

Design at hackathons: new opportunities for design research

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Abstract

Hackathons are short-term events at which participants work in small groups to ideate, develop and present a solution to a problem. Despite their popularity, and significant relevance to design research, they have only recently come into research focus. This study presents a review of the existing literature on the characteristics of designing at hackathons. Hackathon participants are found to follow typical divergence–convergence patterns in their design process throughout the hackathon. Unique features include the initial effort to form teams and the significant emphasis on preparing and delivering a solution demo at the final pitch. Therefore, hackathons present themselves as a unique setting in which design is conducted and learned, and by extension, can be studied. Overall, the review provides a foundation to inform future research on design at hackathons. Methodological limitations of current studies on hackathons are discussed and the feasibility of more systematic studies of design in these types of settings is assessed. Further, we explore how the unique nature of the hackathon format and the diverse profiles of hackathon participants with regards to subject matter knowledge, design expertise and prior hackathon experience may affect design cognition and behaviour at each stage of the design process in distinctive ways.

Keywords: hackathon, design, literature review

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1. Introduction

Hackathons are rapidly growing in popularity. At these events, participants work in small groups to ideate, develop and present a solution to a problem. Thus, while not always explicitly promoted as such, hackathons provide participants with exposure to, and experience in, design (Artiles & Wallace 2013; Komssi *et al.* 2015). Hackathons present themselves as unique and authentic settings at which design activity can be studied.

Hackathons have only recently come into research focus (Trainer *et al.* 2016). Studies have investigated the individual experiences of participants (Olesen, Hansen & Halskov 2018), the effect of expertise diversity in hackathon teams (Legardeur *et al.* 2020) and the use of hackathons to solve problems (Artiles & LeVine 2015; Lewis *et al.* 2015; Uffreduzzi 2017; Kos 2019), teach design (Fowler 2016; Nandi & Mandernach 2016; Page *et al.* 2016; Gama *et al.* 2019) and facilitate a design process (Artiles & Wallace 2013).

We view hackathons as a setting that simulates aspects of design activity as it occurs in real-life practice; yet, the extent and nature of design in this unique environment is not well understood. Research on design activity as it occurs at

hackathons can improve our understanding of rapid design decision-making and provide evidence-based prescriptions for more effective designing of the hackathon events themselves. In this paper, we aim to explore the extent to which design processes have been studied in hackathons and identify future directions and opportunities for design and design education research in this setting.

1.1. What is a hackathon?

There is no finite, agreed-upon set of characteristics that classify an event as a hackathon (Komssi *et al.* 2015), making it difficult to generate a definition inclusive of all variations of hackathon-like events. In general, a hackathon is a problem-focussed, short-term event where small groups work to develop a final product (Briscoe & Mulligan 2014; Komssi *et al.* 2015; Gama 2017; Izvalov, Nedilko & Nedilko 2017; Kollwitz & Dinter 2019). Hackathons tend to be of interest to computer programmers, designers and engineers; it is typical for the theme of the event to be tech-centric. They have been used in a wide variety of contexts and for different purposes, including education, networking and to accelerate innovation (Flores *et al.* 2018). Hackathons could be run as external events (open to anyone), or internally by organisations (Briscoe & Mulligan 2014). The duration of hackathons also varies greatly. Hackathons typically run continuously over 24–36 hours, but may also run for shorter periods of time over a span of weeks, months or even years (Truyen 2016; Taes & Colangelo 2017; Hölttä-Otto *et al.* 2018; Rennick *et al.* 2018; Taylor *et al.* 2018; De Oliveira *et al.* 2019; Richterich 2019).

The term ‘hackathon’ is a combination of the words ‘hack’ and ‘marathon’ (Briscoe & Mulligan 2014); whereas the usual interpretation of ‘hack’ is in reference to a cybercrime, in this context it refers to exploratory programming. The term ‘marathon’ implies a prolonged, race-like event. This accurately describes a hackathon as a tech-centric, speed design event. Since the first known uses of the term ‘hackathon’ to describe such events in 1999 (Briscoe & Mulligan 2014; Richterich 2019), the hackathon phenomenon has rapidly expanded globally and hackathons continue to grow in popularity. Hackathons may also be referred to as *game jams*, *design jams*, *hacking festivals*, *hack days*, *design sprints* and *codefests* (Briscoe & Mulligan 2014), among others. In this review, hackathons that are not labelled as such, but follow a format inspired by hackathons, are considered ‘hackathon-like events’ and are included in our analysis. As the hackathon format continues to be adapted for different uses and by different stakeholders, new names continue to emerge.

Typically, a hackathon starts with a presentation about the event goals, design challenges, sponsors, schedule and prizes. The theme of the event can either be announced beforehand, or at the start of the event, and could be general, or focussed on a specific task. The process of forming teams may have started before the event via existing relationships and the sharing of ideas via collaboration channels, or at the event based on common interests, skills and project ideas. Once teams are formed, work begins. In the typical hackathon, participants work through the night. Teams brainstorm, build prototypes and, at the end of the hackathon, present their work via ‘pitches’ in a competition for prizes (Briscoe & Mulligan 2014).

Hackathons have much in common with a related approach to design – Agile – which also prioritises the creation of working solutions over a short timescale (sprints; Sims & Johnson 2011, p. 40). Not surprisingly, many organisations that have already adopted agile practices will also use hackathons and hackathon-like

events to accelerate innovation (Alkema, Levitt & Chen 2017). Prior studies have reported the emergence of agile practices during hackathons (Alkema *et al.* 2017), and attempts to integrate hackathon and agile approaches into one event (Ferrario *et al.* 2014; Hölttä-Otto *et al.* 2018). Despite the few instances when these two approaches come to overlap, of interest in this paper are the hackathons that follow the more typical structure – a large number of participants gathering over a short period of time (1–2 days) to engage in a design activity that is separate from their regular commitments, whether school or work. In contrast, the goal of design sprints as they are typically described in the literature is problem-solving and innovation within a specific organisational context; as such they are integrated with or complementary to existing organisational processes, and operate at different timescales of 1–4 weeks (Knapp, Zeratsky & Kowitz 2016, p. 40).

1.2. Design and hackathons

Since the 1960s when it first emerged as a discipline, design's development and impact on industry, research and education has occurred in a number of 'waves' (Cooper 2019). The emergence of hackathons in the 1990s and their further gains in popularity in the 2000s (Briscoe & Mulligan 2014; Richterich 2019) coincide with the cusps of the third wave of change, a time of formalising the connection between design and innovation, and the fourth wave, a time of the acceptance of design outside of the discipline (Cooper 2019). The increasing interest in hackathons also aligns with the current (fifth) wave – applying design to understand the future (Cooper 2019) – in that hackathon events increasingly challenge participants to solve complex problems with a focus on benefitting the world and our futures; for example, solving systematic healthcare problems (Alamari, Alabdulkarim & Al-Wabil 2019), addressing sustainability issues such as deforestation (Lodato & DiSalvo 2015) and conceptualising products or services to aid those affected by self-harm (Birbeck *et al.* 2017).

Design reasoning has commonly been conceptualised as the process of developing an artefact (the 'what') that performs some function (the 'how') in order to solve the problem (the 'outcome'; Dorst 2011). The designer must start with the desired 'outcome' and devise a new 'how', and in turn, design the 'what', a pattern known as *design abduction* (Dorst 2011). The typical design problem is ill-structured, meaning it is not well-defined, the goals are underspecified and the potential solutions are practically limitless (Goel & Pirolli 1992). The formulation of such 'wicked' problems cannot follow a linear path (Rittel & Webber 1973); design entails a continuous refinement of both the designer's understanding of the problem and their ideas for solving it, in a process of co-evolution of the problem and solution spaces (Maher, Poon & Boulanger 1996; Dorst & Cross 2001). In other words, a designer must shift their thoughts between the required purpose/function and the appropriate ways to satisfy that purpose. Since there are two unknowns in design abduction (the 'what' and the 'how'), there is a lot of uncertainty and limited knowledge, making design a long and iterative creative process (Dorst 2011).

At hackathons, the limited time available prevents long periods of exploration and iteration. However, the event is structured as an abductive task – participants may spend significant time 'searching' for a problem for which a solution must be designed. Because hackathons are a fairly recent phenomenon, a shared understanding of how this setting affects design behaviour and outcomes has not yet

emerged. While many publications focus on outcomes of hackathons, few include discussion related to design activity at the event(s) (Olesen 2017). Existing literature often consists of experience reports or studies of a singular event, or within a specific domain (Raatikainen *et al.* 2013; Kollwitz & Dinter 2019). The one known attempt to synthesise this knowledge is a recent literature review by Kollwitz & Dinter (2019), who propose a taxonomy of hackathons. However, while their taxonomy accounts for the entire duration of the hackathon from initial idea generation to results, its focus is on how hackathons are/ought to be organised, and not on describing/understanding how hackers design. Other research on hackathons present ways to measure innovation during hackathons (Legardeur, Choulier & Monnier 2010) and investigate how variance in team members' educational backgrounds influences team performance (Legardeur *et al.* 2020). We will revisit these concepts throughout this paper.

1.3. Aims

The study of design at hackathons is a logical extension of design research. The unique characteristics of hackathons bring about heightened and condensed design activity in which the typical design processes are challenged and adapted. A better understanding of design at hackathons can help clarify how these events engage participants in the design process (Olesen *et al.* 2018) and shed light on the consequences of a hackathon's format on participants' ideation, design judgement and knowledge of design. Studying how hackathon participants design can also more broadly enrich our understanding of how designers think during an applied design task when in a condensed time frame.

Motivated by the emerging popularity of hackathons, the unique limitations of time and resources during the events, and the lack of an established understanding of design at hackathons, in this paper, we provide a synthesis on the research seeking to uncover (1) the nature of design activity at hackathons and (2) the role of a hackathon's format and structure on resulting patterns of design behaviour and learning. Based on our review, we then identify a number of knowledge gaps that inspire new potential design research directions in this unique setting. The rest of the paper is organised as follows: Section 2 explains the research methodology, with findings presented in Sections 3 and 4. Section 5 presents possible extensions of this research followed by a conclusion in Section 6.

2. Methodology

The aim of this study was to conduct a systematic literature review; however, such a review can only be conducted within established fields and the literature on design cognition at hackathons is limited. We nevertheless employed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Moher *et al.* 2009) as a means to structure our research. This framework prescribes a four-phase process for conducting systematic literature reviews, as shown in Figure 1.

Key search terms were identified as 'hackathon', 'design' (intended to encompass other terms such as design thinking, design process, design cognition and design activity) and 'creative' (to encompass creativity, creative thinking and creative process). While hackathons have also been identified with alternate names, such as game jams and hack days, these were eventually omitted from the search as 'hackathon' was

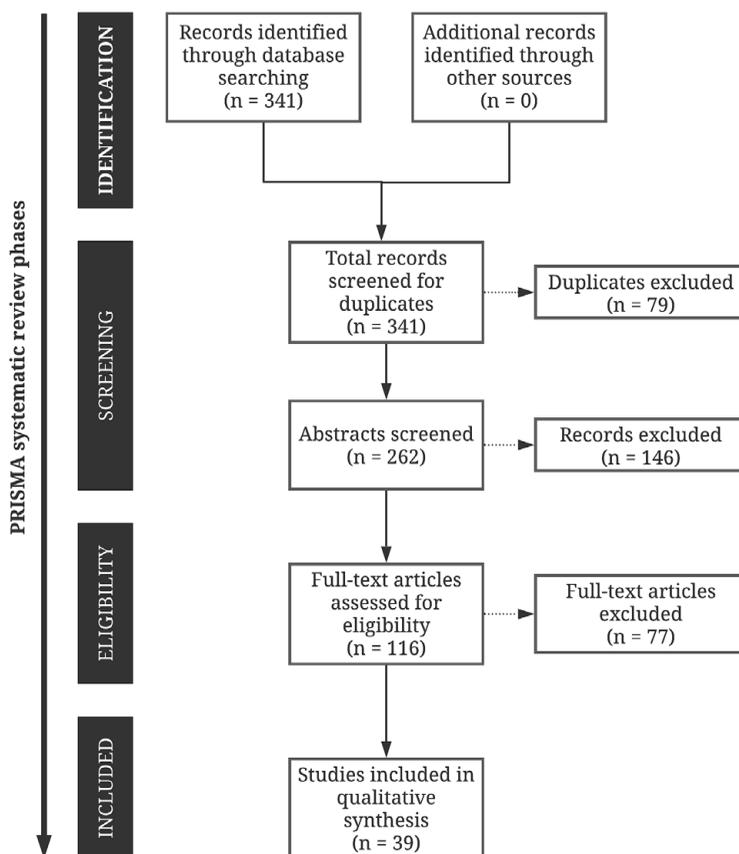


Figure 1. PRISMA flowchart of our literature review.

found to encompass these words in the search results. The search was conducted on 19 November 2019 in the *Scopus* and *Web of Science* research databases. The terms were searched in the ‘titles’, ‘abstracts’ and ‘keywords’ fields. The inclusion criteria for the search were journal articles, conference proceedings, books or book sections, published in English. The exact search syntax is provided in [Table 1](#).

Searches in the *Scopus* and *Web of Science* databases yielded 232 and 109 results, respectively. After duplicates were removed, abstracts of the remaining 262 records were scanned for relevance. At this stage, 146 publications were removed, because they were proceedings of presentations at a hackathon (not publications about design at hackathons), the hackathon was a means to study a different phenomenon, or the publication was not about a hackathon.

A full-text screen was then done on the remaining 116 publications to further screen for applicability. The main reason for exclusion at this stage was the lack of discussion about design activity. After this process, 39 publications were selected as relevant to the topic of study. All 39 publications are included in the literature analysis.

3. Overview of the reviewed publications

[Table 2](#) presents an overview of all reviewed publications and the hackathon(s) they study. All reviewed publications include information on design activity at a

Table 1. Search syntax by database with number of results

Database	Search syntax	Results
Scopus	(TITLE-ABS-KEY (hackathon*) AND TITLE-ABS-KEY (design OR creativ*)) AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English"))	232
Web of Science	TOPIC: (hackathon* AND (design OR creativ*)) Refined by: DOCUMENT TYPES: (PROCEEDINGS PAPER OR ARTICLE) AND LANGUAGES: (ENGLISH)	109

hackathon, or directly study design processes at a hackathon event. Most of the reviewed publications consider hackathons to be design or participatory design activities (e.g., Birbeck *et al.* 2017; Taylor & Clarke 2018). The publications varied in their motivations. A few publications aimed to propose a framework for hackathons (Johnson & Robinson 2014; Buttfield-Addison *et al.* 2016; Flores *et al.* 2018). They either presented a pattern of design behaviour as observed at a hackathon, or a structure to be followed at a hackathon. Other motivations included identifying the purpose of hackathons (Komssi *et al.* 2015), studying the effectiveness of hackathon-like events in teaching design (Artiles & LeVine 2015) and identifying potential benefits of hackathons (Carroll & Beck 2019). A few of the reviewed publications do not aim to study design activity at hackathons, but rather to describe how hackathons are used to find solutions to complex problems, such as accelerating healthcare innovation (Alamari *et al.* 2019), involving citizens in rural community development (Soligno *et al.* 2015) and supporting diversity in software development (Filippova *et al.* 2017). In these cases, discussions on the design processes of participants are limited.

The first section in Table 2 includes information on the publication: citation, subject area and the number of hackathons included in the study. Most of the publications were sourced from journals or conference proceedings in the subject areas of computer science and engineering. Only five publications focus on more than one hackathon, whereas the rest study individual hackathons.

The second section in Table 2 categorises publications based on methodology employed, which spans experimental (8 publications), case study (6), autobiographical (4) observational (14), interview/focus group (13), survey (9), review of literature (4), and even secondary data analysis (1) approaches. For example, in one study, researchers study healthcare innovation at a hackathon by following a set of selected teams throughout the duration of the hackathon and describing the design stages followed (Alamari *et al.* 2019). Similarly, Taylor *et al.* (2017) describe the observed behaviours of participants in a series of *Inventor Days* as they completed various tasks to learn about a community, identify issues and develop solutions for grassroots innovation. In the case of interviews and focus groups, hackathon participants are gathered after the event and asked key questions related to the authors' research question(s). Surveys are also typically administered to hackathon participants post-event; however, in a few cases, surveys are used as a measurement tool (e.g., to assess the effectiveness of an intervention) and thus participants complete both pre- and post-event surveys (Artiles & LeVine 2015). Finally, in at least one case, secondary data analysis is conducted on registration information to study demographic characteristics of the hackathon participants (Izvalov *et al.* 2017).

Table 2. An overview of publications and hackathons included in the review. A check mark indicates a ‘Yes’, an ‘x’ means ‘No’ and ‘n/a’ means the information was not provided in the publication

Citation	Publication subject area	Number of hackathons	Experimental	Case study	Autobiographical	Observations	Interview/focus group	Survey	Literature review	Data analysis	Topic	Design facilitated?	Competitive event?	Targeted participant	Single-application	Application-specific	Technology-specific	Socially oriented	Demographic-specific	Company-internal
Alamari <i>et al.</i> (2019)	Computer science	1	✓			✓					Healthcare	✓	✓	Engineers, clinicians, programmers and designers	✓					
Artiles & LeVine (2015)	Computer science and engineering	3				✓	✓				Education hackathons	x	n/a	Relevant stakeholders		✓				
Aryana, Naderi & Balis (2019)	Computer science and engineering	1			✓	✓					Product design	x	✓	Science, engineering, design and business undergraduate students	✓					
Birbeck <i>et al.</i> (2017)	Computer science	1	✓								Mental health	x	n/a	Undergraduate and graduate students, healthcare workers and public					✓	
Buttfield-Addison, Manning & Nugent (2016)	Computer science	6	✓			✓					Game development	✓	n/a	Programmers, game designers and artists	✓					
Carroll & Beck (2019)	Arts and humanities, computer science and engineering	2	✓				✓				Water quality	x	n/a	Water quality stakeholders					✓	
Damen <i>et al.</i> (2019)	Computer science	1		✓							Community health	x	n/a	Junior researchers from various disciplines					✓	
Filippova, Trainer & Herbsleb (2017)	Computer science	2					✓	✓			Technical software development	✓	x	Software developers and nontechnical participants		✓				
Flores <i>et al.</i> (2018)	Business, management and accounting	1			✓				✓		Employee engagement	✓	✓	Employees						✓
Frey & Luks (2016)	Computer science	2							✓		Various	x	✓	Various						✓
Gama <i>et al.</i> (2019)	Computer science and social sciences	1					✓	✓			Course project (computer science)	✓	x	Computer science and information systems undergraduate students	✓					
Gama (2017)	Computer science	3						✓			Civic hackathons	x	n/a	Software engineers, designers and activists					✓	

Table 2. Continued

Citation	Publication subject area	Number of hackathons	Experimental	Case study	Autobiographical	Observations	Interview/focus group	Survey	Literature review	Data analysis	Topic	Design facilitated?	Competitive event?	Targeted participant	Single-application	Application-specific	Technology-specific	Socially oriented	Demographic-specific	Company-internal
Horton <i>et al.</i> (2018)	Computer science and engineering	1				✓	✓				n/a	x	n/a	Undergraduate engineering students						✓
Izvalov <i>et al.</i> (2017)	Computer science	2					✓			✓	Game development aeronautics	x	✓	IT companies and software developers		✓				
Johnson & Robinson (2014)	Environment and social sciences	n/a							✓		Civic hackathons	x	n/a	n/a						✓
Karlsen & Løvlie (2017)	Arts and humanities	1									Filmmaking	x	x	Filmmakers, artists, designers and software developers		✓				
Komssi <i>et al.</i> (2015)	Computer science	5							✓		Organisation and business hackathon	x	✓	Employees, external companies and researchers		✓		✓		
Lodato & DiSalvo (2015)	Social sciences	2				✓					Sustainability, ecology and food system issues	✓	✓	Developers, designers and topic experts						✓
McGowan (2019)	Social sciences	1	✓								Healthcare	x	x	Librarians						✓
Mielikäinen, Angelva & Tepsa (2019)	Engineering	1	✓					✓			Curricular hackathon	✓	n/a	Undergraduate Information and Communication Technology (ICT) students						✓
Olesen <i>et al.</i> (2018)	Computer science	1			✓						n/a	x	✓	Designers and programmers		✓				
Olesen (2017)	Computer science	n/a									Game development	x	n/a	n/a						✓
Page <i>et al.</i> (2016)	Computer science	1				✓	✓				Digital products (greeting cards)	✓	n/a	Undergraduate students studying product and digital interaction design		✓				
Pe-Than & Herbsleb (2019)	Computer science	2					✓	✓			Science collaboration	x	x	Employees		✓				
Piza <i>et al.</i> (2018)	Medicine	1						✓			Healthcare	x	n/a	Engineers, clinicians and data scientists						✓
Porter <i>et al.</i> (2017)	Computer science	1					✓				Philanthropy	✓	n/a	n/a						✓
Prieto <i>et al.</i> (2019)	Computer science and engineering	1			✓						Game development	x	✓	Designers, software developers and artists						✓

Table 2. Continued

Citation	Publication subject area	Number of hackathons	Experimental	Case study	Autobiographical	Observations	Interview/focus group	Survey	Literature review	Data analysis	Topic	Design facilitated?	Competitive event?	Targeted participant	Single-application	Application-specific	Technology-specific	Socially oriented	Demographic-specific	Company-internal
Raatikainen <i>et al.</i> (2013)	Computer science	1	✓		✓	✓					Cloud-based security software	x	x	Employees						✓
Rennick <i>et al.</i> (2018)	Computer science and engineering	4				✓	✓	✓			Curricular hackathon	x	✓	Undergraduate engineering students						✓
Rey (2017)	Computer science	1				✓					Museum creation	x	x	Graphic designers, software developers, makers and content specialists			✓			
Safarova <i>et al.</i> (2015)	Computer science	1	✓								Diversity awareness	✓		Students of computer science, engineering, business, architecture and design	✓	✓				
Saravi <i>et al.</i> (2018)	Computer science, engineering and materials science	1		✓							Aircraft concepts	x	n/a	Aircraft stakeholders, partners and engineers						✓
Scott, Ghinea & Hamilton (2015)	Computer science and social sciences	1						✓			Game development	x	✓	Game designers and software developers	✓					
Soligno <i>et al.</i> (2015)	Computer science and social sciences	1		✓							Technology in communities	✓	✓	University students and professors		✓				
Suominen, Halvari & Jussila (2019)	Business management	1		✓		✓					Educational hackathon on technology in communities	x	n/a	Student groups from higher education institutions						✓
Taratukhin <i>et al.</i> (2018)	Computer science and engineering	1	✓								Natural disasters	✓	✓	Engineering and humanities students						✓
Taylor & Clarke (2018)	Computer science	6				✓	✓				Various	x	✓	Developers, designers and topic experts						✓
Taylor, Clarke & Gorkovenko (2017)	Computer science	3	✓			✓	✓				Technology in communities	x	x	Community members and makers						✓
Thomer <i>et al.</i> (2016)	Computer science	1				✓					Bioscience (taxonomy)	x	✓	Experts in taxonomy, information science and software development		✓				

The third section in Table 2 lists the topic of each hackathon under study. Five of the studied hackathons are either labelled as ‘game jams’, or have the aim of game development (Scott *et al.* 2015; Buttfield-Addison *et al.* 2016; Izvalov *et al.* 2017; Olesen 2017; Prieto *et al.* 2019). Another five publications present education-oriented activities that follow the hackathon pattern (Horton *et al.* 2018; Rennick *et al.* 2018; Taratukhin *et al.* 2018; Gama *et al.* 2019; Mielikäinen *et al.* 2019). These hackathon-like events aim to engage students in a heightened design activity, either in-class or as an out-of-class activity, where the specific topic is related to the students’ field of study, with the prompts ranging from addressing natural disasters to solving mechanical engineering problems. Five publications discuss ‘civic hackathons’ (Johnson & Robinson 2014; Soligno *et al.* 2015; Gama 2017; Taylor *et al.* 2017; Damen *et al.* 2019), meaning citizens are involved in solving problems related to their communities. Three hackathons are about healthcare (Piza *et al.* 2018; Alamari *et al.* 2019; McGowan 2019), and another three center around the sustainability topics of water quality (Carroll & Beck 2019), biodiversity (Thomer *et al.* 2016) and ecology (Lodato & DiSalvo 2015). Finally, one hackathon is in each of the following areas: mental health (Birbeck *et al.* 2017), education (Artiles & Lande 2016), film and television (Karlsen & Løvlie 2017), aircraft design (Saravi *et al.* 2018), diversity awareness (Safarova *et al.* 2015), museum artefact design (Rey 2017), student life (Aryana *et al.* 2019), greeting card reconceptualisation (Page *et al.* 2016) and app development and financial innovation (Frey & Luks 2016). Also included in the third section is if design was facilitated during the event, if the event was competitive, and the targeted participant profile.

Finally, section four categorises the purpose of the hackathons according to a classification proposed by Briscoe & Mulligan (2014). Hackathons are either ‘tech-centric’ or ‘focus-centric’. Tech-centric hackathons focus on software development and can aim to improve a single application (‘single-application’), a specific platform (‘application-specific’), or create an application within a specific programming language (‘technology-specific’). Applied (or ‘focus-centric’) hackathons focus on contributing to a social issue (‘socially oriented’), targeting a specific demographic (‘demographic-specific’), or addressing a business objective within an organisation (‘company-internal’). The 39 reviewed publications describe a balance of tech- and focus-centric hackathons, with the majority being application-specific or socially oriented.

4. Characteristics of design activity at hackathons

4.1. Participants’ design process

It is evident from the accounts in the publications that participants in hackathons or hackathon-like events follow a design process similar to ones followed in more common design tasks. The overarching pattern of design process at a hackathon includes an initial divergence in order to search for and understand a problem, convergence onto a specific design opportunity, divergence during the development of the solution, a final convergence via testing of the design and preparation and delivery of a final pitch. Specifically, the process typically begins with a *team-building* (Safarova *et al.* 2015) and *problem identification* (Mielikäinen *et al.* 2019) phase, followed by *brainstorming and production* (Safarova *et al.* 2015), *ideation, prototyping* and *testing* (Mielikäinen *et al.* 2019). The hackathon always concludes

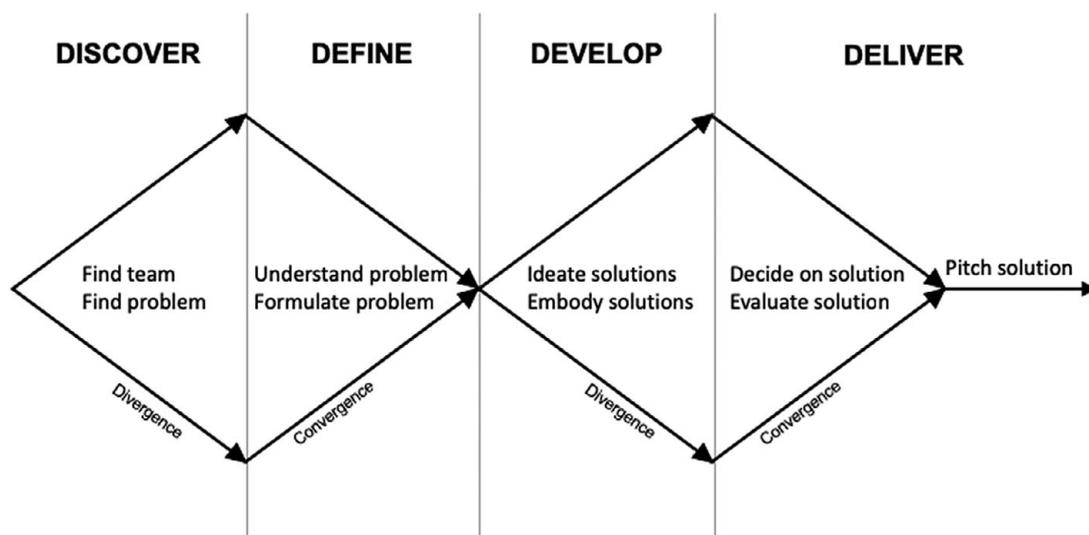


Figure 2. The hackathon (altered) double diamond design process.

with a final pitch, termed the *showcase* (Safarova *et al.* 2015), or *presenting* (Mielikäinen *et al.* 2019) phase. Hackathon participants from the same team may be engaged in multiple phases simultaneously. Further, iteration occurs within and between phases (Buttfield-Addison *et al.* 2016). This pattern closely aligns with the four phases of the well-known Double Diamond design process (Design Council 2005). Below, we use that model to structure our overview of the characteristics of participants’ activities throughout the duration of a hackathon in each phase. The design process followed by hackathon participants, as described in this section, is illustrated in the (altered) double diamond design model shown in Figure 2.

The first phase of the double diamond model is that of ‘Discover’, which describes a divergent activity with the primary goal to gain understanding of the problem or problem area. At hackathons, this phase includes a number of dependent activities. At the beginning of a hackathon, the first activity of significance for participants is to form and get to know their teams, if they have not already formed these teams prior to the event. Once teams are formed, participants identify team skills, knowledge and available resources, and then focus on need finding in order to identify potential topics for their hackathon project. Depending on the hackathon, participants may be given a topic or prompt (e.g., ‘find solutions to “smart villages and territories” problems’; Soligno *et al.* 2015, p. 737), or may need to begin their design process by first identifying a problem area. It is typical for industry to partner with hackathon events, for example, by having industry representatives attend hackathons and propose project areas. The highest degree of industry involvement is a company-internal hackathon, which is a hackathon exclusive to the organisation’s employees that aims to solve a shared problem. For example, at a hackathon hosted by a large IT provider in Germany, 24 employees from various departments split up into 5 teams that competed to develop an app that supported the sharing of a ‘thing’, such as a car or book (Frey & Luks 2016). In this case, the goal of the hackathon was predetermined, requiring less discovery for the

participants. In general, teams either identify their problems from the industry partners (where applicable), from their personal experience (Raatikainen *et al.* 2013; Suominen *et al.* 2019) or by conducting user research (Karlsen & Løvlie 2017; Damen *et al.* 2019). Teams brainstorm potential ideas and use strategies, such as team voting, to converge on a direction for their project (Thomer *et al.* 2016). Altogether, this phase comprises the ‘finding’ of both the design problem and the design team itself. Hackathon participants engage in a process of perceiving the context (i.e., team and setting) to discover available resources – ‘*space, skilled time, knowledge and tools*’ (Prieto *et al.* 2019, p. 2) – to meet their goals.

In the second phase of the model – ‘Define’ – designers construct an understanding of the problem and converge into a problem formulation that defines the aims and requirements of the design and constraints on the solution space. Requirements and constraints may come from the task environment or the designers themselves. In the hackathon setting, a large constraint is time; thus, participants aim to identify a problem for which a viable solution can be developed in the short time frame of the event. Techniques highlighted in the reviewed publications for developing an understanding of the problem include interviews and stakeholder mapping (Damen *et al.* 2019), as well as user profiling (Rey 2017). These techniques allow for teams to identify key features and create a common reference of the problem. At hackathons, regardless if the topic is given or they have to conduct problem finding on their own, participants aim to develop a shared understanding of the problem with the group (Prieto *et al.* 2019). Completing this phase is needed in order for the team to establish a direction for the remainder of the design process (Damen *et al.* 2019).

The third phase – ‘Develop’ – describes another divergent set of activities. At hackathons, development comprise two main tasks: (1) *concept ideation* (Damen *et al.* 2019), which is the generation of possible solution ideas and subsequent iteration on those ideas and (2) *embodiment* (Prieto *et al.* 2019), which includes the development and demoing of initial prototypes. Common design tools used during this phase are sketching (Thomer *et al.* 2016; Karlsen & Løvlie 2017) and prototyping (Karlsen & Løvlie 2017; Rey 2017; Suominen *et al.* 2019). Teams may use provided materials, such as Post-it Notes (Rey 2017), to aid in brainstorming and cheap supplies to build prototypes.

In the fourth and final phase – ‘Deliver’ – teams focus on converging their solution ideas into a final artefact. Teams will test their designs, for example, by assigning a ‘tester’ role to a team member responsible for checking their code for bugs (Pe-Than & Herbsleb 2019), or by asking volunteers to use their prototype to identify any features that do not function as intended (Rey 2017). Test results help determine the design’s final functionality such that teams may have to remove some functionalities of their design in order to complete their projects on time (Rey 2017). The ‘Deliver’ phase is closely linked with the ‘Develop’ phase, and often, teams are observed cycling between the two phases. Once teams finish their evaluation and are satisfied with their results, they synthesise their final design. It is in this last phase that another set of important activities occur.

Hackathons tend to conclude with a final pitch competition, in which participants pitch their designs to a panel of judges (Gama *et al.* 2019) with the hopes of winning prizes and recognition. The presentation of a design solution to an audience (e.g., clients) is not unique to hackathons, but this activity is significantly emphasised at hackathons where it takes up a significant

portion of the event. From both personal experiences and the literature, we have learned of the importance given to the final hackathon pitch. Prizes are dependent on the pitch; thus, teams will dedicate a significant portion of their resources to its development and final presentation (Richterich 2019). We argue, that at hackathons, the building and testing of the design is separate from its pitch. To many participants, a successful pitch is more important than a working final product, as it provides an opportunity to demonstrate what the product *intends* to do, regardless if that functionality is adequately implemented. Some hackathons may not even require a working prototype (Briscoe & Mulligan 2014). While not seen in traditional design processes, we propose *pitching* as a uniquely significant activity in the Deliver phase of the hackathon design process; therefore, we have altered the double diamond design process to include the hackathon pitch in order to emphasise this element of the hackathon and more accurately dedicate a portion of the design process to it.

4.2. Design process facilitated by hackathon structure

The structure of the hackathon event itself can encourage and shape the design process followed by hackers during the event. In this section, we will review studies in which a design process was encouraged or facilitated during a hackathon by the hackathon organisers.

The first way in which hackathon organisers influence the design process of participants is through education and suggested processes. Some hackathons offer participants workshops on specific design phases, such as ideation (Lodato & DiSalvo 2015; Filippova *et al.* 2017), or on the entire design process (Page *et al.* 2016). At these events, participants are not instructed to use the design process; rather, it is merely provided as a tool to help the teams. Other events suggest a design process to teams, such as *Design Thinking* (as popularised by Brown 2008) with an additional ‘pitch’ phase (Flores *et al.* 2018). When design instruction is offered to hackathon teams, there is a tendency for teams to use user-centered design practices (Page *et al.* 2016) and more closely follow an established design process (Flores *et al.* 2018). Further, a design-oriented structure on the event indicates an awareness of design processes on the part of hackathon organisers. Learning about the steps in a design process encourages participants to follow the process, which, in turn, improves outcomes at hackathons (Aryana *et al.* 2019).

Some hackathons include schedules or other types of structures that directly enforce a design process for participants. These hackathons divide the event into phases, which may be reflective of established design frameworks. For example, the timeline at some hackathons followed the phases of *Design Thinking* (Taratukhin *et al.* 2018; Alamari *et al.* 2019), the *Logical Framework Approach* (Soligno *et al.* 2015), the *Challenge-Based Learning Framework* (Gama *et al.* 2019) and the *Mechanics Dynamics Aesthetics* framework (Buttfield-Addison *et al.* 2016). There is evidence to suggest that an imposed hackathon structure that is design process oriented is conducive to effective designing (Soligno *et al.* 2015; Buttfield-Addison *et al.* 2016). Finally, some hackathons facilitate design-related activities and require participation in certain tasks, such as answering guiding questions and documenting design decisions (Gama *et al.* 2019). This strategy encourages hackathon participants to engage in activities typical of design processes without imposing a strict structure.

4.3. Hackathons as a tool to teach design

Event offerings at hackathons, such as workshops and schedules, among others, can encourage and facilitate (if not impose) the use of systematic design processes by hackers. Often, teaching hackers how to design *is* one of the expressed purposes of a hackathon. Similarly, one of the motivations participants have for attending a hackathon is gaining skills, including design skills. Therefore, the facilitation of design processes is unsurprising. In many cases, hackathons promote learning design processes as an official goal.

The hackathon model is sometimes used in educational settings to teach (engineering) design skills. For example, Gama *et al.* (2019) describe undergraduate course projects inspired by the hackathon framework. The hackathon-like events had four phases tied to respective course deliverables: information gathering, user needs identification, requirements specification and prototype building. Students employed design methods to aid in their process, including brainwriting, voting heuristics, SCAMPER (Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse), persona building and physical computing cards. In another design education instance (Page *et al.* 2016), each day of a 4-day hackathon was dedicated to different steps in the double diamond design process model. While students were not required to follow the model, the aim of the instruction on the model was to increase awareness of design processes and to systematically support design learning.

In another example, the hackathon structure is used to facilitate project-based learning (PBL) in engineering. PBL requires significant time and sustained interest from both the instructor and students. Motivated by these drawbacks of PBL in engineering courses, Horton *et al.* (2018) make a case that hackathon events can be used to meet all elements of PBL. This includes (1) meeting student learning goals and (2) providing essential project design elements. These include a challenging and authentic problem that sustains students' inquiry, independent thinking and decision-making, as well as opportunities for design critique and public presentation of the project results.

Perhaps, the most comprehensive use of hackathon-like events for teaching engineering design is described in Rennick *et al.* (2018). Here, curricular hackathons – named 'Engineering Design Days' – form the basis of a design 'lattice' around which other curriculum components (foundational math and science, discipline-specific engineering science, etc.) can develop in an integrated way (Hurst, Rennick & Bedi 2019a). In this format, junior engineering students work in teams to solve an open-ended engineering design problem over the course of 2 days. These events are made possible through coordination among all course instructors in the term who contribute space in their course schedules such that students do not have to attend any additional classes or other curricular activities during the event. Design teaching here is more explicit. In many cases, the event includes a 'warm-up' period that familiarises students with the problem space and explicitly connects aspects of the design problem to concepts from their courses.

How effective are hackathons at teaching design? To the best of our knowledge, given the relatively recent use of hackathons in curricular settings, rigorous studies evaluating the format's effectiveness in improving student participants' design skills have been rare. Certainly, educational hackathon-like activities provide three major advantages to design education. First, at hackathons students experience the entire

design process within a condensed time frame. This is particularly an advantage, as students have otherwise few opportunities to engage with all phases of design (Flus, Rennick & Hurst 2020). Second, design instructors can calibrate many aspects of the design problem and its representation to match them to the students' academic level, context and educational goals (Hurst, Litster & Rennick 2020). Third, hackathons have been found to advance participants' knowledge. At least one previous study has found that through participation in a design hackathon, nondesigner participants display an increased use of design thinking terminology and approaches (Artiles & LeVine 2015). A second study found that hackathons also supported education beyond design; that is, participants engaged in social learning and gained STEM knowledge, such as programming (Fowler 2016). Yet, due to the fast-paced format, participants may also overlook certain good design practices, such as gathering requirements from users or maintaining design quality (Gama 2017). A need arises to more deeply understand how the hackathon format can promote (and perhaps also hinder) design learning, as hackathons become more widely used in an engaging and fast-paced educational environment.

5. Future directions for design research in hackathons

In this review, we have identified the primary ways in which the role of designing is referenced in studies on hackathons. What emerges is a picture of hackathons as an authentic setting in which design activity occurs. How, then, does designing at hackathons compare to designing at other common settings in which design is studied (McMahon 2012)? On the one hand, given the range of participants' design and other types of expertise, their self-motivation for participating in the events and personal interest in the chosen topic, and the significant interest and input from organisations who sponsor them, one could argue that the resulting design activity is more authentic than what is commonly studied in controlled experiments. On the other hand, the structure of hackathons themselves – in particular, the extreme time pressure under which they place participants – constrains design activity in unique ways that may not be representative of or generalisable to the authentic design activity that is typically studied through observations of (expert) designers in field studies. Nevertheless, studying designing as it occurs in hackathons may uncover unique processes designers follow during a heightened design event.

Despite this potential, we have identified a significant gap in the intentional study of design activity in hackathons. No publication included in this review had the main objective of studying the design behaviour of hackathon participants. While few publications outlined group processes, or included personal accounts of a hackathon experience, they do not develop an understanding of the common processes followed at hackathons, beyond the accounts of a few groups. In this section, we outline a number of future directions for design research at hackathons.

5.1. Methodological approaches to studying design at hackathons

A standard methodology for studying design cognition is protocol analysis (Ericsson & Simon 1984) in experimental settings. Unfortunately, protocol analysis is impractical in the case of long, slowly evolving design processes, and for large quantities of data (Goldschmidt & Weil 1998). Hackathons are attended by hundreds

of participants, who continuously design for a significant amount of time in loud and difficult to control settings, thus making verbal protocol analysis infeasible. In order to study them, the publications included in this review employed methodologies such as interviews and ethnography. These methodologies require a lot of manual effort from the researchers; thus, only few groups are able to be studied at a singular event. This limits the size of the study population, the amount of data possible to collect and the applicability of the findings across many hackathons.

It is thus necessary for new methods to be developed that can study design cognition in 'in-situ' environments, such as hackathons. Legardeur *et al.* (2010) utilised a web-based application on which participants self-reported their design activities during hackathons. The advantage of this approach was two-fold: (1) it presented participants with a chance to reflect and assess their progress, while (2) collected data for the research team. While we see the benefit of this approach, we question the extent to which participants will understand their own design process without formal training, as we expect to be the case for software engineers and other typical hackathon participants that have limited design education and/or experience.

The inherent large quantity of data generated at hackathons – for example, question and answer in text-based participant–mentor help channels, final project descriptions and judging criteria and scores, points at opportunities to take new data-driven approaches such as text mining and natural language processing. Combined with more traditional protocol analysis approaches, such as the Function–Behaviour–Structure ontology (Gero & Kannengiesser 2014) or linkography (Goldschmidt 2014), the methods may allow for more efficient data collection and analysis at a larger scale in the challenging in-situ environments of hackathons. Further exploration into data-driven methodologies and how they may need to be adapted to suit a study on hackathons is needed.

5.2. Leveraging alternative hackathon formats

Another significant opportunity to develop new study approaches lies in the emergence of hackathons that are held in an online environment. This format has become particularly more common during the COVID-19 pandemic, during which previously scheduled in-person hackathons were adapted to be held in virtually. These hackathons function similarly to in-person hackathons, but with increased dependency on virtual platforms for communication and collaboration both between participants and event staff and mentors, but also between participants within teams. The online format presents an interesting opportunity for data collection. The digital age has introduced an ease to virtual collaborations. Designers have created ways to simulate physical collaborative experiences (e.g., through interactive Post-it Note software; Everitt *et al.* 2003) to facilitate virtual work. Video and audio calls can be recorded for transcription, data from 'chats' can be collected and digital work produced by teams can be submitted with the final design. These data collection methods would result in an abundance of data and allow for more data-driven methodologies to study design.

At the same time, the virtual and remote nature of collaboration between design team members adds a new dimension to design activity at hackathons, which must be carefully considered when conducting research. Asynchronous and remote work is common among distant collaborators, but compared to face-to-face

settings, synchronous design activities conducted virtually may result in reduced interactions between collaborators. When compared with face-to-face interaction, communication via videoconference has been found to reduce the back-and-forth between participants and increase the length of each turn (van der Kleij *et al.* 2009). Asynchronous collaboration has many additional challenges beyond those typical of collaborative design (Hauck 1995). Collaborators may be in different time zones, have limited access to internet connection and experience limitations when building hardware and physical designs. These additional challenges are important to consider when studying data collected from virtual hackathons. At the same time, investigating virtual hackathons alongside in-person events could highlight the differences between virtual and face-to-face collaborative design.

5.3. The impact of fewer incubation opportunities

Participants grow significantly fatigued at hackathons, where they receive minimal sleep or breaks. Breaks enable people to recover from extended periods of concentration and can serve as *incubation periods* (Woodworth 1938) – a concept that is relevant to a cognitive activity such as design. While in an incubation stage in the creative process, the designer is no longer actively working on the problem (Wallas 1926; Tsenn *et al.* 2014). It is thought that the mind continues to work on the problem subconsciously. Research has found that taking a break during problem-solving may lead to a moment of insight (Burkus 2014). Additionally, incubation has been shown to help reduce design fixation and encourage the generation of a greater number and variety of ideas (Cardoso & Badke-Schaub 2009; Tsenn *et al.* 2014).

But what if the time available to the designer does not permit incubation? In a hackathon, breaks are rare and the breaks participants do take are much shorter than those in more relaxed design situations. In a traditional design project, incubation is naturally built into the project. Design occurs over days, weeks, months or even years. This implies that periods of rest can also span days, weeks, months or years. While these designers may not intentionally include incubation periods, they still receive rest from problem-solving. This helps lessen the effects from fatigue and fixation. We assume that these lengthy breaks are not possible at hackathons. Thus, a need arises to investigate whether the condensed nature of a hackathon causes fewer incubation periods, and how this affects the overall quality of the final design.

5.4. Design thinking in increased uncertainty

According to the dual-process theory (Kahneman 2011), there are two types of thought: fast, intuitive thinking (type 1), and slow, analytical thinking (type 2). Recently, Kannengiesser & Gero (2019) map this theory onto design thinking, what they call fast and slow designing. Experienced designers use more type 1 thinking, or fast design; they can more quickly transform requirements into design solutions (Kannengiesser & Gero 2019; Hurst *et al.* 2019b) using their prior ‘canned’ designs, or ‘design types’ (Schön 1988). Novice designers, too, exhibit fast design behaviour; however, their ability to rely on past designs is limited.

What type of design thinking is employed at hackathons? Progressing from an ill-defined design problem to a final solution is dependent on the designer’s ability

to manage the *'inherent "uncertainty" that pervades real-world design problems'* (Ball & Christensen 2019, p. 36). The atypical setting of a hackathon (e.g., dramatically increased time pressure or a very ill-defined problem statement that is revealed at the hackathon) adds new sources of uncertainty for even experienced designers. This uncertainty would normally require an increased need for slow design. Yet, the added time pressure of a hackathon would suggest increased occurrences of fast design. Time pressure is not necessarily a unique factor of a hackathon, as most, if not all, design tasks have a deadline. However, while 24 total hours to design may not be considered a short design time frame, it is so when the 24 hours are condensed into one day, rather than over an extended period of time. The requirement to progress through the design process quickly and continuously may suggest an increased inclination for fast design. Thus, we reflect on how the conflict between both types of thinking is resolved. What is the predominant type of thinking at a hackathon? How does time pressure affect it? And how do designers manage increased levels of uncertainty during a heightened design task?

5.5. The role of expertise

As a designer's mental function matures and they rise in their level of expertise (Dreyfus & Dreyfus 1980), their understanding of what it means to design may also change (Daly, Adams & Bodner 2012). An individual can have different levels of expertise in different skills; for example, a designer can be an expert in product design but a novice in web design. The variance in expertise demonstrates *'the human ability to respond to an environment and adapt behaviour accordingly'* (Lawson & Dorst 2013, p. 82), such that one's environment directly influences one's expertise. This is evident within hackathons at three levels.

First, by design, hackathons typically enable collaboration between different topic experts (Frey & Luks 2016); thus, different team members may have different subject matter knowledge. Research on the impact of the diversity of expertise on hackathon performance is limited and inconclusive (Legardeur *et al.* 2020).

Second, we hypothesise that performance at a hackathon is related (to some degree) to one's level of expertise in a relevant domain. For example, more experienced software engineers will be better prepared to complete a software design project within the hackathon environment. This extends to the degree of expertise in the discipline of design itself. In a study that we are currently conducting to compare the hackathon experiences of designers to nondesigners, the most notable preliminary finding is the ability of designers to critically discuss their processes and decision-making during hackathons. Designers are able to recall not just *what* decisions they made, but the *rationale* for each decision and how it served their event goal. Nondesigners lack the vocabulary and knowledge to participate in such conversations, and it appears as though the design decisions they make during hackathons are not as intentional as those of their design peers.

Finally, we argue that there is 'hackathon expertise'; that is, valuable experience accumulated from participating in hackathons. Those who have attended more hackathons will have a more advanced understanding of how to approach a hackathon than participants that are new to this type of event. We hypothesise that these varying levels of expertise significantly affect participants' design activities at hackathons.

In summary, a further exploration of team composition at hackathons in terms of diverse subject matter knowledge and expertise, as well as prior hackathon experience, will give more insight into how to optimise team performance at these events.

6. Conclusion

In this paper, we have reviewed the literature with the goal of identifying the role that design – as an activity and/or instructional goal – plays in hackathons. The publications reviewed describe studies on hackathons from a range of disciplines and with widely varying objectives.

The review demonstrated that hackathon participants follow typical divergence–convergence patterns in their design process. Often, hackathons will prescribe and facilitate a design process in order to guide participants and encourage more successful design and learning outcomes. However, the event structure also requires increased emphasis and time in a number of other activities, such as finding and getting to know both team members and problems to solve, and preparing for the solution pitch and demo.

As this review has demonstrated, design occurs at hackathons in expected and unexpected ways. The nature of hackathons – loud environments attended by a large number of participants – poses challenges for studying design cognition, as also demonstrated by the methodological limitations of current studies on hackathons. Yet, hackathons present a unique setting for studying designer activity at each stage of the design, especially under conditions of time pressure, reduced incubation time and across different levels of domain and design expertise. For these reasons, hackathons are valuable and promising opportunities for future design research.

References

- Alamari, N., Alabdulkarim, A. & Al-Wabil, A. 2019 Accelerating healthcare innovation in time-bound multidisciplinary hackathons. In *2nd International Conference on Computer Applications and Information Security, ICCAIS 2019*. doi:[10.1109/CAIS.2019.8769574](https://doi.org/10.1109/CAIS.2019.8769574).
- Alkema, P. J., Levitt, S. P. & Chen, J. Y.-J. 2017 Agile and hackathons: a case study of emergent practices at the FNB codefest. In *ACM International Conference Proceeding Series*. doi:[10.1145/3129416.3129430](https://doi.org/10.1145/3129416.3129430).
- Artiles, J. A. & Lande, M. 2016 Broadening non-designers' solutions for big issues: the Education DesignShop design thinking workshop. *International Journal of Engineering Education* 32 (3), 1418–1427.
- Artiles, J. A. & LeVine, K. 2015 Ta-Da! You're a design thinker! Validating the DesignShop as a model for teaching design thinking to non-designers and achieving systemic re-design in the education system. In *2015 ASEE Annual Conference and Exposition Proceedings*. 2015 ASEE Annual Conference and Exposition, Seattle, WA, USA. doi:[10.18260/p.24792](https://doi.org/10.18260/p.24792).
- Artiles, J. A. & Wallace, D. R. 2013 Borrowing from hackathons: overnight designathons as a template for creative idea hubs in the space of hands-on learning, digital learning, and systems re-thinking. In *WEEF 2013, Cartagena*.
- Aryana, B., Naderi, E. & Balis, G. 2019 Strategies for empowering collective design. *The Design Journal* 22 (1), 2073–2088. doi:[10.1080/14606925.2019.1594931](https://doi.org/10.1080/14606925.2019.1594931).

- Ball, L. J. & Christensen, B. T.** 2019 Advancing an understanding of design cognition and design metacognition: progress and prospects. *Design Studies* **65**, 35–59. doi:[10.1016/j.destud.2019.10.003](https://doi.org/10.1016/j.destud.2019.10.003).
- Birbeck, N., Lawson, S., Morrissey, K., Rapley, T. & Olivier, P.** 2017 Self harmony: rethinking hackathons to design and critique digital technologies for those affected by self-harm. In *Proceedings of the Conference on Human Factors in Computing Systems*, pp. 146–157. doi:[10.1145/3025453.3025931](https://doi.org/10.1145/3025453.3025931).
- Briscoe, G. & Mulligan, C.** 2014 *Digital Innovation: The Hackathon Phenomenon*. Creativeworks London.
- Brown, T.** 2008 Design thinking. *Harvard Business Review* **86** (6), 84–92.
- Burkus, D.** 2014 The eureka myth. In *The Myths of Creativity*, 17–31. Jossey-Bass.
- Buttfield-Addison, P., Manning, J. & Nugent, T.** 2016 A better recipe for game jams: using the mechanics dynamics aesthetics framework for planning. In *Proceedings of the International Conference on Game Jams, Hackathons, and Game Creation Events, GJH and GC 2016*, pp. 30–33. doi:[10.1145/2897167.2897183](https://doi.org/10.1145/2897167.2897183).
- Cardoso, C. & Badke-Schaub, P.** 2009 Give design a break? The role of incubation periods during idea generation. In *International Conference on Engineering Design. ICED'09, Stanford, CA, USA*.
- Carroll, J. M. & Beck, J.** 2019 Co-designing platform collectivism. *CoDesign* **15** (3), 272–287. doi:[10.1080/15710882.2019.1631353](https://doi.org/10.1080/15710882.2019.1631353).
- Cooper, R.** 2019 Design research – its 50-year transformation. *Design Studies* **65**, 6–17. doi:[10.1016/j.destud.2019.10.002](https://doi.org/10.1016/j.destud.2019.10.002).
- Daly, S. R., Adams, R. S. & Bodner, G. M.** 2012 What does it mean to design? A qualitative investigation of design professionals' experiences. *Journal of Engineering Education* **101** (2), 187–219. doi:[10.1002/j.2168-9830.2012.tb00048.x](https://doi.org/10.1002/j.2168-9830.2012.tb00048.x).
- Damen, I., Xue, M., Grave, A., Brankaert, R., Chen, X. & Vos, S.** 2019 Root: a multi-disciplinary approach to urban health challenges with HCI. In *Proceedings of the Conference on Human Factors in Computing Systems*. doi:[10.1145/3290607.3299051](https://doi.org/10.1145/3290607.3299051).
- De Oliveira, C. M. C., Canedo, E. D., Faria, H., Amaral, L. H. V. & Bonifacio, R.** 2019 Improving student's learning and cooperation skills using coding dojos (in the wild!). In *Proceedings of the Frontiers in Education Conference, FIE*. doi:[10.1109/FIE.2018.8659056](https://doi.org/10.1109/FIE.2018.8659056).
- Design Council.** 2005 *The “Double Diamond” Design Process*. Design Council.
- Dorst, K.** 2011 The core of ‘design thinking’ and its application. *Design Studies* **32** (6), 521–532. doi:[10.1016/j.destud.2011.07.006](https://doi.org/10.1016/j.destud.2011.07.006).
- Dorst, K. & Cross, N.** 2001 Creativity in the design process: co-evolution of problem–solution. *Design Studies* **22** (5), 425–437. doi:[10.1016/S0142-694X\(01\)00009-6](https://doi.org/10.1016/S0142-694X(01)00009-6).
- Dreyfus, S. E. & Dreyfus, H. L.** 1980 *A Five-Stage Model of the Mental Activities Involved in Directed Skill Acquisition*. Defense Technical Information Center. doi:[10.21236/ADA084551](https://doi.org/10.21236/ADA084551).
- Ericsson, K. A. & Simon, H. A.** 1984 *Protocol Analysis: Verbal Reports as Data, Revised Edition*. The MIT Press.
- Everitt, K. M., Klemmer, S. R., Lee, R. & Landay, J. A.** 2003 Two worlds apart: bridging the gap between physical and virtual media for distributed design collaboration. *New Horizons* **5**, 8.
- Ferrario, M. A., Simm, W., Newman, P., Forshaw, S. & Whittle, J.** 2014 Software engineering for “social good”: integrating action research, participatory design, and agile development. In *Proceedings of the 36th International Conference on Software Engineering, ICSE Companion 2014*, pp. 520–523. doi:[10.1145/2591062.2591121](https://doi.org/10.1145/2591062.2591121).

- Filippova, A., Trainer, E. & Herbsleb, J. D.** 2017 From diversity by numbers to diversity as process: supporting inclusiveness in software development teams with brainstorming. In *Proceedings of the 2017 IEEE/ACM 39th International Conference on Software Engineering, ICSE 2017*, pp. 152–163. doi:[10.1109/ICSE.2017.22](https://doi.org/10.1109/ICSE.2017.22).
- Flores, M., Golob, M., Maklin, D., Herrera, M., Tucci, C., Al-Ashaab, A., Williams, L., Encinas, A., Martinez, V., Zaki, M., Sosa, L. & Pineda, K. F.** 2018 How can hackathons accelerate corporate innovation? In *Advances in Production Management Systems (Vol. 535)* (ed. I. Moon, G. Lee, J. Park, D. Kiritsis & G. von Cieminski), pp. 167–175. Springer. doi:[10.1007/978-3-319-99704-9_21](https://doi.org/10.1007/978-3-319-99704-9_21).
- Flus, M., Rennick, C. & Hurst, A.** 2020 Work in progress: improving engineering students' need finding abilities. In *2020 ASEE Virtual Annual Conference Content Access*. doi:[10.18260/1-2--35649](https://doi.org/10.18260/1-2--35649).
- Fowler, A.** 2016 Informal STEM learning in game jams, hackathons and game creation events. In *Proceedings of the International Conference on Game Jams, Hackathons, and Game Creation Events – GJH&GC '16*, pp. 38–41. doi:[10.1145/2897167.2897179](https://doi.org/10.1145/2897167.2897179).
- Frey, F. J. & Luks, M.** 2016 The innovation-driven hackathon – one means for accelerating innovation. In *ACM International Conference Proceeding Series*. doi:[10.1145/3011784.3011794](https://doi.org/10.1145/3011784.3011794).
- Gama K.** 2017 Preliminary findings on software engineering practices in civic hackathons. In *Proceedings of the 2017 IEEE/ACM 4th International Workshop on Crowd Sourcing in Software Engineering, CSI-SE 2017*, pp. 14–20. doi:[10.1109/CSI-SE.2017.5](https://doi.org/10.1109/CSI-SE.2017.5).
- Gama K., Alencar, B., Calegario, F., Neves, A. & Alessio, P.** 2019 A hackathon methodology for undergraduate course projects. In *Proceedings of the Frontiers in Education Conference, FIE*. doi:[10.1109/FIE.2018.8659264](https://doi.org/10.1109/FIE.2018.8659264).
- Gero, J. S. & Kannengiesser, U.** 2014 The function–behaviour–structure ontology of design. In *An Anthology of Theories and Models of Design* (ed. A. Chakrabarti & L. T. M. Blessing), pp. 263–283. Springer. doi:[10.1007/978-1-4471-6338-1_13](https://doi.org/10.1007/978-1-4471-6338-1_13).
- Goel, V. & Pirolli, P.** 1992 The structure of design problem spaces. *Cognitive Science* **16** (3), 395–429. doi:[10.1207/s15516709cog1603_3](https://doi.org/10.1207/s15516709cog1603_3).
- Goldschmidt, G.** 2014 *Linkography: Unfolding the Design Process*. MIT Press.
- Goldschmidt, G. & Weil, M.** 1998 Contents and structure in design reasoning. *Design Issues* **14** (3). doi:[10.2307/1511899](https://doi.org/10.2307/1511899).
- Hauck, S.** 1995 Asynchronous design methodologies: an overview. *Proceedings of the IEEE* **83**, 69–93.
- Hölttä-Otto, K., Niutanen, V., Eppinger, S., Browning, T. R., Stowe, H. M., Lampinen, R. & Rahardjo, A.** 2018 Design sprint for complex system architecture analysis. In *Proceedings of the ASME Design Engineering Technical Conference, Vol. 7*. doi:[10.1115/DETC2018-85774](https://doi.org/10.1115/DETC2018-85774).
- Horton, P. A., Jordan, S. S., Weiner, S. & Lande, M.** 2018 Project-based learning among engineering students during short-form hackathon events. In *ASEE Annual Conference and Exposition, Conference Proceedings*.
- Hurst, A., Rennick, C. & Bedi, S.** 2019a A “lattice” approach to design education: bringing real and integrated design experience to the classroom through engineering design days. *Proceedings of the Design Society* **1**, 429–438.
- Hurst, A., Nespoli, O. G., Abdellahi, S. & Gero, J. S.** 2019b A comparison of design activity of academics and practitioners using the FBS ontology: a case study. *Proceedings of the Design Society: International Conference on Engineering Design* **1** (1), 1323–1332. doi:[10.1017/dsi.2019.138](https://doi.org/10.1017/dsi.2019.138).
- Hurst, A., Litster, G. & Rennick, C.** 2020 Operationalizing Jonassen's design theory of problem solving: an instrument to characterize educational design activities. In *2020 ASEE Virtual Annual Conference Content Access*. doi:[10.18260/1-2--35011](https://doi.org/10.18260/1-2--35011).

- Izvalov, A., Nedilko, S. & Nedilko, V. 2017 Comparison of game creation and engineering hackathons on the global and local levels. In *ACM International Conference Proceeding Series*, pp. 22–25. doi:[10.1145/3055116.3055119](https://doi.org/10.1145/3055116.3055119).
- Johnson, P. & Robinson, P. 2014 Civic hackathons: innovation, procurement, or civic engagement? *Review of Policy Research* 31 (4), 349–357. doi:[10.1111/ropr.12074](https://doi.org/10.1111/ropr.12074).
- Kahneman, D. 2011 *Thinking, Fast and Slow*. Anchor Canada.
- Kannengiesser, U. & Gero, J. S. 2019 Design thinking, fast and slow: a framework for Kahneman's dual-system theory in design. *Design Science* 5, e10. doi:[10.1017/dsj.2019.9](https://doi.org/10.1017/dsj.2019.9).
- Karlsen, J. & Løvlie, A. S. 2017 'You can dance your prototype if you like': independent filmmakers adapting the hackathon. *Digital Creativity* 28 (3), 224–239. doi:[10.1080/14626268.2017.1351992](https://doi.org/10.1080/14626268.2017.1351992).
- Knapp, J., Zeratsky, J. & Kowitz, B. 2016 *Sprint: How to Solve Big Problems and Test New Ideas in Just Five Days*. Simon and Schuster.
- Kollwitz, C. & Dinter, B. 2019 *What the Hack? – Towards a Taxonomy of Hackathons*. In *Lecture Notes in Computer Science* (Vol. 11675) (ed. T. Hildebrandt, B. van Dongen, M. Röglinger & J. Mendling). Springer. doi:[10.1007/978-3-030-26619-6_23](https://doi.org/10.1007/978-3-030-26619-6_23).
- Komssi, M., Pichlis, D., Raatikainen, M., Kindstrom, K. & Jarvinen, J. 2015 What are hackathons for? *IEEE Software* 32 (5), 60–67. doi:[10.1109/MS.2014.78](https://doi.org/10.1109/MS.2014.78).
- Kos, B. A. 2019 Understanding female-focused hackathon participants' collaboration styles and event goals. In *Proceedings of the International Conference on Game Jams, Hackathons and Game Creation Events 2019 – ICGJ 2019*, pp. 1–4. doi:[10.1145/3316287.3316292](https://doi.org/10.1145/3316287.3316292).
- Lawson, B. & Dorst, K. 2013 *Design Expertise*. Routledge.
- Legardeur, J., Choulier, D. & Monnier, B. 2010 How to evaluate creative and innovative concepts during the contest of “the 24h of innovation”? *Projectics/Proyèctica/Projectique* 5 (2). doi:[10.3917/proj.005.0105](https://doi.org/10.3917/proj.005.0105).
- Legardeur, J., Masson, D., Gardoni, M. & Pimapunsri, K. 2020 *The Paradox of Diversity's Influence on the Creative Teams Lessons Learned from the Analysis of 14 Editions of 'the 24h of Innovation' Hackathon*. ISPIIM Connects Bangkok.
- Lewis, B. A., Parker, J., Cheng, L. W. S. & Resnick, M. 2015 UX day design challenge: hackathon to apply rapid design ideation to a practical user experience challenge. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, Vol. 59*, pp. 304–306. doi:[10.1177/1541931215591063](https://doi.org/10.1177/1541931215591063).
- Lodato, T. J. & DiSalvo, C. 2015 Issue-oriented hackathons as material participation. *New Media and Society* 18 (4), 539–557. doi:[10.1177/1461444816629467](https://doi.org/10.1177/1461444816629467).
- Maher, M. L., Poon, J. & Boulanger, S. 1996 Formalising design exploration as co-evolution: a combined gene approach. In *Advances in Formal Design Methods for CAD* (ed. J. Gero & F. Sudweeks), pp. 3–30. Chapman Hall.
- McGowan, B. 2019 The role of the university library in creating inclusive healthcare hackathons: a case study with design-thinking processes. *IFLA Journal* 45 (3), 246–253. doi:[10.1177/0340035219854214](https://doi.org/10.1177/0340035219854214).
- McMahon, C. A. 2012 Reflections on diversity in design research. *Journal of Engineering Design* 23 (8), 563–576. doi:[10.1080/09544828.2012.676634](https://doi.org/10.1080/09544828.2012.676634).
- Mielikäinen, M., Angelva, J. & Tepsa, T. 2019 Hackathon as a kickstart for integrated ICT engineering. In *Proceedings of the 46th SEFI Annual Conference 2018: Creativity, Innovation and Entrepreneurship for Engineering Education Excellence*, pp. 1073–1080.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. & The PRISMA Group. 2009 Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Medicine* 6 (7). doi:[10.1371/journal.pmed](https://doi.org/10.1371/journal.pmed).

- Nandi, A. & Mandernach, M.** 2016 Hackathons as an informal learning platform. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education – SIGCSE '16*, pp. 346–351. doi:[10.1145/2839509.2844590](https://doi.org/10.1145/2839509.2844590).
- Olesen, J. F.** 2017 Design processes in game jams: studies of rapid design processes. In *CHI PLAY 2017 Extended Abstracts – Extended Abstracts Publication of the Annual Symposium on Computer–Human Interaction in Play*, pp. 723–726. doi:[10.1145/3130859.3133226](https://doi.org/10.1145/3130859.3133226).
- Olesen, J. F., Hansen, N. B. & Halskov, K.** 2018 Four factors informing design judgement at a hackathon. In *Proceedings of the 30th Australian Conference on Computer–Human Interaction – OzCHI '18*, pp. 473–483. doi:[10.1145/3292147.3292155](https://doi.org/10.1145/3292147.3292155).
- Page, F., Sweeney, S., Bruce, F. & Baxter, S.** 2016 The use of the “hackathon” in design education: an opportunistic exploration. In *Proceedings of the 18th International Conference on Engineering and Product Design Education: Design Education: Collaboration and Cross-Disciplinarity, E and PDE 2016*, pp. 246–251.
- Pe-Tham, E. P. P. & Herbsleb, J. D.** 2019 Understanding hackathons for science: collaboration, affordances, and outcomes. In *ICConference 2019: Information in Contemporary Society, Vol. 11420*, pp. 27–37. doi:[10.1007/978-3-030-15742-5_3](https://doi.org/10.1007/978-3-030-15742-5_3).
- Piza, F. M. D. T., Celi, L. A., Deliberato, R. O., Bulgarelli, L., de Carvalho, F. R. T., Filho, R. R., de La Hoz, M. A. A. & Kesselheim, J. C.** 2018 Assessing team effectiveness and affective learning in a datathon. *International Journal of Medical Informatics* **112**, 40–44. doi:[10.1016/j.ijmedinf.2018.01.005](https://doi.org/10.1016/j.ijmedinf.2018.01.005).
- Porter, E., Bopp, C., Gerber, E., & Volda, A.** (2017). Reappropriating Hackathons: The Production Work of the CHI4 Good Day of Service. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*, 810–814. <https://doi.org/10.1145/3025453.3025637>.
- Prieto, M., Unnikrishnan, K., Keenan, C., Saetern, K. D. & Wei, W.** 2019 Designing for collaborative play in new realities: a values-aligned approach. In *2019 IEEE Games, Entertainment, Media Conference, GEM 2019*. doi:[10.1109/GEM.2019.8811545](https://doi.org/10.1109/GEM.2019.8811545).
- Raatikainen, M., Komssi, M., Dal Bianco, V., Kindstom, K. & Jarvinen, J.** 2013 Industrial experiences of organizing a hackathon to assess a device-centric cloud ecosystem. In *Proceedings of the International Computer Software and Applications Conference*, pp. 790–799. doi:[10.1109/COMPSAC.2013.130](https://doi.org/10.1109/COMPSAC.2013.130).
- Rennick, C., Hulls, C., Wright, D., Milne, A. J. B., Li, E. & Bedi, S.** 2018 Engineering design days: engaging students with authentic problem-solving in an academic hackathon. In *ASEE Annual Conference and Exposition, Conference Proceedings*.
- Rey, S.** 2017 Museumix: lessons learned from an open creative hackathon in museums. In *CEUR Workshop Proceedings, Vol. 1861*, pp. 24–28.
- Richterich, A.** 2019 Hacking events: project development practices and technology use at hackathons. *Convergence: The International Journal of Research into New Media Technologies* **25** (5–6), 1000–1026. doi:[10.1177/1354856517709405](https://doi.org/10.1177/1354856517709405).
- Rittel, H. W. J. & Webber, M.** 1973 Dilemmas in a general theory of planning. *Policy Sciences* **4**, 155–169.
- Safarova, B., Ledesma, E., Luhan, G., Caffey, S. & Giusti, C.** 2015 Learning from collaborative integration: the hackathon as design charrette. In *ECAADE 2015: Real Time – Extending the Reach of Computation (Vol. 2)* (ed. B. Martens, G. Wurzer, T. Grasl, W. E. Lorenz & R. Schaffranek), pp. 233–240. Autodesk; Bentley; TU Wien, Fac Architecture & Reg Planning; ArchIng Akademie.
- Saravi, S., Joannou, D., Kalawsky, R. S., King, M. R. N., Marr, I., Hall, M., Wright, P. C. J., Ravindranath, R. & Hill, A.** 2018 A systems engineering hackathon – a methodology involving multiple stakeholders to progress conceptual design of a complex engineered product. *IEEE Access* **6**, 38399–38410. doi:[10.1109/ACCESS.2018.2851384](https://doi.org/10.1109/ACCESS.2018.2851384).

- Schön, D. A. 1988 Designing: rules, types and worlds. *Design Studies* 9 (3), 181–190.
- Scott, M. J., Ghinea, G. & Hamilton, I. 2015 Promoting inclusive design practice at the Global Game Jam: a pilot evaluation. In *Proceedings of the Frontiers in Education Conference, FIE*. doi:[10.1109/FIE.2014.7044162](https://doi.org/10.1109/FIE.2014.7044162).
- Sims, C. & Johnson, H. L. 2011 *The Elements of Scrum*. Dymax.
- Soligno, R., Scorza, F., Amato, F., Casas, G. L. & Murgante, B. 2015 Citizens participation in improving rural communities quality of life. In *Computational Science and Its Applications – ICCSA 2015, Vol. 9156*. doi:[10.1007/978-3-319-21407-8_52](https://doi.org/10.1007/978-3-319-21407-8_52).
- Suominen, A. H., Halvari, S. & Jussila, J. 2019 World Heritage meets smart city in an urban-educational hackathon in Rauma. *Technology Innovation Management Review* 9 (9), 44–53. doi:[10.22215/timreview/1268](https://doi.org/10.22215/timreview/1268).
- Taratukhin, V., Kupriyanov, Y. V., Welch, C. & Anikushina, V. 2018 Leveraging the tech-savvy next-generation talents and hackathon techniques to accelerate digital enterprise journey and space-related endeavors. In *ASEE Annual Conference and Exposition, Conference Proceedings*.
- Taylor, N. & Clarke, L. 2018 Everybody's hacking: participation and the mainstreaming of Hackathons. In *Proceedings of the Conference on Human Factors in Computing Systems*. doi:[10.1145/3173574.3173746](https://doi.org/10.1145/3173574.3173746).
- Taylor, N., Clarke, L. & Gorkovenko, K. 2017 Community inventor days: scaffolding grassroots innovation with maker events. In *DIS 2017 – Proceedings of the 2017 ACM Conference on Designing Interactive Systems*, pp. 1201–1212. doi:[10.1145/3064663.3064723](https://doi.org/10.1145/3064663.3064723).
- Taylor, N., Clarke, L., Skelly, M. & Nevay, S. 2018 Strategies for engaging communities in creating physical civic technologies. In *Proceedings of the Conference on Human Factors in Computing Systems*. doi:[10.1145/3173574.3174081](https://doi.org/10.1145/3173574.3174081).
- Thomer, A. K., Twidale, M. B., Guo, J. & Yoder, M. J. 2016 Co-designing scientific software: hackathons for participatory interface design. In *Proceedings of the Conference on Human Factors in Computing Systems*, pp. 3219–3226. doi:[10.1145/2851581.2892549](https://doi.org/10.1145/2851581.2892549).
- Trainer, E. H., Kalyanasundaram, A., Chaihirunkarn, C. & Herbsleb, J. D. 2016 How to hackathon: socio-technical tradeoffs in brief, intensive collocation. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing – CSCW '16*, pp. 1116–1128. doi:[10.1145/2818048.2819946](https://doi.org/10.1145/2818048.2819946).
- F. Truyen, S. Taes, C. Colangelo, R. Wyns. 2016 Getting Creative with Europeana: Innovative strategies & new tools for Education. *EDULEARN16 Proceedings*, pp. 6606–6614.
- Tsenn, J., Atilola, O., McAdams, D. A. & Linsey, J. S. 2014 The effects of time and incubation on design concept generation. *Design Studies* 35 (5), 500–526. doi:[10.1016/j.destud.2014.02.003](https://doi.org/10.1016/j.destud.2014.02.003).
- Uffreduzzi, M. 2017 *Hackathon as Emerging Innovation Practice: Exploring Opportunities and Challenges Through 8 In-Depth Case Studies*. Politecnico di Milano.
- van der Kleij, R., Maarten Schraagen, J., Werkhoven, P. & De Dreu, C. K. 2009 How conversations change over time in face-to-face and video-mediated communication. *Small Group Research* 40 (4), 355–381.
- Wallas, G. 1926 *The Art of Thought*. Jonathan Cape.
- Woodworth, R. S. 1938 *Experimental Psychology*. Henry Holt.