects have been studied in collocated hackathon events. However, this study seeks to explore the same findings in a remote hackathon setting.

Although the research on remote hackathons is limited, findings that can be associated with online events have been identified by Brereton [15] and Bertello et al. [23] in their papers about the EUvsVirus event and Braune et al. [10], who studied a health-themed online hackathon EasterHack. In the case of studied events, it was found that spending long hours behind the computer can be tiring and that participants also engage in other work-related and personal commitments in parallel to the hackathon [10], [15]. Additionally, disadvantages of the used online platforms, such as a steep learning curve [15], technical issues, data security, and overwhelming effect [10], were reported. For example, in the EUvsVirus hackathon, the glitches on the Devpost platform delayed the allocation of mentors and teams [15]. Participants of the event also mentioned that mentoring was harder to access than in physical hackathons [23]. Furthermore, the participants of EasterHack would have preferred more introductory activities in order to understand the online

hackathon concept and familiarise with other team members [10]. However, the remote format was also found to have similarities and advantages to in-person events. For example, Braune et al. [10] found that by their dynamics and synergies, remote and in-person events are quite similar. Nevertheless, online events are more cost-effective as they are noticeably cheaper. Another advantage is that the mentors and participants could participate from different geographic locations, avoiding the travel costs and resulting in a broader, more diverse audience. Although these findings are derived from studies around single events, the same aspects are aimed to be covered in the current paper.

Despite the fact that online hackathons haven't been researched that thoroughly, other forms of online collaboration have been studied before. In 1994 Grudin [19] published his typology of collaborative systems where he distinguishes between two dimensions of collaboration – space and time. As the focus of the current study is collaborative online events, the definition of remote synchronous collaboration – a collaboration that happens simultaneously but in a different place - from Grudins' taxonomy is relevant in this context. Remote synchronous collaboration has been studied by Olson and Olson [24], who established the four key concepts for effective distance work. After exploring synchronous work both in a collocated and distributed setting and analysing the results, they created a framework to predict future successes and failures. The concept includes aspects such as common ground, coupling, collaboration readiness, and collaboration technology readiness. Common ground refers to the mutual understandings amongst members who are collaborating. Coupling defines how the work is organised. Collaboration readiness looks at how willing are the team members to collaborate with others, and collaboration technology readiness assesses the eagerness to adopt different technologies for more successful cooperation. Ultimately, it was found that teams with high common ground, who couple their work loosely and are open to collaboration while using collaborative technologies, are most likely to succeed in remote work [24]. Even though the previously discussed research was conducted in a corporate setting, the findings around remote collaboration can be transferred and observed in the hackathon context.

3 Methodology

To answer the research questions (RQ1, RQ2) stated in the introduction, a mixed-methods, multiple case study was conducted. This methodology was chosen to research remote hackathons in their natural context, as they are a phenomenon that has not been extensively studied before [36]. The focus of the study was two remote hackathons held in 2020, the 48 for the Future hackathon organised by an Estonian company, Garage 48, and the PEARC20 hackathon, which took place adjacent to the PEARC20 conference organised in the USA. The following section describes the setting in which the research was conducted (section 3.1), how the data was collected during the study (section 3.2) and the approach to analysis (section 3.3) in further detail.

3.1 Setting

The following part introduces the setup of the mentioned hackathons, which are the basis of this study. The sub-sections describe the 48 for the Future hackathon and the PEARC20 hackathon in further detail. These two events were selected for the study as they are different in their design. The events vary, for example, in their focus, participants, themes, duration, idea selection, and participant recruitment strategies. The specific comparison of the events is brought in Table 2. The difference of the events contributes to receiving a more versatile input for the study and answering the second research question about the effect of hackathon setting in particular.

48 for the Future hackathon

48 for the Future is a remote hackathon that was held from the 3rd to 6th of December in 2020. The hackathon was organised by Garage 48, which is an Estonian foundation focused on organising hackathons and makeathons (events where the focus is on creating physical objects instead of IT-based prototypes) both locally and globally [37]. Therefore the 48 for the Future hackathon was also organised and led from Estonia. However, the participants could join in from all over the world. The 72-hour hackathon was a follow-up event for a prior Garage 48 hackathon, Hack the Crisis, held in March 2020. The theme of both hackathons was coping with post-COVID changes and finding solutions to the issues caused by the COVID-19 pandemic. Therefore, there was not a certain target audience for the hackathon, and everyone with an idea or a wish to contribute could join. Nevertheless, the teams were divided between 7 main topics – future of creating trusted networks, future of education, future of work, future of healthcare, future of travel, tourism and hospitality, future of entertainment and sports, and future of small and mid-sized enterprises (SMEs).

In the case of 48 for the Future, both teams and individuals could register. One week prior to the hackathon, two matchmaking events were held. These were meant for existing teams to recruit additional members, individuals to present their ideas and assemble a team or find a suitable idea to contribute to. Thus, the teams were formed before the event. After the registration and matchmaking, the organisers chose the teams which qualified for the hackathon – 41 ideas were selected for the event, and 37 demos were presented at the finals. Due to the COVID-19 pandemic, the hackathon was held in a fully remote setting. All the

activities took place in digital channels, and hackathon participants and organisers did not meet physically. For the hackathon communication, organisers had set up a Slack workspace, where most of the important information was exchanged. Slack was also the suggested communication tool for the participants, as each team had its own channel. The video calls between organisers and participants were held over Zoom, and presentations to all the participants, such as ceremonies and pitching, were broadcasted over Facebook Live.

The hackathon was structured around five checkpoints altogether that took place each morning and evening. For every checkpoint, there was a list of tasks that the teams needed to prepare and present. The check-up meetings were led by lead mentors assigned according to the seven topics of the hackathon. In addition to the lead mentors, there were additional 74 mentors available for helping the participants. The mentors were grouped into four batches by their expertise – business development, marketing, design, technology. The teams could contact mentors over Slack or book one-on-one Zoom calls. By the end of the hackathon, all teams were required to submit a video pitch of their idea. From 41 participating teams, the 15 best pitches were selected, which made it to the finals. At the end of the event, a seven-member jury of experts selected seven top teams who received follow-up mentoring as a prize.

PEARC20 hackathon

PEARC20 remote hackathon took place from 27th to 29th of June in 2020 adjacent to the Conference on Practice and Experience in Advanced Research Computing (PEARC). It was organised by members of the high-performance computing (HPC) community in the US. The aim of the 48-hour hackathon was to attract students to the HPC community. The hackathon was organised remotely, meaning that all hackathon activities took place in online channels and extended over three times zones of the US.

Before the hackathon, the organisers recruited mentors and participants. The participants could register via an online form, and altogether 14 participants from various fields such as computer science, environmental science, and biology joined in. The mentors were invited from the HPC community. Both the mentors and participants were trained before the hackathon to prepare for the event. In the case of the PEARC20 hackathon, the teams were created after the hackathon kick-off. The teams formed around the themes of the hackathon, which were proposed by the mentors, based on their prior interests. At first, the participants could choose which theme they were interested in, and after joining a specific mentor, a concrete project idea was developed. Altogether four hackathon teams were formed.

The communication of the hackathon took place in Slack and Zoom. All the teams had their dedicated Slack channel together with the mentor, and this was used for keeping in touch between the Zoom calls. Zoom was used for the kick-off of the event, and afterwards, the teams could work in dedicated breakout rooms. The organisational info, such as the event agenda and contact information, was accessible from a GitHub page.

For structuring the event, checkpoints were held twice a day. Teams were required to present their progress and received feedback. The event concluded with a final checkpoint, where teams presented their idea and had to submit the code to GitHub. The presentations were

also broadcasted to the HPC community, who chose their favourite idea. Additionally, a jury of HPC community members selected the winner. Finally, both the viewers' favourite and the jury's top one received a prize.

Table 2. Comparison of hackathons selected for the study

	48 for the Future	**PEARC20**
Duration	72 hours	48 hours
Theme	Hacking the post-crisis economy	High-performance computing
Goal	Creating solutions to build a stronger post-crisis economy	Attract students to HPC community
Idea selection	Prior to the event	At the beginning of the event
Team formation	Prior to the event	At the beginning of the event
Checkpoints	Two times per day	Two times per day
Showcasing solutions	Pre-recorded video pitch	Live pitching via Zoom

3.2 Data Collection

The following sub-sections give an overview of how the data for the study was collected. Sub-section "Participants" explains how and on which basis the participants for the study were recruited. This is followed by the description of the two research methods used for collecting the input – interviews and survey.

Participants

To research the remote hackathon phenomena, understand the collaboration of teams (RQ1) and the impact of the hackathon setting (RQ2), the participants for the study were recruited from the previously described hackathons - 48 for the Future and PEARC20. When selecting the participants, the aim was to cover as large a variety of team characteristics as possible. The goal was to interview teams which differ in various dimensions, such as familiarity, idea creation, and team formation so that the effect of specific characteristics on collaboration in remote setting could be observed. The first dimension that was taken into account was familiarity between team members, meaning whether participants of a team knew each other before the event or not [8]. This was important for understanding whether familiarity influences the collaboration within the team, as it has been found that trust amongst team members, which derives from knowing each other, can improve teamwork [8]. Another dimension observed was idea creation, meaning whether the teams had the idea before the hackathon or came up with it during the event. That was expected to change the experience of participants. Finally, the aspect of team formation was considered, so whether teams were formed prior to the event or at the beginning. As pre-formed teams have the opportunity to prepare for the hackathon amongst each other, this aspect is presumed to influence collaboration.

The 48 for the Future hackathon had altogether 41 teams participating. Because of the multitude of teams, a selection had to be made for the study. Therefore, the teams for research were separately recruited based on the previously described dimensions. The qualified teams were found via Slack, which was the primary communication tool for the organisers and teams. An announcement was posted in Slack, inviting teams to participate in the study. When some teams showed interest, further screening questions were asked regarding the expected characteristics (e.g., "Did your team meet at the hackathon or knew each other beforehand?"). During this process, three suitable teams were selected for the study, and three members from each team were recruited for the interviews. The fit with idea creation and team formation dimensions were assured by the event's design, as only pre-formed teams with at least four members and an existing idea could register for the hackathon.

However, the PEARC20 hackathon had only four teams participating altogether. Therefore, the goal was to recruit all the teams for the study, although one team was failed to be included. Ultimately, six people from three different teams were interviewed, therefore two participants from each team. Regarding the recruitment requirements, these were covered by the way the PEARC20 hackathon was designed. The teams were formed at the beginning of the hackathon, which meant that, in most cases, the participants did not know each other prior to the event. Furthermore, the ideas were chosen after the event's kick-off, meaning that teams could not do any preparation regarding the idea. Table 3 provides an overview of recruited teams and their characteristics.

Table 3. Characteristics of hackathon teams recruited for the study

Hackathon	**Team ID**	**Familiarity**	**Team size**	**Had an idea prior to the hackathon**	**When the team was formed**
48 for the Future	H1A	All knew each other before the hackathon	4	Yes	Prior to the hackathon
	H1B	3 knew each other before the hackathon	5	Yes	Prior to the hackathon
	H1C	5 knew each other before the hackathon	6	Yes	Prior to the hackathon
PEARC20	H2A	None of them knew each other before the hackathon	4	No	Beginning of the hackathon
	H2B	None of them knew each other before the hackathon	4	No	Beginning of the hackathon
	H2C	All knew each other before the hackathon	3	No	Beginning of the hackathon

Interviews

The data was collected from two primary sources. To begin with, semi-structured interviews were conducted with the participants, which were followed by a survey. In order to answer the research questions around remote collaboration (RQ1), the interviews featured open-ended questions about the individual and collaborative experience at the hackathon, which

required elaborative answers from the participants. Altogether six different teams from two different hackathons were interviewed in the course of this study.

All the interviews were conducted within a week from the end of the hackathon to ensure that the feedback from participants would be timely. The interviews were semi-structured and chronologically organised, meaning that in the beginning, the motivations were discussed (e.g., "What was your main motivation for participating in the hackathon?") then the activities during the hackathon (e.g., "Please tell me a little about how you worked as a team?"). The interview concluded with a reflection (e.g., "What was good? What would you do differently next time?"). In order to answer the first research question, "*How do different teams collaborate during an online hackathon?*" (RQ1), the themes of task division (e.g., "How did you decide for who would do what?") and teamwork (e.g., "Which challenges you encountered during the hackathon as a team?") were explored. In addition, the interview focused on the organisation of the hackathon (e.g., "Which tools did you use for working and communicating during the hackathon?") and the remote setting (e.g., "Which challenges did you face because of the remote setting?") to understand how the hackathon setting influences the team collaboration (RQ2). Throughout two hackathons, a total of 15 interviews were conducted (Table 4). In the case of the PEARC20 hackathon, the interviews lasted between 15 and 37 minutes. For the second round of interviews, the interview guide was improved, and the 48 for the Future interviews lasted from 27 to 48 minutes. The improved interview guide is available in appendix I.

Table 4. Overview of study participants

Hackathon	**Team**	**Interview participants**	**Survey participants**
48 for the Future	H1A	H1A01, H1A02, H1A03	8
	H1B	H1B01, H1B02, H1B03	
	H1C	H1C01, H1C02, H1C03	
PEARC20	H2A	H2A01, H2A02	10
	H2B	H2B01, H2B02	
	H2C	H2C01, H2C02	

Survey

In addition to the interviews, a post-hackathon survey was carried out. The survey was compiled as an additional measure to understand the participants' characteristics and compare the teams' experiences and perceptions. It was shared with the participants immediately after the interview, and the answers were received approximately during a week. The survey aimed to contextualise the interview answers and understand the individual and team level collaboration at the hackathon (RQ1). For achieving this, themes such as teamwork, feedback to participation, and personal background were included. The scales for evaluating the mentioned aspects were derived from Filippova et al. [38] as they had been already adapted and validated for self-evaluation in the context of hackathons.

The teamwork section of the survey focused on leadership ("Was there a team leader?"), communication ("To what extent do you agree with the following statements related to

communication within the team."), goals ("To what extent do you agree with the following statements related to your team's goals?") and process ("Would you describe your team process as more...") of the team. The following section about participation contributed to understanding motivations ("To what extent was your decision to participate in the hackathon motivated by…") and satisfaction with the outcomes ("Please indicate your level of agreement with the following statements related to your satisfaction with the outcomes of the hackathon."). The last section aimed to collect demographic details in order to create a context around previous survey and interview answers. A total of 18 answers were collected for the survey. Regarding 48 for the Future hackathon, the survey was sent to nine people who were interviewed, and eight answers were received. In the case of the PEARC20 hackathon, all 14 participants of the hackathon were requested to answer the survey. However, 10 participants responded in total, including the six interviewees and four additional participants. The full survey structure is available in appendix II.

3.3 Method for Analysis

The data for this study were collected from 15 interviews and 18 survey responses. Before the data could be analysed, all the interviews were transcribed. The data were analysed by applying qualitative content analysis [36]. Therefore, the first step was developing initial codes, which would be a basis for analysing the interviews. The initial codes were derived from interview themes and covered topics such as motivations (e.g., motivation to participate), individual experience (e.g., contribution), teamwork (e.g., task alignment, team communication), remote setting, tools (e.g., suggested tools by organisers, technical problems). To structure everything according to codes after studying the interview results, the findings were organised to an affinity diagram [39] using an online whiteboard Miro [40], as seen in Figure 1. Through this process, the initial codes were refined.

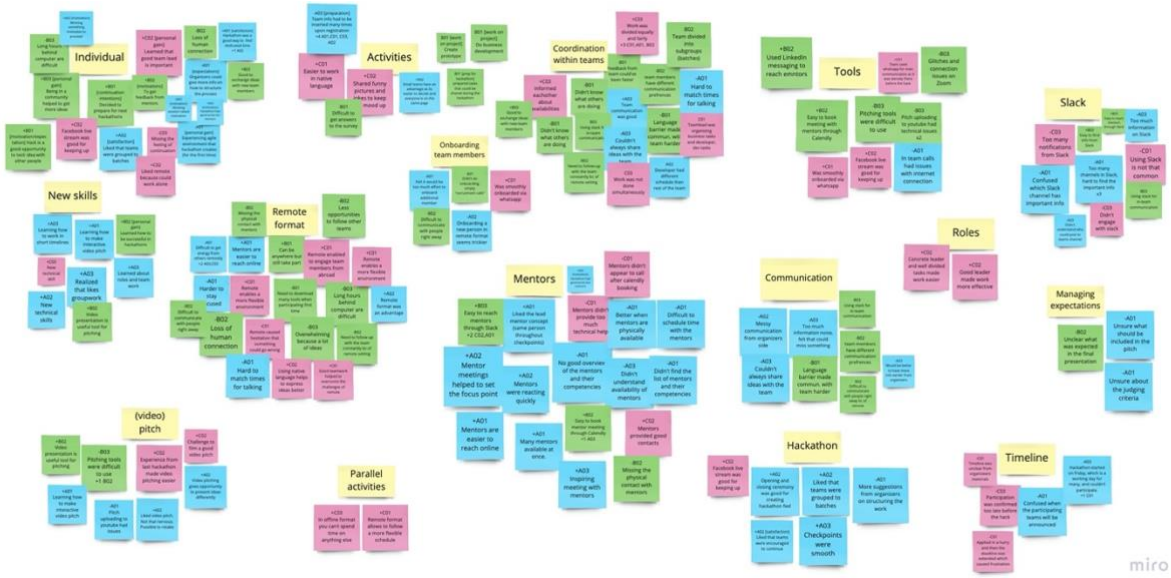

Figure 1. Example of an affinity diagram

After coding based on themes and further research on the topic, the classification of key concepts in distributed team collaboration by Olson and Olson [24] was selected as the foundation for further analysis. The paper introduces an overarching framework for categorizing non-collocated synchronous collaboration by proposing four key concepts – common ground, coupling, collaboration readiness, and collaboration technology readiness. Furthermore, the theory by Olson and Olson aligns with the team collaboration (RQ1) and setting (RQ2) related research questions of the current study. After studying the paper, the existing findings were clustered based on the mentioned concepts by Olson and Olson [24]. The study results were refined iteratively until no new codes were discovered and findings were clustered accordingly. However, some findings could not be categorized according to the Olson and Olson framework as they did not fit the organisational context, which is the main focus of their study [24]. Therefore, an additional section explaining hackathon-specific findings was added. The section focuses on findings that are common in a hackathon context but do not occur in a regular work context, such as specific motivations for participating, the collaboration between teams, mentoring, and expectation management.

4 Findings

The following sections present an overview of the study findings, which are mainly structured according to the four key concepts of distributed team collaboration by Olson and Olson [24] – common ground (section 4.1), coupling (section 4.2), collaboration readiness (section 4.3) and collaboration technology readiness (section 4.4). However, the hackathon context involves additional aspects to the regular work setting, which was studied by Olson and Olson [24]. Therefore, the last section of the findings (section 4.5) focuses on aspects that are specific to hackathons, such as event-specific motivations, the collaboration between teams, mentoring, and expectation management.

The findings are based on 15 interviews and 18 survey answers from two different hackathons – 48 for the Future and PEARC20. Seven of the interviewees were women, and six were men, whereas most of them belonged to the age groups of 18 to 24 and 25 to 34, one respondent was in the 45 to 54 age group. The study participants from the 48 for the Future hackathon were mainly IT professionals apart from one marketing associate and two learning and development experts. Most of them had previously participated in one to three hackathons. On the contrary, all the PEARC20 hackathon participants were college students from juniors to seniors, mainly studying computer science or biomedical engineering. What is more, only one person of them had previous hackathon experience.

4.1 Common ground

Common ground refers to the common understanding amongst team members and awareness in which aspects different team members have the same perception [24]. In the context of remote hackathons, the common ground aspect is explored regarding the project scope and the state and skills of team members. Table 5 presents the overview of findings related to common ground, which are described in detail in the following sub-sections.

Table 5. Overview of study findings on the aspect of common ground

	48 for the Future	**PEARC20**
Project scoping	Teams were discussing project goals (H1A, H1C) and potential activities (H1C) amongst themselves prior to the hackathon.	Teams were discussing project goals (H2C) and scope (H2B) together with the mentor at the beginning of the event.
Skill and task alignment	A clear distinction between development and business development tasks (H1A, H1C). Remaining tasks were divided based on skills (H1A, H1C).	Work division was based on skills (H2A, H2B) but also interest (H2B, H2C).
Common understanding	Two teams out of three were aware of each other's availabilities by aligning schedules (H1A) and updating each other (H1C). One team had issues with awareness (H1B).	One team used calls throughout the day to keep each other updated (H2C). Another team had issues with the awareness of all members (H2A).

Project scoping

Project scoping is a part of creating common ground amongst participants, as it helps them to prepare for the upcoming collaboration. In the context of this study, project scoping is considered as the agreement on objectives, activities, and deliverables necessary for successful idea development. The findings differ depending on event design. In the case of 48 for the Future hackathon, where teams and ideas were pre-formed, the project scoping took place prior to the hackathon, as H1A01 describes, *"Before the hackathon, we were thinking through the goals for the hackathon, in a sense that, what would we like to achieve throughout this weekend. We're also thinking through the user journey of the previous click-through prototype that we developed and identifying the biggest gaps that need to be filled"* (H1A01). Similarly, H1C01 talks about the preparatory activities for aligning the team "*Before the hackathon, we had a call together with the team […] we discussed what we will do, who will do approximately what and who will be needed during what period of time?"* (H1C01). However, in the case of the PEARC20 hackathon, where the teams and ideas were formed around lead mentors at the beginning of the event, the scoping was dependent on the mentors as well. For example, H2C01 describes that "*We had the kind of the prompt from [the mentors] [...] what, uh, our, our group of three was looking at [...] so we then had some discussions on what we want to accomplish […] [the lead- mentor] was kind of providing some guidance"* (H2C01) and H2B01 characterises the first meeting "*So the first meeting, it was more so just, um, trying to figure out the scope of our project. [...] So [our lead mentor] laid down that foundation and was like, this is what you need to do. This is what you're wanting to say. And like, this is what our project is wanting to achieve"* (H2B01).

Furthermore, the following graph (Figure 2) based upon survey results complements the findings on project scoping, as it illustrates how clearly did the participants perceive the teams' goals. The responses were provided on a 5-point scale, with answers varying from *strongly agree* (5) to *strongly disagree* (1). The bars represent the mean and standard deviation for each team. The line indicator represents the average result per hackathon.

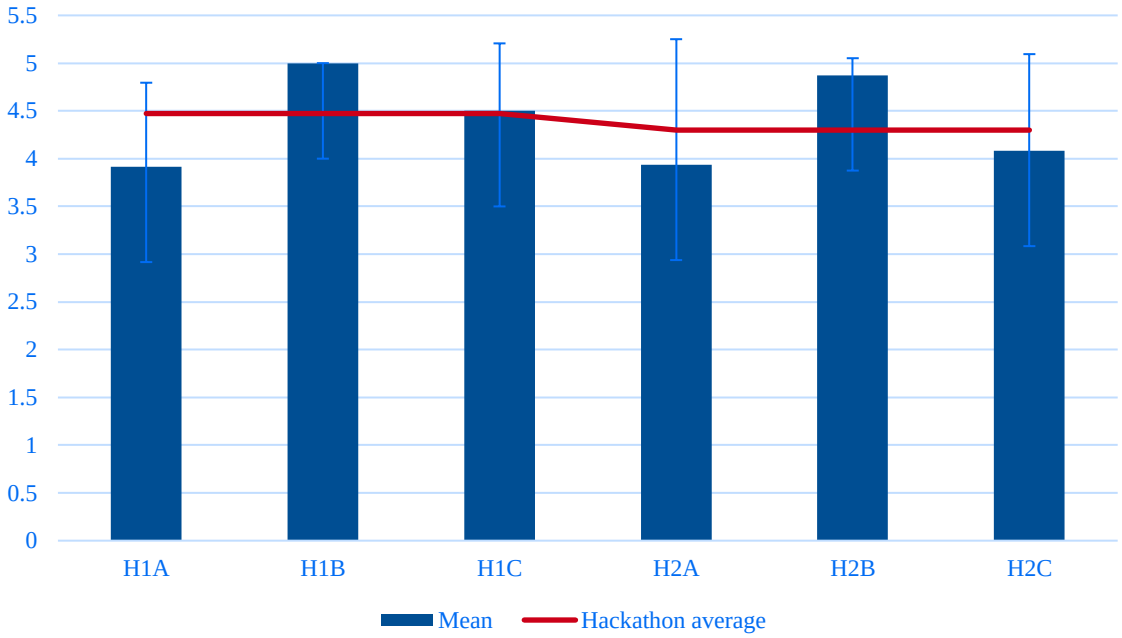

Figure 2. Teams' perception of goal clarity.

Skill and task alignment

In addition to establishing common ground related to their project goals, participants also needed to develop an understanding about who within their team would be able and willing to take over a specific task. The tasks within a team were expected to be divided in two ways - based on the skills of participants to achieve the optimal result, or the interests of team members, to enhance personal development. In several cases, the skills of people were exploited, as H1C03 describes, *"The task division was rather based on skills and peoples' engagement, so I could choose what I want to do. If I can do a specific task, I can take it and do it"* (H1C03). Additionally, H2A01 states that *"Since I had experienced grabbing datasets off the internet before, I was one of the people who used requests and to get it off and into the program. There was a guy in my team who had experienced with doing maps before. So he handled a lot of the map stuff and Plotly"* (H2A01). A similar approach was taken in team H1C *"The work division was based on skills and background people"* (H1C02).

Another pattern that emerged was a distinct division between coding and business development tasks, which could be clearly observed in teams H1A and H1C. Participant H1A01 describes that *"Mainly the tasks were divided by skills of course, because we knew that we have a developer in the team, so she will be focusing on that side. And then anything else that was left was divided between me and the third team member"* (H1A01), and the developer from the same team also explains, *"Regarding task division, I wanted to deal with this development part. And I didn't want to be a part of every discussion, because otherwise, I just don't have enough time"* (H1A03). Likewise, H1C01 discusses, *"I as the team lead was actually trying to understand who should do what, and to assign the tasks. […] I was the one who was assigning business tasks. And my friend developer, he was assigning*

development tasks, in the case he needed something. But also, our technical team was quite independent" (H1C01).

However, in some cases, the skills were not that dominant, and interest-based task division was applied. To illustrate, H2C01 says that *"it became clear that [one team member] was interested in producing a visualization, that [H2C02] was very curious about the data transformation […] and that I was kind of interested in, um, finding out more about Docker Kubernetes [...] And then by the morning of the second day we decided what roles we take".* Furthermore, team H2B was a good example of balancing the importance of skills and interest *"So I broke down everything that needed to be done. [...] And then we said, okay, is there any part that anyone in particular wants to take and does anyone feel like anything is in there, like area of specialty? And so then we filled out about three quarters of the tasks that way. [...] I tried to balance the workload past that and then make sure that everyone actually has something that they're interested in working on and they have this skill set to work on"* (H2B02).

Common understanding

Common understanding is another aspect of aligning the team, as it helps participants to assess the state of other team members and plan the collaboration according to that. Additionally, creating this awareness of each other has been found to be more difficult in an online setting [24]. Although in the current study, a comparison between physical and remote settings cannot be made, awareness is still explored as an influence on team collaboration. In several cases, it happened that at some point in time during the hackathon, certain team members could not be reached. For example, H1B01 describes the following situation *"The biggest problem at the hackathon for me fast feedback. Because I didn't know what my team was doing. […] So, I asked them and had to wait for answer. […] It was difficult for me […] because maybe they needed my help but I'm not aware"* (H1B01). A similar situation took place in team H2A *"We all checked in [before the checkpoint] to see where we were […] but it was kind of hard because some group members weren't available at times"* (H2A02).

By contrast, team H1A could predict such a situation and took precautions. H1A01 describes that *"We already knew that we all had different periods of unavailability throughout the weekend. And I actually created an availability spreadsheet for us, which would have all the important checkpoints and then we would mark like when we are present, when the availability is kind of maybe and when we are not present"* (H1A01). Furthermore, the developer from team H1A states that she even preferred not to be as aware of others, as she wanted to concentrate on her work and felt that too many discussions with team members would distract her. Moreover, teams H1C and H2C had a good experience which can be associated with keeping other team members updated. For example, H1C02 describes *"Yeah, so I knew that if I'm writing that, someone will respond, or all people will or only a particular person will respond"* (H1C02), and H1C03 adds, *"Yes, we definitely informed each other that this is the time I can't make it or going to be away for a few hours from this*

moment" (H1C03). Team H2C was using calls throughout the day to keep each other updated.

4.2 Coupling

Coupling draws together all the aspects of how the team collaborates. According to Olson and Olson [24], collaboration can be categorized as tightly or loosely coupled. Deriving from that, hackathons present a case of tightly coupled work, as the collaboration requires frequent communication among team members, short feedback loops and multiple streams of information. Additionally, Olson and Olson [24] find that tightly coupled work should be collocated, straightforward, and unambiguous to succeed. Therefore, this section contributes to understanding how tightly coupled collaboration succeeds in the non-collocated environment of a remote hackathon. The analysis focuses on hackathon organisation (incl. team formation, project selection), coordination issues, parallel activities and role division within teams. Table 6 presents the overview of findings related to coupling, which are further described in the following sub-sections.

Table 6. Overview of study findings on the aspect of coupling

	48 for the Future	**PEARC20**
Hackathon organisation	Teams formed prior to the event (H1A, H1C), in one case, additional members were recruited from matchmaking sessions (H1B). Teams had two checkpoints per day, for presenting progress, which only one member attended.	Teams formed at the beginning of the event around lead mentors. Teams had two checkpoints per day, for presenting progress, which the whole team attended.
Project selection	Ideas were formed before the event, and teams formed naturally; specific project selection was not evident.	Projects were selected at the beginning of the event based on personal development opportunities (H2A), interest (H2A) and the impression of the lead-mentor (H2B).
Collaboration styles	Collaboration over different messaging tools such as Facebook Messenger (H1A), Slack (H1B) and WhatsApp (H1C). Occasional Zoom calls for aligning with the team (H1A, H1C).	Collaborating over hours-long Zoom calls to stay in contact with all team members (H2A, H2B). Slack used as the main messaging tool in case of all teams.
Coordination issues	Evident in one team, as some team members could not be reached when needed (H1B).	Some team members could not be reached when needed (H2A, H2B). Another team lost a team member (H2A).
Parallel activities	Hackathon started on a working day, so on the first day, some participants could not contribute (H1A, H1C). Also personal activities were mentioned (H1A).	Parallel activities were not evident.

Role division in the team	All teams had a clear leader. Clear task division in all teams.	Team lead role evident only in one team (H2B). Role division in teams was flexible throughout the event.

Derived from the survey results, the following graph (Figure 3) presents an overview of participants' overall satisfaction with their teams' process. The responses were provided on a 5-point scale, with answers varying from *strongly agree* (5) to *strongly disagree* (1). The bars represent the mean and standard deviation for each team. The line indicator represents the average result per hackathon.

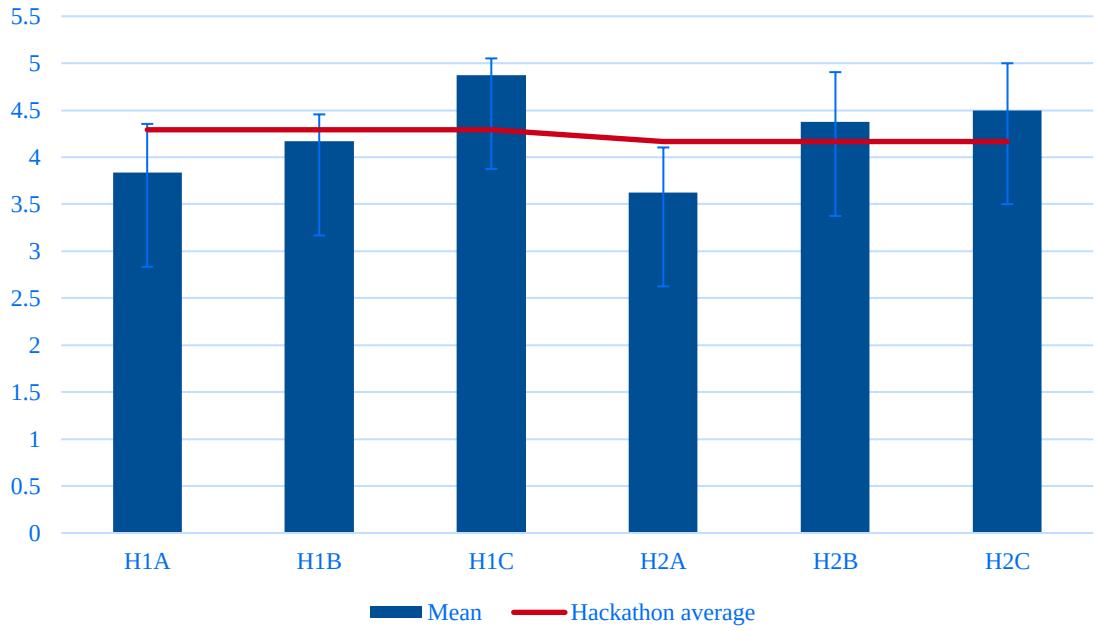

Figure 3. Participants' satisfaction with teams' process.

Hackathon organisation

The design of studied hackathons differs in various aspects (Table 2), therefore the differences in the hackathon organisation (e.g., how teams were formed, and ideas selected) were found to influence the teamwork. In the case of the 48 for the Future hackathon, the participants were mostly working professionals, and as the hackathon started on Thursday, participants needed to clear their schedules, if that was possible. Participants H1A02 describes *"I took two days off, like Thursday and Friday and I was I started on Thursday afternoon actually already, and I think the time consumption for me was a bit different then for others, but I know that my other team members had their school stuff and work stuff"* (H1A02). Moreover, the checkpoints proposed by organisers were handled differently. For example, in team H1C, only the team lead attended the checkpoints and later shared the results, however, in team H1A, the checkpoints were divided by team members, as everyone had different availabilities. For the PEARC20 hackathon, the teams attended checkpoints together and did prior preparation as H2B01 explains, *"We were trying to schedule stuff out so that we were prepared before each [checkpoint]. So, it was like, you know, okay, so this upcoming meeting, we need to have a presentation. It's like, alright, let's get together for*

like the last hour or last 30 minutes. And let's build out a presentation of everything that we've worked on" (H2B01).

The hackathon organisation also impacts the way the hackathon teams are created. In the case of some events, organisers expect already existing teams to register and in other cases, the teams are composed at the beginning of the event. In the case of 48 for the Future hackathon, only preformed teams could participate, therefore the team formation took place prior to the event. Team H1B recruited additional members from the matchmaking sessions held before the hackathon *"So during matchmaking I explained our idea, and there was a bunch of people interested so, I followed up with each of them, one by one. And then I did like a 15–20 minute calls, to see if there was a match between what they wanted and the idea we have"* (H1B02). Whereas team H1C composed a team from their network, *"We didn't have team from the beginning […] so we were getting people one by one. And I believe two weeks before hackathon, where we already had this WhatsApp group"* (H2C01). In comparison, the teams at the PEARC20 hackathon were formed during the event kick-off, H2A01 describes, *"I watched all the mentors talk about their projects and I found [one of the mentors] project most interesting […] So, I kind of signed up for their project and whoever was interested in theirs as well was on my team."* (H2A01).

Project selection

Project selection refers to how and when the project pursued during the hackathon was selected. The importance of project selection was more notable in the case of the PEARC20 event, as the challenges were selected at the beginning of the event. The selection was based on either interest, like H2A02 describes *"[The topic] was recommended through the, uh, through SGCI and, um, you know, the topic was kind of interesting"* (H2A02), the possibility of personal development *"I watched all the mentors talk about their projects and I found, I found, um, [the mentors] project most interesting because [...] it seemed like I could learn some things from their project"* (H2A01) or previous experience *"I was initially interested in, uh, the topological data analysis project because that's, uh, what I was studying in grad school"* (H2C01). However, in the case of participant H2B02, the selection was made based on the impression of the lead-mentor presenting the project *"I ended up going with [the mentor of team H2B] because the way he talked about things and the way he presented himself. I'm very much a newbie when it comes to coding and it didn't really seem like he would mind as [...] he seemed a little bit more approachable from like a novice perspective on that"* (H2B02). In the case of, 48 for the Future hackathon, the projects were mostly selected prior to the event. Only in the case of team H1B one member was recruited from the matchmaking and had to select between different projects *"After I pitched my idea, five or six people who contacted me and the team leader of [H1B] was one of them […] then I just selected between different ideas and different people"* (H1B01).

Collaboration styles

Collaboration styles refer to the way a team is organising their work. In the case of this study, the focus is on understanding how the communication and work in the non-collocated team is arranged and which tools are used for that. In most of the cases, a combination of

video calls and a messaging medium was used, however, the specific tools and distribution between them differed. For example, participant H1A03 describes that *"[H1A01] prepared on Google Drive for us for a time frame, to understand who is available and who is not. For the short messages, we used (Facebook) messenger. And if we wanted to talk to each other, then we used Zoom or messenger video call"* (H1A03). Likewise, H1B02 states that *"For communication we used mostly Slack direct messages and we had a Slack channel. Also, we got our working document with lots of comments within the document. We also had like a couple of all team meetings, which was everyone on a Zoom call but no fancy tools"* (H1B02). To contrast, in some cases the Zoom calls had a more central role, as H2A01 describes that their team was on a Zoom call for hours because that way they could ask questions and discuss with each other at any point (*"Yeah, we were on zoom calls for hours. Um, just if anyone had a problem, we could just speak up and ask a mentor or someone else on the team."*, H2A01). A similar approach was taken by team H2B (*"I pretty much had a zoom meeting open all the time for the team. And then we also used text and Slack and Discord a lot. So, we jumped on Slack anytime we wanted help from [our mentors], um, Discord, we sent files through a lot."*, H2B02).

Next to different communication styles, the teams also took various approaches to managing the tasks and checkpoints. To illustrate, H1A2 says that *"I wanted to deal with this development part and didn't want to be a part of every discussion, because otherwise, I just don't have enough time. […] we just came together, like we had some checkpoints which we discussed and then met again"* (H1A2). Similarly, H1C03 shares, *"We had the regular check ins, we had a WhatsApp group where we would share the progress or any kind of information what we have obtained. We would have a check in before each checkpoint with the mentor. […] after that as well, just to know how it went"* (H1C03). In the case of PEARC20, the approach was more collaborative, as H2C02 describes, *"[Our mentor] would kind of set checkpoints like a couple hours before any of those, the full group, uh, checkpoints, just so we'd internally as a group, uh, kind of get together and see where everybody's at"* (H2C02).

Furthermore, the survey provided insights to the satisfaction with communication within the team (Figure 4). The responses were provided on a 5-point scale, with answers varying from *strongly agree* (5) to *strongly disagree* (1). The bars represent the mean and standard deviation for each team. The line indicator represents the average result per hackathon.

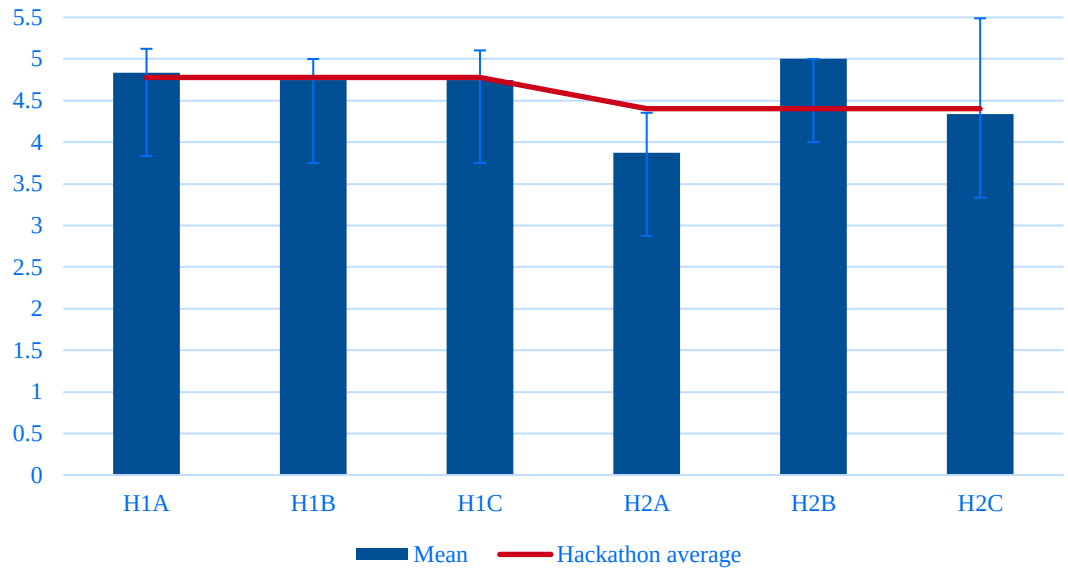

Figure 4. Satisfaction with communication within the teams.

Coordination issues

It was stated by Olson and Olson [24] that closely coupled collaboration works best in a collocated environment because of the proximity and unambiguousness. Therefore, due to the context of the remote setting, an assumption of possible coordination issues was made, which contributed to understanding the impact of the setting. As it turned out, coordination issues appeared when other team members could not be reached. One such example was outlined by participant H1B01 *"The biggest problem at the hackathon for me fast feedback. Because I didn't know what my team was doing. […] So, I asked them and had to wait for answer. […] It was difficult for me that I didn't know what they are doing, because maybe they needed my help but I'm not aware"* (H1B01). A similar situation happened in team H2A, as H2A02 described, *"[Before checkpoints] we all checked in to see where we were, um, but with some group members, it was kind of hard because they weren't available at times"* (H2A02). In one particular case, a team member was not available as he had slept in (*"[One team member] had stayed up really late coding and then he was asleep and hadn't really woken up on time for when he said he was going to get on the zoom call. So we're all calling him like where are you?"*, H2B02). Moreover, one team lost a member during the hackathon (*"At the very beginning we had […] three other people and by the time the hackathon was over, one of those people wasn't around anymore. She just kind of stopped talking to us"*, H2A01).

Parallel activities

Since one of the characteristics of remote hackathons is the fact that participants can join the event from everywhere, it was discovered that the hackathon activities are not the only thing participants engage in during the event. As the 48 for the Future hackathon lasted from Thursday to Sunday, some participants still needed to work during the first days. For example, H1A03 tells that *"I knew already that on Friday, I can't participate the full day*

because I had a working day" (H1A03). Likewise, H1C01 states, *"The work in our team was well divided, apart from the fact that to our team members continued to work on Friday, it was a full working day for them. So that is why, of course they couldn't participate as much as they wanted"* (H1C01). Furthermore, in the case of the remote setting, people participate from the comfort of their home, meaning that day-to-day activities still need to be taken care of (*"I know that […] one of my team members twins had a birthday during the hackathon"*, H1A2).

Role division in the team

Regarding the role division in the team, it was discovered that the approach to leadership and general task alignment was different. Leadership refers to the aspect that whether the team had a clear leader or not. As with previous themes, the findings differed depending on the hackathon design. The leadership concept was more evident in the case of 48 for the Future hackathon, where the teams were pre-formed. The role of the leader was mentioned for all the teams, however, it was most definite in team H1C. To illustrate, H1C02 explains that *"I would say that this remote hackathon was more efficient because of our team lead and how she took the role of the leader. She kind of directed us to the right directions and was telling what to do"* (H1C02). Furthermore, participant H1C03 explains how the team lead organised the collaboration *"Our team lead mostly just organised and communicated the plan, what time we do what to when and etc., what's expected what needs to be covered? And then we just took on the tasks each on their specific area"* (H1C03). What is more, the team lead herself illustrates that although she could have done several business tasks throughout the hackathon, she had to delegate them away to leave time for reporting and summing up that was needed for the checkpoints (*"I could of course do any business task also, but I understood that actually I need time for reporting and summing up. So that is why some tasks were kind of distributed"*, H1C01). However, during the interviews with PEARC20 hackathon participants, the concept of team lead was not once mentioned. Although, in the case of team H2B, participant H2B02 took the managing role *"So I broke down everything that needed to be done. And then I talked to my teammates and said, you know, what coding language do you think we're going to need for this? What do we think we need for this part? And we kind of, so we said, what is the task? What has to be done to accomplish the task"* (H2B02). Contradicting to the input from interview, the combined survey results indicate that 17 out of 18 respondents felt there was a clear team lead.

Concerning general task division, teams had different approaches, however, in most cases, the tasks were divided based on previous experience. For example, the team lead of H1B describes how they created a task list and matched it through with everyone's skills (*"We created this document with tasks and matched them with the skills each one of us have"*, H1B02). Participants H1B01 adds that *"I worked on business development and I did [different business development tasks] I have strong skill in this direction because I'm business analyst for about 10 years so I know it"* (H1B01). Furthermore, interviewee H2A01 describes how the roles changed throughout the hackathon *"At the beginning we mostly had separate jobs, but at the end, when we started putting everything together, I started doing some of the maps too. [...] so in the beginning, you basically try to sort of split*

it up in order to be more efficient […] and then in the end, of course, you have to stick it together" (H2A01). Another approach was dividing roles based on the tasks like H2B01 tells *"We have 4 members, so two of us were handling the backend stuff and two of us were handling the frontend stuff"* (H2B01).

4.3 Collaboration readiness

Collaboration readiness refers to the motivation of team members to collaborate with each other. In several cases, the participants joined the hackathon to get more experience of working in groups. For example, participants from the PEARC20 hackathon describe *"Having not had too much practical exposure, hands on experience, especially as a group. Um, [joining the hackathon] was something that I thought would be interesting"* (H2C02) and H2A02 adds *"Also I do like meeting new people from other areas and working in groups"* (H2A02). In addition, the networking effect and collaborating with like-minded people was brought out (*"I was looking for good founders to join, and I also wanted to find likeminded people in the start-up environment"*, H1B01). Another motivation for collaborating was the opportunity to test something new (*"The main motivation for participating was to test the idea"*, H1C01). Within an existing team, the hackathon was identified as a good opportunity for taking dedicated time to develop an existing product further (*"When I saw this hackathon, I thought it's a good opportunity for us to develop our product"*, H1A01). Although generally, participants were willing to collaborate, it also happened that the collaboration was unsuccessful (*"The biggest problem at the hackathon for me fast feedback. Because I didn't know what my team was doing. […] So, I asked them and had to wait for answer."*, H1B01). Further motivations which are associated with the hackathon format rather than collaboration are discussed in the section of hackathon specific findings.

4.4 Collaboration technology readiness

The collaboration technology readiness addresses the selection of technologies that a team uses to collaborate in a non-collocated environment [24]. In the context of this study, the concept is extended to the technologies proposed by organisers in order to compare if and how the suggestions of organisers and preferences of participants differ. Moreover, the findings on different purposes and issues of technologies are presented. Table 7 presents the overview of findings related to collaboration technology readiness, which are described in detail in the following sub-sections.

Table 7. Overview of study findings on the aspect of collaboration technology readiness

	48 for the Future	**PEARC20**
Tools suggested by organisers vs tools used by participants	Suggested tools were Zoom and Slack. Teams additionally used Facebook Messenger (H1A) and WhatsApp (H1C).	Suggested tools were Zoom and Slack, which were the main tools in use. One team additionally used Discord (H2B).

Issues with tools	Organisers posted a lot of information in Slack, which became overwhelming (H1A, H1C). Technical issues occurred with uploading pitches to YouTube (H1A, H1B).	In one case, the variety of information channels was mentioned to be confusing. (H2C)
General technical issues	Internet connection issues were mentioned in one case (H1A).	Issues of power outage and computer performance were mentioned in one case (H2B).

Tools suggested by organisers vs tools used by participants

The tools suggested by hackathon organisers to collaborate in a remote work setting were mostly twofold – a tool for video calls and a tool for messaging, which in the case of both studied hackathons were Zoom and Slack accordingly. However, the mentioned tools were not the only ones in use. For example, participant H1A01 explained that they used Facebook Messenger both for messaging and calling because it was easier (*"When we just wanted to discuss, then we decided to use messenger because it was easier for calls actually",* H1A02*)* Team H1C preferred WhatsApp for messaging, as it was available before the hackathon Slack was created (*"And I believe two weeks before the hackathon, where we already had this WhatsApp group, we got the link to Slack later",* H1C01*)*. Similarly, team H2C operated solely on Slack as the Zoom calls were found to be redundant, as private Slack channels have the same functionality available (*"I think the zoom breakout rooms were actually kind of redundant, like, um, given that Slack was able to do, uh, like private channel video calls"*, H2C01). In addition to the video and messaging technologies, the teams used different tools for file and code management. The most popular ones were Google Docs and GitHub, additionally, the usage of Discord for file-sharing was mentioned in one case. To illustrate, H1A03 tells that *"[H1A01] prepared on Google Drive for us for a time frame, to understand who is available and who is not"* (H1A03). Likewise, H1B02 mentions, *"Mostly we connected through Slack. […] And we used Google Doc"* (H1B02). Furthermore, interviewee H2A01 described that whenever they finished a task, the code was pushed to GitHub so that the whole team could stay up to date.

In addition, it was found that tools were used for different synchronous and asynchronous purposes. Teams at the PEARC20 hackathon used long Zoom calls for synchronised work as H2A01 tells *"Yeah, we were on zoom calls for hours. Um, just if anyone had a problem, we could just speak up and ask a mentor or someone else on the team"* (H2A01). Team H2B operated in the same manner, and participant H2B02 mentioned that almost no independent work was done. In contrast, in team H1C, calls were used for aligning the team and distributing tasks, and synchronous communication took place over WhatsApp *"Even in parallel with checkpoints, we all the time are communicating in WhatsApp, for example during the finals, I was sitting with my phone, and I was reading the messages of my team members all the time. So we had Zoom calls, just understand who is doing what is the team that actually was trying to understand who should do what, and to assign the tasks*" (H1C01). Furthermore, messaging was used to keep the mood of the team as H1C02

describes, *"We continued communicating through WhatsApp group […] we're discussing plans or sharing some ideas or some interesting information, what we can find in internet related to our project. We're also sharing some fun part, you know, some jokes and funny pictures"* (H1C02).

Issues with tools

However, in some cases, the used tools were found to cause confusion. For example, in 48 for the Future hackathon, several participants mentioned the issues with Slack *"The first thing with Slack is that there were so many channels. Already before the hackathon started, like so many of them, you know, had something posted, […] and all things are lighting up with messages. And then it's very hard to find like where is the info […]. And sometimes I was confused, like, which one of those has the important stuff"* (H1A01). The overwhelming number of messages was also mentioned by H1C03, who explained that it resulted in too many pings from Slack, which turned out to be annoying for the technical side of the team (*"The technical guys complained that they received too much pings from Slack […] So they were annoyed by that"*, H1C03). Likewise, in the PEARC20 hackathon, the number of different communication channels was found to be misleading *"What was confusing that all the resources were kind of in different places. Um, you'd see some things through email, some things through the website, some things through Slack"* (H2C02).

Moreover, the participants encountered technical errors while using the suggested tools. For example, the organisers of the 48 for the Future hackathon required using YouTube for uploading the pre-recorded video pitch. However, not everything went as planned, as H1A01 tells *"There were these technical issues that came up with the pitch, because I just couldn't upload the pitch properly to YouTube"* (H1A01). A similar issue is explained by participant H1B03 *"the last video [pitch], it was like in the last minute, so we were trying to edit the video and make it nice and then when we uploaded the video on YouTube, we noticed it had a technical error, so we had to load it again, and that was a bit of trouble"* (H1B03). Although the pre-recorded pitching was troublesome, it was also described as a good opportunity *("This video part is so nice because you are not judging people by their presenter skills because they can, however, they want to visualize this idea. […] there might be a lot of introverted people who have great ideas, but they don't participate because they don't want to do this pitch part")*, H1A02.

General technical issues

Furthermore, it was expected that the remote setting could bring about other technical issues not connected to the tools. This proved to be the case as, for example, a participant from team H2B had issues with their computer *"So he would sometimes pop in and be like, Hey, who's working on this and I have a question and then he would pop back out. So, his computer wouldn't get angry and lose connection and stop working. […] he had a lot of technical issues during that"* (H2B02), and another team member was disturbed by a six-hour power outage, according to H2B02 (*"And [another team members] power went out for like six hours"*, H2B02). Moreover, issues related to the internet connection were

mentioned, *"In some of our team calls we had some problems with internet or Zoom"* (H1A01).

4.5 Hackathon specific findings

While the framework by Olson and Olson [24] concentrates on collaborative work in a corporate setting, several findings are specific to the hackathon context and do not fit the previously used concept. Therefore, in this section, the findings on event-specific motivations, the collaboration between teams, mentoring, and expectations are presented. Table 8 presents the overview of hackathon specific findings, which are further described in the following sub-sections.

Table 8. Overview of hackathon specific study findings

	48 for the Future	**PEARC20**
Motivations	Motivations for participating included developing personal skills (H1C), accessing mentors (H1A), getting feedback on the idea (H1B).	Motivations for participating included personal development and getting practical experience in coding (H2A).
Collaboration between teams and networking	No collaboration between teams was identified.	In one case, mentor-facilitated collaboration within teams was identified (H2C).
Mentoring	Many mentors available who were easy to reach. The lead mentor was assigned to a batch of teams.	The lead mentor had a central role in the team.
Expectation management	Expectations for the final presentation were unclear (H1A, H1B). Judging criteria could have been communicated earlier (H1B).	Judging criteria could have been communicated earlier (H2B).

Motivations

In addition to the motivations that were found to contribute to collaboration (section 4.3), several other reasons for taking part in a hackathon were identified. The majority of incentives could be categorised twofold. In multiple cases, the participants mentioned personal development as the primary motivator for participating in a hackathon. For instance, H2A01 mentioned that *"I signed up because I wanted to learn more about coding. Um, I, I felt [...] this would be a really good experience for me because every project you do, that makes your portfolio stronger and gives you more skills and it's a really good way to learn and get ready for the real world"* (H2A01). Next to the professional development also testing personal skills (*"I joined the hackathon to test the idea, to test my skills, to improve the pitching I also wanted to improve the understanding of the business and building the business model, talk to mentors and sell the idea."*, H1C03) and gaining new experience was brought out. However, in the case of a hackathon, where the idea was required upon registration, developing the teams' idea and access to mentoring were mentioned as the main motivation to participate. For example, participant H1A01 brought

out that in addition to collaborating further on their teams' product, she attended the hackathon also for the mentors and further support (*"When I saw this hackathon, I thought it's a good opportunity for us to develop our product further and get some useful insights from mentors and potentially get some further support"*, H1A01). Likewise, H1B02, from the same hackathon, said that *"The hackathon is a perfect opportunity to test the idea with different people, with all the mentors, even customers, and get fast feedback"* (H1B02).

In addition to the findings from the interviews, the following graph (Figure 5), which is based on the survey results, depicts the extent of different motivations the participants had for attending the hackathons. The responses were provided on a 5-point scale, with answers varying from *completely motivated* (5) to *not at all motivated* (1). The bars represent the mean and standard deviation per hackathon.

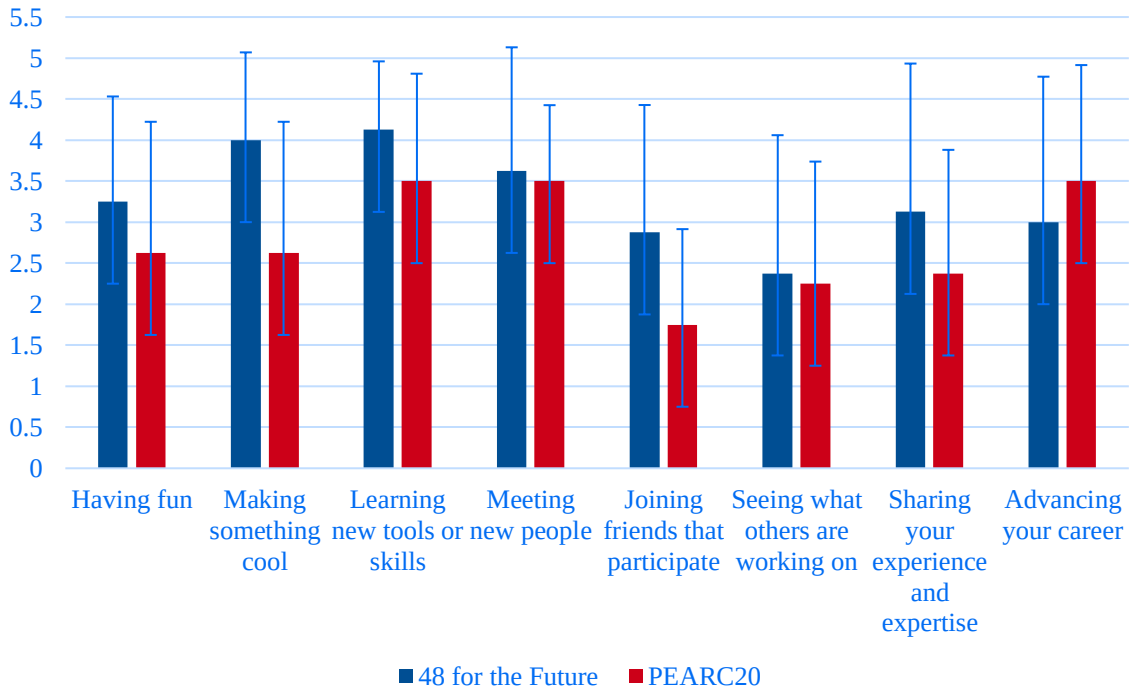

Figure 5. The extent of motivations to join the hackathon

Collaboration between teams and networking

Collaboration between teams refers to the cooperation across hackathon participants from different teams. The findings indicate that because of the remote setting, it was challenging to communicate with other teams and create the networking effect intrinsic to traditional hackathons. For example, participant H1C02 compares the remote and physical hackathon setting *"I like to network and to know people. So of course, it would be great also to speak more time with other people with other teams and to get more of their ideas. And to be honest, like, we didn't have much time to follow other teams. So, we just basically, we were first on the checkpoints, […] And then we switched off and get back to our work. […] But when you're on place. Basically, you still listen, when people present, you still hear their ideas, and you also have a chance to speak with them"* (H1C02). A similar concern is expressed by participant H2B01 *"I really didn't know anything that the other teams were*

doing. Like no idea, like what the other teams have done until like the very last, you know, check-in". However, a mentor-facilitated collaboration over a similar issue was mentioned in one case *"At one point we did have a shared call with the [other] group. I think we were fighting the same issue and that [our mentor] was kind of checking in with [the other mentor] here and there, and realised we were fighting through similar [topics][…]"* (H2C02).

Mentoring

Mentoring was found to be of importance in both studied hackathons. In the case of the PEARC20 hackathon, mentors had a more central role, as they were the ones proposing ideas and the teams were gathered around them (*"I watched all the mentors talk about their projects and I found, I found, um, [the H2A mentors] project most interesting"*, H2A01). Whereas in the 48 for the Future event, a whole batch of teams were gathered under one lead mentor (*"So they had this concept of lead mentors, who was like the same person throughout all the checkpoints"*, H1A01). However, at both events, the mentors were consulted for further advice and support as H2A01 describes *"Um, just if anyone had a problem, we could just speak up and ask a mentor"* (H2A01) and H1B03 also explains, *"We had this one mentor, and in this chat, I could ask and they were like, reacting really quickly"* (H1B03).

In the case of 48 for the Future hackathon, the participants were satisfied that so many mentors were available (*"I think what was great that they had a lot of mentors from different fields"*, H1A01) and that they were easy to reach (*"we had this one mentor, and in this chat, I could ask and they were like, reacting really quickly. This part was really nice"*, H1A02). In addition to contacting mentors through Slack, there was also a possibility to schedule 15-minute calls with them through a booking tool, Calendly (*"Some of the mentors even had, like a calendar, so you can do like appoint appointment slots with them."*, H1B02). Furthermore, it was brought out that the online setting made approaching mentors easier (*"I think this was a benefit of the online that you can approach them faster for like small stuff, like if you have just some small question"*, H1A01).

Expectation management

When asking the interviewees about their satisfaction with the hackathons, the dissatisfaction with communicating expectations was brought out in both cases. To illustrate, participant H1A01 commented that the judging criteria were unclear, and in different channels, the information varied (*"What was also unclear was what exactly is the jury judging and what needs to be in the pitch? Because there were different information posted in different [Slack] channels"*, H1A01). Furthermore, in the case of both hackathons, it was brought out that the expectations to the final presentation could have been published earlier (*"At the end was kind of unclear about the expectations of the final presentation. So they waited a little bit on that, like, almost through the last day instead of like, making that info available at the beginning"*, H1B02), which would have resulted in improved final presentation as H2B02 explains, *"Maybe a little bit more at the beginning [tell] about what judges criteria are, […] we would have probably changed our presentation style, instead of*

trying to look like professional and competent, we probably would have highlighted more of like what we learned" (H2B02).

5 Discussion

The goal of this thesis was to study the novel phenomena of remote hackathons. Until now, the research around hackathons has concentrated chiefly on collocated events [8], [12], [20], [22]. However, with the emergence of COVID-19 pandemics and work shifting online, remote hackathons have gained popularity. Thus, based on the findings of this study, the following discussion provides an understanding of how teams collaborate during an online hackathon (RQ1) and how the event setting affects their collaboration (RQ2). Furthermore, implications for hackathon participants (section 5.3), organisers (section 5.4), research (section 5.5), and the study limitations (section 5.6) are presented.

5.1 How do different teams collaborate during an online hackathon? (RQ1)

The affordances of in-person hackathons, such as intense collaboration among teammates, the interactions with other teams, the casual and easy access to mentors, the networking during coffee breaks or random walks participants could do in the hackathon premises, have found to change when these events are transferred to an online environment. Although some of these characteristics could also be noticed in the online versions, others diminished or even disappeared.

In the case of in-person hackathons, it has been found that prior to the event, teams engage in preparatory activities such as project planning and task alignment [14]. A similar pattern was identified in remote events as teams that were formed prior to the event prepared by aligning on project scope, goals and possible activities. This, in return, contributed to creating a shared understanding, essential in the case of distributed collaboration [24]. Furthermore, it was also a way of creating trust amongst team members, as they aligned on a common goal and agreed on roles. Although creating trust in online environments has been found to be more difficult [34], it was not identified during this study. A possible reason could be that most of the teams had members who were already familiar with each other, and therefore creating the trust was not mentioned to be challenging. Similarly, in the case of teams, with previously unfamiliar members, no issues were mentioned. However, it was noticed that in the latter case, mentors rather than participants facilitated the first discussions.

Further findings align with those of Braune et al. [10], that hackathon activities are not the only thing participants engage in during an online event. Some participants mentioned that they had to work during the hackathon, and also family matters were brought out. The unawareness about each other's plans resulted in misunderstandings, where team members could not be reached, and in one case, a team even lost a member. However, it could be identified that teams who mapped their availabilities prior to the event experienced fewer shortcomings, as participants were aware of each other's schedules. Therefore, a connection between pre-hackathon planning and coordination issues can be made.

In addition to having a common understanding within a team, it is also important to retain this awareness and organise the work accordingly. An effective way to achieve successful

collaboration has been found by keeping the coupling of the work minimal [24]. Due to the characteristics of a hackathon, the work is generally tightly coupled, however, some teams managed to change the paradigm. For example, in the case of teams from the 48 for the Future hackathon, the collaboration was mostly asynchronous, with a precise distribution of tasks and less synchronous communication. Whereas in the PEARC20 event, teams collaborated mainly synchronously by keeping Zoom calls open most of the time. The survey results further support the evidence from previous observations by Olson and Olson [24], as they indicate a higher satisfaction rate with teams' outcomes (Figure 3), in the case of 48 for the Future hackathon where the collaboration was mostly asynchronous, and coupling minimized. Moreover, teams with strong leadership, such as team H1C, which additionally contributed to reducing the coupling, were found to achieve better results and higher satisfaction rates (Figure 3). Therefore, it could be concluded that the online setting provides more opportunities for decoupling the work because the participants are distributed. It is also easier to engage in individual tasks, which is the key to achieving more in the restricted timeframe of hackathons.

In addition to the different collaboration methods helping to decouple the work, they also allowed participants to collaborate successfully in the remote format. As briefly mentioned, the collaboration in a distributed team is dependent on the usage of different technological tools, such as Zoom and Slack, which enable communication amongst team members [10]. By combining the tools, participants found creative ways to mimic the radical collocation of a physical hackathon [12]. As mentioned previously, at the PEARC20 hackathon, teams worked together over hours-long Zoom calls to create the effect of proximity which enabled them to ask questions at any time and stay up to date with what others are doing. However, in 48 for the Future hackathon, the synchronous collaboration was applied only in case of shorter calls for alignment or discussion. Nonetheless, synchronous work was complemented with an asynchronous approach of different messaging tools. For example, when participants needed to concentrate alone or because of parallel activities needed a pause from hackathon activities. The main messaging tool in use, which was also suggested by organisers, was Slack. Although, in several cases throughout the findings, it was stated that too much information was posted there, which became confusing and overwhelming. This finding also aligns with that of Brereton [15] and Braune et al. [10], who found that the technological solutions used in remote hackathons could propose challenges whilst using. Consequently, the participants shifted to their own tools according to their preference. Next to the hackathons Slack channel, asynchronous collaboration was found to take place in Facebook Messenger, WhatsApp or a separate Slack workspace. Furthermore, Google Drive was used for file management, Discord for sending files between participants and GitHub for collaborating on coding.

Similarly to in-person hackathons (Table 1), the teams worked intensively on developing the ideas, attended checkpoints for presenting progress and receiving guidance, and finished the hackathon by pitching their ideas. However, a noticeable difference to collocated events was the minimal collaboration between teams and the lack of networking opportunities deriving from that. On the contrary to in-person hackathons, where other teams could be

simply overheard and spontaneously engaged with [31], the participants mentioned that no connections outside the team were made. The remote teams were constantly engaged with their own projects, and there were not many opportunities to network. This could be regarded as one of the most compromised aspects of moving hackathons online, as networking and meeting like-minded people has been previously identified as one of the main reasons people attend hackathons [5].

5.2 How does the hackathon setting impact team collaboration? (RQ2)

To understand how the hackathon setting impacts team collaboration, two remote hackathons with different theme and design were studied. Consequently, several findings were identified to be influenced by the remote setup or differ based on the specifics of two studied events.

When putting together a hackathon, the organisers have several design decisions to make [20]. Choices regarding team formation and idea selection are the ones that affect the pre-hackathon phase [2]. The effect of the same decisions was found to influence the collaboration within remote hackathon teams. Forming the teams and selecting the idea prior to the event allowed participants to engage in preparatory activities such as project scoping, task division and availability scheduling (Table 5). This, in turn, helped create common ground, which is especially important in distributed setting [24], already before the event, and leave more time for developing the idea. Whereas, when the teams and ideas were selected at the beginning of the hackathon, participants had less time to align with each other. What is more, teams who engaged in preparatory activities prior to the event were found to have higher goal clarity (Figure 2).

Furthermore, the hackathon duration was found to influence team collaboration. In the case of 48 for the Future hackathon, the event started on Thursday evening, which meant that some participants still had to work for a third of the hackathon, as taking a day off was not possible for everyone. This affected the team collaboration as some team members could not contribute before Friday evening.

Similar to the suggestions of Nolte et al. [20] for in-person hackathons, the observed events included checkpoints for the organisers to get an overview of teams' work and the mentors to give suggestions. Mentoring was found to affect teams throughout the events, although the approach taken to mentoring at the two hackathons was different. In 48 for the Future hackathon, there were over 70 mentors available, and each batch of teams had a lead-mentor whom they met in checkpoints. The other mentors could be contacted over Slack or pre-scheduled 15-minute calls. However, the PEARC20 hackathon was much more mentor-centric, as the teams were formed around mentors, and they were constantly available for participants. This approach allowed a more personal connection to be developed, as Nolte et al. [21] suggested. Although it was mentioned that the remote setting of the hackathon allowed to reach mentors more efficiently, one participant attentively described that as the remote format rules out the opportunity to simply bump into the mentors and ask for advice, they must be approached consciously.

Towards the end of the event, the teams were expected to present their results as it is common to hackathons [5]. However, in several cases, the judging criteria were mentioned to be unclear, and that expectations for the final presentation could have been published earlier. This created confusion amongst the participants, which based on the findings derived from the number of digital channels for informing the participants, as it was mentioned that different information could be found from different channels. In addition, the final presentation proposed a challenge in the case of 48 for the Future hackathon, where the pitches were required to be pre-recorded and uploaded to YouTube. Considering the intense hackathon schedule, the uploading was left to the last minute. In two cases out of three, the YouTube uploading had issues, and teams failed to submit the pitches in time. In the PEARC20 event where the pitching took place over a live stream, the issue did not occur. Nevertheless, the advantages of a pre-recorded pitch were aptly summarized by a participant "This video part is so nice because you are not judging people by their presenter skills because they can, however, they want to visualize this idea. […] there might be a lot of introverted people who have great ideas, but they don't participate because they don't want to do this pitch part".

5.3 Implications for hackathon participants

Several practical implications for both the participants and organisers of hackathons could be derived from the study results. As the research on remote hackathons is modest, the study outlines various discoveries regarding collaboration at these remote events. Thus, the first suggestion to the participants of a remote hackathon would be to account for being distributed consciously. Since it was found that the networking effect has diminished and the misunderstandings in the team are more likely to arise, it is important that the participants acknowledge the characteristics of the remote event and knowingly ask, feedback, plan and communicate more. A more specific suggestion in this regard would be mapping each team member's availability prior to or at the beginning of the event, which helps to create awareness and avoid misunderstandings during the event. In addition, a suggestion on clearly distributing the tasks could be made. An organised approach to teamwork enables to minimise coupling and therefore improve collaboration. Furthermore, as the distributed setting eliminates the opportunity to simply bump into the mentors and ask advice, they should be approached consciously. What is more, the remote format requires the usage of different technological solutions, which in some cases might propose challenges. If the pitching does not take place live and the presentations are required to be uploaded, the technical solution should be tested out beforehand. It can be suggested not to leave the uploading to the last minute as long uploading time or other technical issues might hinder the submission of materials.

5.4 Implications for hackathon organisers

In the case of the organisers, it would be suggested to keep in mind that the remote format diminishes the networking effect, which is one of the most common motivations of participating in hackathons. Therefore, more networking opportunities should be created deliberately. What is more, the duration of the hackathon is recommended to be carefully

considered, as the findings indicate a lower contribution from participants when a working day is included in the schedule. It is especially relevant when the target group of the hackathon is working professionals, as it was in the case of 48 for the Future. Based on the findings, it could also be suggested that when organising a remote hackathon, forming teams, and selecting ideas prior to the event could yield better results. Because preformed teams with existing ideas have more opportunities to prepare for the hackathon and therefore more time at the event for idea development. The pre-hackathon activities were also found to result in higher goal clarity.

The participants' dissatisfaction around organiser communication leads to another suggestion – the important organisational information should be kept as clear and precise as possible. More specifically, the selected communication tool (e.g., Slack) should not have too many channels, as the multiplicity of channels was found confusing. Although preliminary, the findings around pitching suggest that the communication of judging criteria and expectations on the pitch should also be presented as clearly and early as possible. This eliminates confusion, ensures that all teams align with the expectations similarly, and have the opportunity to design their pitches accordingly. In addition, when considering pre-recorded pitching, it should be cautioned beforehand that tools, such as YouTube, could bring about technical issues, and uploading could take longer than expected. Therefore, if the capacity of the event allows, live-streamed pitching should be considered, as based on the findings, it can be associated with fewer risks for the participants.

5.5 Implications for research

Despite the findings and implications for practice, the study also raises questions for future research. Deriving from the findings of limited networking effect, further research could concentrate on how to successfully enable networking in a remote hackathon setting. What is more, the usage of different communication tools could be studied, and the optimal combination of tools suggested. Also, the effectiveness of remote hackathons comparing to in-person events could be researched. Prior work has mentioned the cost-effectiveness of the remote format, but does it also yield better results in terms of idea development and continuation? In addition, comprehensive guidelines for organizing a remote hackathon could be developed.

5.6 Limitations

This study aimed to analyse how teams collaborate during an online hackathon and how the event setting can potentially affect their collaboration. Thus a mixed-methods multiple-case study was conducted, as it allows to study the novel phenomenon of collaboration during online hackathons in the context it occurs [36]. However, several limitations, which are discussed followingly, could be associated with the described qualitative research design. The study was based on two remote hackathons organised in 2020. The events were selected to be focusing on different themes and to vary in their design. Altogether 15 hackathon participants were interviewed, and 18 survey answers were collected. Although the event selection criteria were fulfilled and the input for the analysis was varied, it is acknowledged that the results of this study are not generalisable and cannot be expanded outside the context

of this research. Studying events with a different theme, design and participants might yield different results.

Furthermore, utilising interviews and surveys can introduce different biases. To begin with, the interview design could potentially affect the input from the interviewees, as different questions could lead to other results. The aspect was mitigated by including general and open-ended questions so that the respondent would have a chance to elaborate. Additionally, the interview themes were selected based on the research questions and collaboratively evaluated beforehand. Another bias around interviews is the perception of participants, which could affect their report of the event. To address these limitations, the interviews were conducted as close to the event as possible so that the participants would remember as many of the details. Moreover, at least two members from each team were interviewed, which ensured that different viewpoints would be included. In addition to interviews, also survey design could influence the study results. For reducing the possible effect, all the survey questions were based on previously established scales, and the results were utilised only as additional qualitative data points, as the sample size was limited.

Likewise, the way of analysing the collected input could potentially affect the outcomes of the study. Since analysing qualitative data is a complex task, the results could depend on both the individual conducting the analysis and the methods selected for it. Thus, the analysis was done based on academically exploited methodologies, and the results were presented in a way that would abstain from making causal claims. Instead, the findings were discussed to avoid interpreter bias, and a detailed description of the perceptions of participants was provided. Nevertheless, despite all the mitigations, it is acknowledged that the research findings might still be biased. Therefore, the results of this study should be interpreted with caution as the generalisability is limited.

6 Conclusion

Hackathons are rapid design and development events used by organisations to maintain their competitive advantage, create innovations, and explore new business opportunities. Until lately, hackathons have been primarily in-person events where collocated teams solve challenges of interest to them. However, due to the global COVID-19 pandemics and work shifting online, remote hackathons have become the norm. On the contrary to collocated hackathons, participants at remote hackathons are distributed, and the activities are realised through different technological tools that enable collaboration.

The research around the remote hackathon phenomena is being developed, and this study contributes to exploring the format from a collaborative aspect. More specifically, the way teams collaborate in a remote setting and the effect of the hackathon setting on collaboration was studied. In order to explore the topic further, two remote hackathons were researched, altogether 15 interviews were conducted, and 18 survey answers were collected. Qualitative data analysis was applied to the gathered data, and through coding and affinity mapping, the study findings were identified. The discoveries were structured based on the four key concepts of remote collaboration identified by Olson and Olson [24]. However, an additional section around hackathon-specific findings was added, as the mentioned framework concentrates solely on an organizational work setting.

When analysing the study results, it was found that some of the characteristics of in-person hackathons could also be noticed in the online events, however, others diminished or even disappeared. For example, it was identified that some of the common affordances of in-person hackathons, such as collaboration between teams and networking, had noticeably decreased. The remote setting eliminates the opportunity to simply bump into other participants in the hackathon venue, therefore organisers and participants should aim to create these connections consciously. Furthermore, the importance of establishing common ground was discovered as teams who prepared for the event achieved higher goal clarity. More specifically, the positive effect of availability mapping within the team was identified, as it led to fewer misunderstandings during the hacking. Having an overview of each other's schedules was further of use, as during a remote hackathon, participants engaged in parallel activities not connected to the event. What is more, the remote format proposed technical constraints because different technological tools, such as Slack, Zoom, WhatsApp, Facebook messenger, etc., need to be used for successful communication. Similarly to in-person events, the collaboration within teams was intense, progress was presented in checkpoints, and the role of mentors had remained.

As a result of the research, a set of implications were developed both for remote hackathon participants and organizers. The primary suggestion to participants is to consciously approach the remote format, especially in terms of networking and mentoring, as in distributed setting, the casual encounters are minimal. In terms of organisers, it is suggested to keep the communication clear, caution participants on the risks of using different technological solutions, and knowingly contribute to creating more networking opportunities, which are otherwise minimised because of the remote setting.

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Appendix

I. Interview guide

I'm Tähe-Kai, from the University of Tartu, Innovation and Technology Management masters' course. I'm writing my thesis on remote hackathons. The goal of this interview is to understand how teams with different dynamics and characteristics operate in an online hackathon setting and which challenges they face. When choosing participants, we were looking for diversity in the teams and whether team members previously knew each other or not.

We will mainly talk about the hackathon experience and your team. The interview will take about an hour.

Before the hackathon: What was your main motivation for participating in the "48 for future" hackathon? (idea, prizes, experience, networking)

- How did you prepare for this hackathon? (idea development, gathered feedback, additional learning)

In the beginning of the hackathon: What was the idea your team worked on? Whose idea was it? (When did you have it?)

- How well did you know your teammates before the hackathon?
- How did you meet with your team members? How was the team formation organised? (Did you have the team before, did people join in)?
- How big was the team? Did you gain/lose any members during the hackathon??

During the hackathon: Please tell me a little about how you worked as a team? (structuring the work, tools, roles, frustrations)

- Were you all participating remotely or some of you were working together in the same place?
- Were there people who were more or less active?
    - If they were less active what was the reason? (Communication, shyness) Did you attempt to include them? How did that go?
    - How much time did you commit? Was it more or less that you expected?
- What was your role in the team? Have you been in this role before?
- How did you decide for who would do what? (Based on skills, interest)
- How well did the communication work? (probe: more issues with people you didn't know?)
- Which tools did you use for working and communicating during the hackathon? How did you decide for these tools? (Remider: which tools did the organisers propose)
    - Did you face any issues (probe: technical issues)

- Which challenges you encounter during the hackathon as a team?
- [If has participated in physical hackathons before] How was this experience different from the in person hackathon experience? (team perspective)
    - What was particularly difficult to you in the remote setting?

Final about the team: Tell me something that worked really well? What would you do differently next time?

Generally

- How far did you get with your idea?
    - Was there something you would've liked to do but didn't?
- Did you always get the support that you needed? (mentors)
- How did you interact with the mentors?
- Were you at all times aware what you needed to too? (Was the organisation clear)

After the hackathon: What were the main outcomes for you from the hackathon? (professional/business value, learning, new acquaintances/networking, satisfaction...)

- Which challenges did you face because of the remote setting – differences to in person hackathons (long hours behind the computer, less networking, miscommunication)
- Did you encounter any technical errors during the hackathon? (Communication tools, prototyping, wifi connection etc.)

Generally about the hackathon: What was good? What would you do differently next time?

Final: Is there something you would like to add (probe: remote setting)?

II. Survey questions

Teamwork during the hackathon

1. Please provide the name of your team.
2. Was there a team leader?
3. To what extent do you agree with the following statements related to communication within the team. (Not at all, To some extent, To a moderate extent, To a large extent, Completely) *based on Filippova et al. (2017) [38]*
    - Everyone had a chance to express his/her opinion.
    - The group members responded to the comments made by others.
    - The group members participated very actively during the project.
    - Overall, the participation of each member in the project was effective.
4. To what extent do you agree with the following statements related to your team's goals? (Not at all, To some extent, To a moderate extent, To a large extent, Completely) *based on Filippova et al. (2017) [38]*
    - I was uncertain of my duties and responsibilities in this team.
    - I was unclear about the goals and objectives for my work in this team.
    - I was clear about the expected results of my work in this team.
    - I was unsure how my work relates to the overall objectives of my team.
5. Would you describe your team process as more...? *based on Filippova et al. (2017) [38]*
    - Inefficient to Efficient (1 to 5)
    - Uncoordinated to Coordinated (1 to 5)
    - Unfair to Fair (1 to 5)
    - Confusing to Easy to Understand (1 to 5)

Participation in the hackathon

6. To what extent was your decision to participate in the hackathon motivated by: (Not at all, To some extent, To a moderate extent, To a large extent, Completely) *based on Filippova et al. (2017) [38]*
    - Having fun
    - Making something cool
    - Learning new tools or skills
    - Meeting new people
    - Joining friends that participate
    - Seeing what others are working on
    - Sharing your experience and expertise
    - Advancing your career
7. Please indicate your level of agreement with the following statements related to your SATISFACTION with the OUTCOMES of the hackathon. (Strongly disagree, Somewhat disagree, Neither agree nor disagree, Somewhat agree, Strongly agree) *based on Filippova et al. (2017) [38]*
    - I am satisfied with the work completed in my project.
    - I am satisfied with the quality of my group’s output.

- My ideal outcome coming into my project achieved.
- My expectations towards my project were met.

Additional info

8. Your name
9. Your age
10. What is your current occupation?
11. Do you consider yourself a minority? (For example, in terms of race, gender, expertise or in another way)
    - Yes
    - No
    - Rather not say
12. In how many hackathons have you participated previously?
13. How many of them were online hackathons?

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