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Hackathons as a Novel Pedagogy in Engineering Design Education*

MEAGAN FLUS and ADA HURST
Department of Management Sciences, University of Waterloo, 200 University Ave. W., Waterloo, ON., N2L 3G1, Canada.
E-mail: meagan.flus@uwaterloo.ca, adahurst@uwaterloo.ca

Hackathons and hackathon-like events are gaining significant popularity as extra-curricular events among engineering undergraduate students. While not always explicitly promoted as such, these events provide participants with exposure to, and experience in design. Not surprisingly then, the hackathon format is slowly starting to be used as a novel design pedagogy in engineering, increasingly in curricular settings. In this paper we review several examples of hackathons as a teaching tool in engineering design education and provide a qualitative evaluation on their effectiveness. We further discuss the educational potential and limitations of hackathons and identify several related research directions in engineering design education.

Keywords: hackathon; engineering education; design pedagogy

1. Introduction

Design is central to engineering; however, it is extremely hard to teach [1]. While the teaching of design in engineering education is almost entirely classroom-based [2], engineering lacks a strong design pedagogy tradition when compared, for example, to the design studio pedagogy in architecture [3]. Typically, engineering educators have taken a "learn-by-doing" approach to design teaching: there may be design projects in early courses, typically followed by a major design experience in students senior design projects [4]. However, even in the latter design experience, rarely are engineering students able to engage with the entire design process, from need finding to solution implementation [5].

The "Maker movement", which is the emerging idea of innovative creation in open spaces or labs, is increasingly influencing education due to the centrality of "making" in real-world problem solving [6]. The popularity of hackathons is exemplar of this Maker movement, especially in the context of education. Hackathons are popular events in which groups of participants, or "hackers", attempt to "hack" a solution to a design problem in a short time frame, often 24 to 36 hours [7]. Recently, hackathons, or hackathon-like events, have been recognized as an emerging alternative setting in which design activity occurs [8], and thus design can be taught and assessed. As the main focus of hackathons is problem solving, hackers typically engage with the entire design process. Further, hackathons encourage peer learning, project management, and skill development [7]. These features of hackathons closely align with objectives of engineering design education. As such, there have recently been a number of published examples of the use of the format in educational settings, including within curricula [9–13].

This paper aims to critically evaluate hackathons as a tool for teaching and learning design. First, we will outline research on design in hackathons. Then, we will explore how the hackathon structure has been used in design education. Finally, we will evaluate the implications of hackathons for teaching design.

2. Background

2.1 About Hackathons

Hackathons are quickly gaining popularity, garnering significant interest among computer programmers, designers, and engineers in particular. In a review of hackathon events, Briscoe and Mulligan [7] describe the format as containing several components and stages, as follows. The event begins with a welcome presentation, introducing the organizing team, sponsors, and mentors, as applicable. The theme of the event, including any problem prompts that the hackathon may have, are introduced during this presentation or before the event starts, if at all. Hackers then form teams and begin brainstorming. If the event is overnight, hackers are often given space for rest; however, in our experiences, hackers rarely sleep during the event as they would rather use the time to work on their projects. At the end of the event, hackers typically pitch their projects to a team of judges and compete for prizes.

Due to their popularity, hackathon and hacka-

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thon-like events have been implemented in a wide variety of contexts and domains, and thus vary along several important dimensions, including goals, theme, and duration. There is, therefore, a lack of strong agreement on what classifies an event as a hackathon [14]. For instance, while hackathons typically have the goal of product development, the final product can range from software programs to hardware prototypes, depending on the style and goal of the hackathon [7]. Further, hackathons can vary in their theme (e.g., healthcare, aircraft design, etc. [8]) and length. Typically, events run overnight for 24–36 hours, but some events run for a shorter period of time, such as a work day, and others over a longer period of time, ranging from days to weeks, or even years [13, 15–19]. While the variability in these features makes it difficult to define a hackathon, the inherent flexibility in the format allows organizers to adapt hackathons to meet their specific objectives. For this reason, hackathons may also be referred to as game jams, design jams, hacking festivals, hack days, or codefests, among others [7]. New names continue to emerge as the hackathon format is adapted for different uses. Hackathons and hackathon-like events of all names are considered in this paper. Finally, hackathons are also organized to achieve a variety of objectives; for example, hackathons are run as networking events, within organizations to ideate solutions to large problems, and to teach participants. This paper focusses on the latter type, in particular focusing on hackathons that aim to teach *design*.

2.2 Design at Hackathons

Design is an iterative process that requires time for exploring and formulating the problem space while, at the same time, developing the solution space [20] – a back-and-forth commonly referred to as design co-evolution [21, 22]. Design comprises both the definition of a problem and the identification of the most effective solution [23]. In the context of hackathons, design is the process hackers follow while developing their final product; as such, common tasks at hackathons – for example, brainstorming, prototyping, and testing – are considered design activities. Hackathons differ from traditional design activities in that the entire design process, which usually is completed over several discrete periods, is instead compressed into one continuous and brief period.

We recently conducted a systematic literature review on the study of design at hackathons [8]. The reviewed publications, all of which studied at least one hackathon or hackathon-like event, employed different methodologies, including case studies, ethnography, interviews, surveys, and focus groups. The review found that hackers tend to follow a design process similar to that typical of a common design task. Our review presented this design process as an altered Double Diamond Design Process [24], as visualized in Fig. 1.

According to the Double Diamond Design process, the first phase is *Discover* [24]. During this first step of the hackathon design process, hackers form teams and work to identify potential problems to address [25]. This initial phase is divergent, followed by convergence in the *Define* phase. During the second phase, hackers select a problem and develop a shared understanding of it, along with corresponding requirements and constraints [25, 26]. The next phase is the *Develop* phase, during which teams once again diverge in order to explore and prototype solutions [25, 26]. The final phase, *Deliver*, is the cumulative convergence of the final project, which involves an evaluation of the solution [26], often comprising testing and iteration. The hackathon process proposed in Flus and Hurst

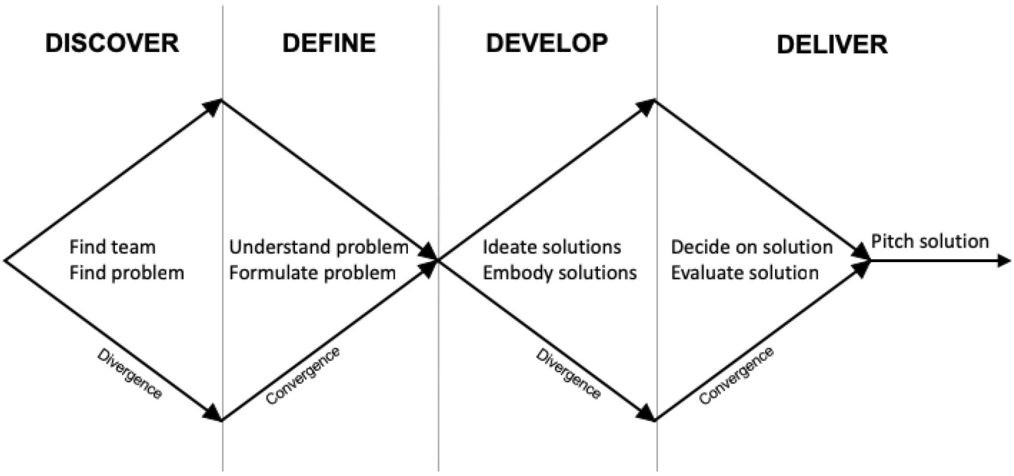

Fig. 1. The summarized design process from a literature review on design activity in hackathons [8].

[8] differs from the traditional Double Diamond process in that it emphasizes the *pitching* portion of the hackathon in the *Deliver* phase. While not every hackathon has a final pitching contest, it is very common and often requires a significant amount of time and resources to prepare [8]. Teams develop their presentation, rehearse, and aim to have a working prototype. The pitch is the culminating task of the event, requiring significant team resources and as such, the pitch portion of the event should be accurately represented in the hackathon design process [8]. As is typical of design processes, teams do not follow the process linearly, but instead iterate through one or more phases, which vary in length and order. Our research has concluded that, at hackathons, iteration within a phase is more common than across.

Our review also revealed that organizers can use the event structure to prescribe and facilitate a design process [8]. Some hackathon events offered hackers workshops on design practices, such as ideation [27, 28]. Other events introduced established frameworks, such as *Design Thinking* [29], and encouraged participants to follow a design process. The most direct "enforcement" of the design process at hackathons was at events with imposed schedules that aligned with design phases.

The typical hacker is a university student [7]; many hackathons run on university campuses, and are often supported, or even organized, by student volunteers. As a result, participating in hackathons is a popular extra-curricular activity among many university students. Not surprisingly, given hackathons' ability to both facilitate design through their structure as well as to motivate hackers (students) to learn at the event, the hackathon format is increasingly also being used to teach design in educational settings [8]. In the following sections, we will further explore how the hackathon model has been adapted to educational settings to teach engineering design skills and evaluate the effectiveness of the model in teaching and learning design.

3. Hackathons for Teaching and Learning Design

3.1 Design in Engineering Education

Design is widely considered to be the most distinguished activity of engineering [30]. Design takes a critical role in engineering education, both as a set of skills in itself (e.g., design methods) and as a means by which the integration and application of disciplinary knowledge is achieved and demonstrated, what Hurst et al. [2] liken to a curricular design "lattice".

Despite its central role, design pedagogy in engineering education does not have a strong tradition. In their infancy, engineering schools adopted a form of the traditional master-apprentice approach [31]; while most courses were taught by professors, programs relied on practicing engineers to teach design to engineering students [32]. As engineering grew in scope and complexity, math, natural science, and engineering science took a much more prominent place in the field of engineering and engineering education [33]. Accordingly, the teaching of engineering became more theory-focused, further reducing student exposure to practical skills, in particular design. In the last two decades, this model has been rightly critiqued, and the over-siloed and book-end approach to design teaching and lack of practical design experience identified as key concerns [34].

In compliance with accreditation requirements, engineering programs have relied on senior (or capstone) design projects as settings in which students can practice and demonstrate design skills. Design projects at smaller scales have naturally propagated to courses in lower years, embedded within projects or as means to integrate knowledge from several courses. In all these cases, educators have typically relied on a project-based learning (PrjBL) approach [1], a pedagogy that emphasizes active experimentation with real-world challenges and problems [35].

While PrjBL is well suited to teaching design, it requires significant time and sustained interest from both the instructor and students. Courses that implement PrjBL often struggle with class time usage and students have a difficult time understanding the learning objectives [11]. Motivated by these drawbacks of PrjBL in engineering courses, Horton et al. [11] make a case that hackathon events can be used to facilitate all elements of PrjBL in engineering education by (1) meeting student learning goals; (2) providing essential project design elements; and (3) providing opportunities for design critique and public presentation of the project results.

3.2 Design Teaching at Hackathons

There have recently been several publications connecting hackathons to design teaching and learning. While some studies highlight the opportunities to learn design at a hackathon event [36], others explicitly describe implementations of hackathons as novel pedagogies for teaching design in engineering education. This section will explore the latter.

The earliest example we could find of hackathons used for design instruction was a study by Page et al. [12], which followed a four-day hackathon event at the University of Dundee for undergraduate students enrolled in courses of product design and digital interaction design. Students were tasked with reconceptualizing new digital products for a client who was a leading retailer in greeting cards. Each of the four days had a dedicated focus, following the Double Diamond Design process model. On Day 1 teams conducted research and analysis, as per the *Discover* phase. On Day 2 students *Defined* the nature and scope of the problem. On Day 3, students *Developed* ideas by sketching and prototyping. The hackathon concluded on Day 4 with the *Deliver* phase, in which students presented a product demonstration. Students were not required to follow the Double Diamond Design model, but "*it was hoped that it would increase some of the student's awareness of the different stages of a particular design process whilst also supporting their learning in a systematic way*" [p. 3]. The study concluded with a list of recommendations for hosting a hackathon for teaching and learning design in engineering education. The suggestions aimed at maintaining motivation among students and included points such as providing guidelines on team formation and management, large team workspaces, and guidelines for progress and performance assessment. This hackathon event did not take place within the curriculum but presents a methodology for incorporating the hackathon format across multiple days within an engineering design course.

In contrast with Page et al. [12], which described design teaching in an extra-curricular setting, Gama et al. [37] aimed to present hackathons as a realistic experience within an undergraduate course. Instructors from the Federal University of Pernambuco developed the final term project for an Internet of Things (IoT) course as a one-day event. Groups of computer science and information systems undergraduate students had to find IoT problems, identify stakeholders, and present solutions under strict time pressure within the context of their course. An experience report on the event found that the "hack-day" provided an opportunity for hands-on and quick learning about both course content and practical design skills [38]. Further benefits included increased peer learning, high student engagement, and an enjoyable social aspect. The themes of fatigue and time constraint were listed as challenges. However, the consensus from students was that they learned more during the hack-day than from lectures, and as a result, the pros outweighed the cons [37].

More recently, Gama et al. [10] present a methodology for organizing a hackathon within an undergraduate course project. The researchers combined Challenge-Based Learning (CBL) concepts with Design Thinking techniques to "*accelerate the ideation of hackathon projects, systematizing the conception of ideas to transform them into solutions*" [p. 1]. Students completed their final project for a course during a 24-hour event. Students were guided through design phases with guiding questions (e.g., who are your users?) and instructional kits, such as a worksheet for brainstorming. The intent was for students to create and maintain documentation of their decisions and process, which was collected by their instructors at the end of the event. The course hackathon had five phases: domain definition, information gathering, user needs identification, envisioning and evaluation, and project development. Students were also taught methodologies to aid in their process, including brainwriting, voting heuristics, the thinking technique "SCAMPER" (Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse), persona building, and physical computing cards. The study revealed that students found the methodology to be helpful for problem definition, idea generation, idea convergence, and guidance through design phases. Students also strongly agreed that they enjoyed the course hackathon, and it could be used as a teaching tool in other courses. This study found general agreement on the effectiveness of using hackathons in design courses; however, hosting a 24-hour event within a course may not always be feasible.

Perhaps the most comprehensive use of hackathon-like events for teaching engineering design are the "Engineering Design Days" [2, 13, 39] at the University of Waterloo, which are in-class, curricular design events that follow a hackathon-like format. These events bring together junior engineering students (first or second year) in small groups to solve an open-ended engineering design problem over the course of two days. Examples of such problems include designing a mobile robotic ping-pong ball launcher (for electrical and computer engineering students) and a water-powered mechanical clock (for mechanical engineering students) [2]. All course instructors coordinate and allot space in their course schedules so that students do not have to attend additional classes or other curricular activities during the event. Design teaching is explicit during this event as there is often a starting period during which students explore the problem space and connect aspects of the design problem to concepts from their courses. Similar to traditional hackathons, the organizers of Engineering Design Days found the events were difficult to schedule within a course and required additional workload from staff and students [13]. Nevertheless, they concluded that they are effective at teaching course learning objectives and contributed to increased student understanding of design and creativity.

4. Evaluation

Due to their strong relationship to design and the popularity of the format with university students, hackathons and hackathon-like events are being recognized by engineering educators as presenting novel opportunities in which to engage students with engineering design. As such, they are slowly emerging as co-curricular or even curricular events in engineering education. In this section we present a qualitative evaluation of the effectiveness of the hackathon format for teaching better engineering design and identify opportunities for future research. This discussion is not comprehensive, as there are many factors to consider when implementing a new teaching pedagogy. Our evaluation explores the points we deemed most critical.

4.1 Advantages

In our view, there are several advantages to implementing educational hackathons and hackathon-like events in engineering design education.

First, a hackathon effectively simulates a "crash-course" of the design process. A study by Artiles and LeVine [36] found that by participating in a design hackathon, hackers exhibit increased design literacy post-event and non-designer participants display an increased use of design thinking terminology and approaches, suggesting hackathons are effective in teaching design, even in such a short time frame. When hackathons are implemented in curricular settings, students are expected to complete an entire design cycle – design, build, and test [13] – during a limited time frame. The condensed time available requires students to quickly problem-solve and naturally promotes high student engagement and independence. As such, design-centered hackathon-like events are particularly valuable in early years, when most students are novices to the design process. During these early years, much of the space in the curriculum is taken up by fundamental math and natural science courses, and the fast-paced and social nature of a hackathon event can serve as an early means of "socializing" new students into a program and introducing design concepts.

Another advantage of the format is its flexibility: the hackathon theme, timing, and structure, can all be adapted to meet the needs of the specific event. This is clearly demonstrated by the range of implementations – from the one-day hackathon event studied by Gama et al. [37, 38], to the four-day event studied by Page et al. [12]. While both followed a structure, these were adjusted to either progress teams through the design process quickly, or spread the process over a few days, respectively. Further, design instructors can change the nature of the design problem and its representation to match the students' academic level, context, educational goals, and course objectives [42, 43]. Several factors within the purview of the instructor, such as the level of scaffolding, whether the problem integrates content from several courses, and team characteristics, can significantly impact its perceived complexity by students, and the characteristics of the design activity and learning. In a curricular hackathon, instructors shift from teachers to facilitators and enable a co-creation mindset that has been found to be an effective and inspirational model for students [6].

It is important to note the pedagogical potential of hackathons beyond that of design. While the examples in Section 3.2 demonstrated the use of hackathons for teaching and learning design, it has been found that implementing hackathons within a course supplements course content in other areas as well [40]. Since hackathons can be adjusted to meet the goals of courses and can be run within a course, they also support the teaching and learning of math, science, and discipline-specific engineering concepts. Fowler et al. [40] found that students who participated in a game jam had a higher academic performance in computing courses than their peers who did not. Their findings suggest that hackathons have the potential to positively impact academic performance beyond design. The application of course content in rapid problem solving – a form of *active experimentation* [41] – is a clear advantage of implementing hackathons within curriculum. Hackathons enable students to practice "hands-on" skills [6] that will be necessary in industry. Finally, the hackathon environment encourages socializing, thus allowing social or situational learning from peers, mentors, organizers, sponsors, and guests [40].

4.2 Limitations

There are also many challenges to implementing hackathons in educational settings, most of which are tied to hackathons' primary features – uninterrupted immersion over a short overall event duration.

First, due to the very condensed timeframe, all stages in the design process must be performed within a very short time and participants may overlook certain design practices that would advance a design process outside of the hackathon environment [44]. For example, there is generally no time for hackers to gather requirements from users or to conduct extensive user testing. Need finding and analysis – an important but often overlooked step by student design teams [5, 45] – is limited in hackathons. In the hackathon setting, the ultimate goal of producing a demo-ready prototype for the judges during the pitch session pressures hackers to complete the problem identification [25] stage as soon as possible so that the "real" designing (i.e., exploration [26] or embodiment [25]) can begin. Finally, the condensed time frame deters design iterations, which become limited to smaller cycles within a design phase and can rarely span multiple phases [8]. Adapting hackathons to curricula may promote a version of the design process that is not reflective of design practices and behaviours that designers exhibit in natural design situations. An under-emphasis on research, prototyping, and testing is dangerous if students are not made aware and allowed to reflect on the way in which the hackathon format "forces" them to prioritize certain design activities and stages over others.

Second, fatigue and increased levels of stress are common at hackathons, as hackers tend to work continuously for the duration of the event in order to finish their projects on time. Fatigue and increased stress are not feelings that should be encouraged among students. Research has found that high mental fatigue results in reduced well-being and lower academic performance among university students [46]. Therefore, the introduction of activities in curricula needs to be in consideration of student mental health. As we point out in our literature review [8], the lack of breaks may also lead to reduced opportunities for design incubation, a period in the design process in which the designer briefly pauses their work. It is thought that during this time, knowledge is digested at the threshold of the conscious mind, which in turn aids the designer in reframing the problem and/or having a moment of insight [47]. In an educational context, the lack of breaks could translate not only into possibly inferior design outputs, but also, more importantly, even more limited opportunities for student reflection on their designing [48] – an important meta-cognitive activity.

Third, while the hackathon is very condensed, it can still be difficult for educators to fit a hackathon-like event into a curriculum.

Considering the peculiar time requirements, introducing such an event into the curriculum presents a scheduling problem for faculty and students alike. Additionally, the format requires commitment beyond that of traditional course lectures and projects. It requires extensive organization and resources to host, including instructional support and appropriate spaces in which the event can be held. These types of efforts may exceed the capacity of individual instructors or small groups of instructors, necessitating broader support at higher institutional levels, beyond what is normally available to instructors within the scope of singular courses.

Finally, while students work together in teams, they also are in competition with other teams for prizes that are awarded at the end of the hackathon. There is, therefore, a natural tension between competition and collaboration. This tension greatly impacts the peer learning potential of the event since projects are being *ranked* in addition to *marked*. The motivation then exists to be better than, rather than helping, peers. The pressures of a competitive environment may also demotivate some students, especially women [49], greatly disadvantaging a large portion of students and threatening the achievement of the intended learning outcomes.

5. Research Opportunities

There are many opportunities for design research at hackathons. In the context of curricular hackathons in particular, many questions remain on the advantages and limitations of adapting the hackathon format for teaching engineering design. Future research can explore how much of the design process students actively engage in, whether a hackathon can be framed to emphasize some design phases over others (e.g., a hackathon focussed on need finding), and whether hackathons can replace existing course components and deliverables (e.g., a hackathon in place of a final assessment). Additionally, the impact of high stress, fatigue, and competition on student performance needs to be better understood.

Given the relatively recent use of hackathons in curricular settings, to the best of our knowledge, rigorous studies evaluating the format's effectiveness in improving student participants' design skills have been rare [e.g., 13, 39]. Therefore, a need arises to more deeply understand how the hackathon format can promote (and perhaps also hinder) design learning. One such way of assessing the effectiveness of hackathons at teaching design would be to relate the study to *The Informed Design Teaching and Learning Matrix* [50] and measure the degree to which learning at hackathons advanced student design knowledge towards that of an experienced designer.

Another interesting area of research relates to hackers' motivations for participating in hackathons. Having begun to research this space, we are presently gaining some insight into hacker experiences and motivations [54]. These seem to differ greatly between hackers: some attend events to win, others to network, others to learn, and some to socialize and have fun [8]. We have found that hackers' motivations greatly impact the design strategy they follow at a hackathon. Those who are motivated to win will focus on developing a strong idea and a working demonstration that can impress judges in the pitching stage, while those there to learn focus more on the development/build stage. Experienced hackers understand that this heightened event is not suitable for learning a new skill but is rather an opportunity for applying their knowledge to a new task or to a side project. Hackers' motivations also drive how they spend their time at the event. Those motivated to win may not take breaks or sleep, pausing only to eat with their group over conversations of their project. In contrast, other hackers will network with event sponsors, meet new people, sleep, and take breaks when needed. To further complicate the motivations of hackers, said motivations may differ between team members [51]. Hackers must then balance their personal motivations with their teammates in order to reduce conflict while at the event.

The range of motivations and behaviours in hackathons has direct relevance to designing hackathon-like events in engineering education. While it is important for the goals of the event to align with the goals of the attendees, it is ultimately more important for the event organizers to have goal awareness [51]. As such, in curricular settings, it is important for instructional staff to understand what students desire to gain from the hackathon experience, and also for them to outline the purpose of the event. While teaching design is sometimes a goal of a hackathon, making this goal an explicit learning objective encourages engagement with design methods. Students should be aware that the curricular hackathon aims to teach design, so they pay attention to the design teachings in addition to completing hackathon tasks.

Finally, the COVID-19 pandemic has forced many hackathons to adapt to virtual offerings. For example, TOHacks [52] and the largest hackathon in North America, Hack the North [53], were offered online in 2020. Through hackathon promotional material and discussions with organizers and participants, we have learned that online hackathons require participants to participate virtually, so all communication and collaboration is facilitated online via a communication platform, such as *Discord* or *Slack*. Virtual hackathons are more accessible to participants, as they eliminate travel requirements and are more flexible in the required time commitment. Because of these features, we argue that the virtual hackathon format may be more easily implemented in curricular settings, requires less schedule coordination and fewer resources. The impact of the virtual format on design at hackathons has yet to be researched, thus we know little about the effectiveness of teaching and learning design in this setting.

6. Conclusion

The hackathon format has emerged as an effective and exciting new way to structure educational activities for teaching and learning design. As several examples reviewed in this paper have demonstrated, it is possible for hackathons and hackathon-like events to be used in curricular settings as a design pedagogy tool.

In this paper, we explored the advantages and limitations to adapting hackathons to curricula. The condensed time frame, flexibility of the format, and the multidisciplinary learning opportunities provide a novel paradigm in which design teaching and learning can occur. Nevertheless, the limited opportunities to engage in a thorough design process, high levels of fatigue and stress, instructional challenges to hosting the event, and added competition in hackathons challenges the use of hackathons in the classroom. While it is clear that hackathons have their limitations in terms of introducing more design experience in the classroom, they present themselves as an exciting new design pedagogy that can complement and enhance existing design curricula.

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Meagan Flus is a PhD student in the Department of Mechanical and Industrial Engineering at the University of Toronto. Her research explores design cognition in unique environments, with special interest in hackathons. She received a bachelor's degree in Knowledge Integration followed by a master's degree in Management Sciences, both from the University of Waterloo.

Ada Hurst is a continuing lecturer in the Department of Management Sciences at the University of Waterloo. Her research falls in the areas of design cognition, and design teaching and learning. She is interested in innovations in engineering design pedagogy and regularly teaches engineering capstone design courses. She received a bachelor's in electrical engineering, followed by master's and doctorate degrees in management sciences, all from the University of Waterloo.