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Investigating Student Motivation in a Curricular Hackathon

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1 Introduction

Active learning has been promoted as an ideal in engineering education for many years. Felder and Brent have championed the use of active learning, recognizing "that true learning results from doing things and reflecting on the outcomes, not from passively receiving information." [1, p. 111] In design education specifically, Project-Based Learning (PBL) has become the de facto standard approach of active learning across engineering curricula [2]. Its success, however, depends on student motivation - without it, students may struggle to engage fully, potentially limiting the positive outcomes of the pedagogy.

The key feature of active learning is that it is learner-centred and therefore places more responsibility on the student than teacher-centred methods. Past research has described several barriers to student engagement with innovative active learning approaches including student familiarity with the method(s), incoming student skills, student risk tolerance, environmental constraints (e.g. class size), perceived risks (e.g. on grades), perceived workload, social influences, and context-specific motivations [3]. Other research has identified that these barriers to student engagement can differ between individual students, or between communities of students. Felder and Brent described the challenges of active learning, where some students are comfortable whereas others may struggle [1].

For specific communities of students like Indigenous students, for example, the importance of the experience is critical to many learners. Leddy and Miller stated that "scaffolded experiential learning is a mainstay in Indigenous communities" and that the critical components needed to be present, such as time and uncertainty [4, pp. 52-53]. As another example, research on gender-based differences in STEM fields has reported differences in student motivation in STEM project-based courses by participant gender [5], and gender differences in how students engaged with different active learning modes like "play" [6]. PBL has also been shown to have a more significant uptake rate and positive impact on exam grades for women versus men in a sophomore physics class [7], and a more long-term, positive impact on women alumni compared to the effect on men [8]. If engineering educators are to improve access and retention of under-represented communities in engineering programs, attention must be paid to understanding the specific needs of these communities in the design of project-based learning environments.

This paper describes a formative design activity which sought to increase student motivation in engineering design early in students' first academic semester. This activity was a multi-day, team-based, design-build-test activity with a theme of "audio engineering". To evaluate the effectiveness of this design activity, students were asked to complete a survey to measure their situational motivation as they completed the activity. This paper is structured as follows: section 2 provides an overview of motivation and the assessment instrument used in this study, section 3 provides an overview of the development and structure of the activity, section 4 describes the methods used to evaluate the activity, section 5 describes the results, and sections 6 and 7 are discussion and conclusion, respectively.

2 Background - Motivation

Self-determination theory is one approach to understanding human motivation [9]. According to this theory, there are three general categories of motivation: intrinsic motivation (internally driven); extrinsic motivation (externally driven); and amotivation. A person with more intrinsic motivation can be expected to show more interest, confidence, and excitement; and are expected to exhibit enhanced performance, persistence, and creativity [9]. Generally, then, teaching activities which emphasize or enhance intrinsic motivation can be expected to have better learning outcomes for participants.

One instrument for assessing the situational motivation of participants in an activity is the Situational Motivation Scale (SIMS) developed by Guay *et al.* [10]. In it, they sought to measure four types of motivation, which from highest impact on self-determination to lowest are:

1. Intrinsic motivation – behaviours engaged in for their own sake, for the pleasure and satisfaction from performing those behaviours,
2. Identified regulation – a type of extrinsic motivation for a behaviour chosen by oneself but which is a means to an end,
3. External regulation – a type of extrinsic motivation regulated by rewards or avoiding negative consequences, and
4. Amotivation – behaviours which are engaged in without a sense of purpose and no expectation of reward.

Stolk *et al.* [5], in a large investigation of gendered patterns of motivation in the classroom environment using the SIMS instrument, found that students enrolled in non-traditional (e.g. project-based) courses reported higher intrinsic motivation, and lower external regulation compared to students enrolled in other types of courses. Stolk *et al.* also found that women reported lower intrinsic motivation and higher external regulation than males in traditional (e.g. lecture-based) teaching environments, and women expressed much lower external regulation than men in non-traditional courses [5]. These findings indicated that PBL leads to higher self-determined engagement, especially for women-identifying students. One form of PBL that is growing in popularity is adapting the extra-curricular hackathon format to the classroom environment, which will be discussed next.

2.1 Student Motivation in Hackathons

Extra-curricular hackathons have become very popular among university-age students, and research has shown that they are effective at developing skills including professional skills, technical skills, and design [11] [12]. Recent research has found that participants generally followed a similar design process to the Double Diamond [13] process of “Discover-Define-Develop-Deliver” [14] while completing their hackathon prototypes. In the last 5-10 years, this format has begun to be adapted to the classroom environment, with several recent papers describing the practical implications of adapting the hackathon format for curricular activities [15] [16]. However, hackathons, both curricular and extra-curricular, have often relied on identified regulation motivators (e.g. an expectation that participant technical skills will improve), and external regulation motivators (e.g. explicit prizes, grades, employment prospects) [16]. Extra-curricular hackathons also have a history of being alienating or hostile towards under-represented groups in the STEM community [11], including women-identifying students [12]. Combined, the reliance on motivation with lower self-determination in existing hackathons, and the differences in outcomes for diverse student populations that have been observed could lead to negative consequences for under-represented minorities in STEM. Therefore, it is important to understand the perceptions of under-represented students in hackathon settings if these activities are to become part of core engineering curricula.

This paper is part of a larger research study to identify whether (or not) STEM environments are providing safe and inclusive spaces for people of all genders to encourage diversity and equity within this field. Phase 1 of this study, which concluded in 2024, examined student motivation in two ***extra-curricular*** hackathons offered at the same institution in fall 2023 [17]. The first, a single-day hackathon, was a Women in Engineering (WiE) event, offered to fewer than 100 participants, and was structured to minimize competition, included training and mentorship opportunities, and featured a problem statement focused on social good. The second hackathon was a larger event (approximately 150 participants) that took place over 2.5 days and used a real problem faced by an industry partner in their manufacturing operations. As with the first hackathon, students with no prior hackathon experience were encouraged to participate and the event supported students with the technical challenge.

The SIMS instrument was used to assess participant motivations at both events. The results suggested that gender-diverse populations may have exhibited less intrinsic motivation than their man-identified peers when participating in hackathons with the general student population, but that events designed to be welcoming to gender-diverse participants could increase the intrinsic motivation of participants [17]. The nature of the hackathon topic, such as one focused on a more altruistic problem-space, and social motivations may have also played a role in the difference in results observed.

The Pearl Sullivan Engineering IDEAs Clinic (PSEIC) at the University of Waterloo, in Ontario, Canada, has pioneered the use of “curricular hackathons” in courses across engineering. Curricular hackathons have been defined as short, high-intensity social experiences that guide students through the design-build-test cycle of an engineering design problem. These curricular hackathons have included opportunities for student reflection and have achieved some level of integration and/or embedding into a program [15]. These open-ended events were intended to build intrinsic motivation in students through the three mechanisms identified in self-determination theory (viz. satisfying the needs for competence, relatedness, and autonomy) [9] by developing student self-efficacy in engineering design, introducing them to their discipline, classmates, and instructors, and connecting their classroom learning to real-world problems.

The event described in this paper is similar to the concept of “designettes” but was of longer duration at 12-16 hours of student contact time [18], and focussed on the latter implementation phases of design, with correspondingly less emphasis on the early stages of problem definition. Research on an earlier iteration of this event reported that students saw value in the activity and that it provided an opportunity to develop their professional skills like teamwork, problem-solving, and communication [19]; however, motivation was not assessed in this earlier iteration of the activity design.

This paper describes the development and implementation of a curricular hackathon for first-year Mechatronics Engineering students and investigates its impact on student motivation. This study – in addition to describing a project-based learning activity in the theme of audio engineering – investigates student motivation in a ***curricular*** hackathon, which was a mandatory activity as part of an introductory design course in the Mechatronics Engineering curriculum. The development and structure of the curricular hackathon activity is described in the next section.

3 Overview of Activity Design

"Audio engineering" was chosen as the problem space for this event because the developers of this activity felt that exploring music would be of interest to students. This event began as a short pilot activity in fall 2022 before being expanded into a two-day-long course activity in fall 2023 and 2024. The activity has also been offered as part of a series of extra-curricular workshops (held at various times in 2023 and 2024) for students in the Faculties of Engineering and Mathematics (Math). The overall development of the activity closely mirrored the process described in figure 8 of Wood *et al.* [20]; and was developed by undergraduate engineering students on co-operative work terms with the PSEIC with support from faculty and staff from both Math and Engineering.

3.1 Pilot Implementation

The pilot activity was designed to show applications of first-year calculus and algebra concepts to first-year engineering students. In the past, this integration was achieved through robotics applications [19], however the instructors wanted to identify a new problem domain that would interest students in both Math and Engineering. Sound waves and the fundamentals of audio synthesis were selected as the instructors felt all students had a common sense understanding of sound, and a general appreciation of music. The pilot implementation was approximately a half-day long, and while students were meant to work in groups, the nature of the tasks they were asked to do were difficult to complete in groups, and so most students completed them as individuals (e.g. the students needed to wear headphones to hear the sounds they were producing).

Anecdotal feedback on this version of the event from students was that the domain was interesting, but it lacked design opportunities and authentic collaboration with peers. One student wrote: "it felt like we were reading through a document with no end goal in mind. After a while I did not feel motivated to continue". The authors of "How Learning Works" posit that a student will be most highly motivated in a setting where they see the value of the activity, their efficacy is high, and the environment is supportive [21, pp. 70-90]. In this early iteration, it seemed that the value proposition of the activity was not perceived by the student participants. Or to use the language of self-determination theory [9], perhaps the students were not given sufficient autonomy in the pilot activity design. The idea of the activity seemed to have merit, however, and so the workshop was improved and expanded.

3.2 Extra-curricular Workshop Overview

Due to growing interest, the activity was expanded into a four-day, extra-curricular workshop that was open to all engineering students, regardless of their program or year of study. This extra-curricular version sought to address some of the shortcomings of the pilot activity by providing design opportunities and opportunities for collaboration. Each day of the workshop lasted approximately 3 hours, and was self-contained, allowing students to drop in as their schedules permitted.

The four-day workshop began with a primer on soundwaves and digital representations of sound. This paved the way for a discussion on audio synthesis on the second day, as students designed and used inexpensive audio synthesizers. On the third day, students built noise cancelling devices, and on the fourth day, students saw some applications of AI in audio engineering, which included improving audio quality, extracting target audio signals from a mix and noise removal using audio.

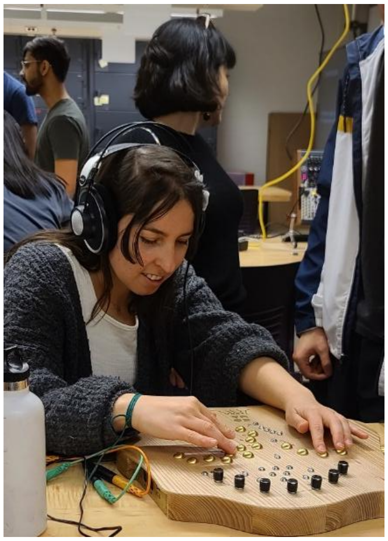
During this four-day activity, students gained hands-on experience with tasks such as manipulating sound waves using Audacity, analyzing waveforms with the Wave Python library, assembling and programming synthesizers using an Arduino, and exploring AI tools like Spleeter for audio engineering. Table 1 is a breakdown of concepts covered, and tools used in this four-day workshop.

Table 1: Breakdown of the four-day version of the Audio Workshop

Title	**Summary**	**Tools Used**
Day 1: Introduction to Soundwaves	Students learned the fundamentals of sound. Frequency analysis of some musical instruments using Audacity.	Audacity, Python
Day 2: Building a Synthesizer	Students learned how to synthesize sounds from component frequencies and build a synthesizer. Students worked with commercially available synths.	Python, Arduino, Various commercial synthesizers.
Day 3: Dealing with Noise	Students learned how noise cancelling works with practical examples (headphones and spaces).	Audacity, Arduino
Day 4: AI in Audio engineering	Students learned to use and build two AI models: one to split a song into its individual components (a creative tool for DJs) and another to remove noise from audio files.	Python, Spleeter Audio Library

The workshop also provided opportunities for students to interact with professionals in the audio engineering field. These experts included synth designers, musicians, and researchers. For instance, a researcher working at the intersection of AI and audio, delivered a presentation on their research. Additionally, an audio enthusiast and online content creator taught students how to create custom synthesizers. These presentations not only deepened students' understanding of potential career opportunities but also occasionally included information about open positions, providing tangible benefits to participants.

Students enjoyed the hands-on nature of the workshop. For example, one student commented: “The hands-on tools were a good way to get people more involved with the synths”. Students also enjoyed the opportunities to collaborate with one student reporting “I really think menti/kahoot [games] got everyone working together and engaged and actually got us to pay attention.”



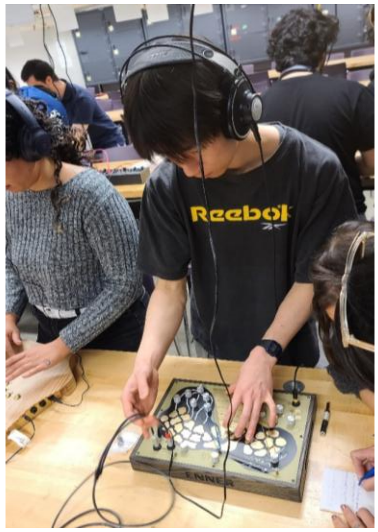


Figure 1: Students playing with different synths to solidify different audio synthesis concepts

3.3 Curricular Hackathon Overview

The pilot activity was also expanded to run in two 8-hour days within a Mechatronics Engineering design course for first-year students. This two-day curricular hackathon activity, called "Tron Days", introduced students to practical applications of audio engineering through hands-on projects, and connected to the design, graphical communication, math, and programming courses students were enrolled in that term. This activity was first implemented in 2023, but the fall 2024 implementation of the audio engineering activity in Tron Days is the focus of the rest of this paper.

On day one, students manipulated sound waves and recreated a piano note using software tools like Audacity and python. The students then designed and built a speaker cabinet out of common crafting materials and basic circuits. This activity emphasized both functionality and aesthetics and culminated in a competition for the loudest and best-designed speaker. On the second day, students assembled and programmed synthesizers capable of producing various sounds, and learned about different synthesis techniques such as subtractive and frequency modulation. The second day also included an optional noise-cancelling activity, where students built and tested passive noise-cancelling systems, which provided an introductory exposure to oscilloscopes. Throughout the activity, students worked in teams, presented their designs to the course teaching team and reflected on their learning. The event fostered collaboration and deepened their understanding of the knowledge and skills they used during the event. Table 2 provides an overview of the event structure.

Many of the materials used in the curricular version of this activity were also used in the extra-curricular workshop version, including the Arduino-based synthesizers and Audacity to experiment with soundwaves. As mentioned in the previous section, however, the extra-curricular workshop version of the activity had extensions into more advanced domains like AI and more advanced programming techniques than the first-year Mechatronics Engineering students have been formally taught.

Table 2: The table below shows a breakdown of concepts covered and tools used in Tron Days

Title	**Summary**	**Tools Used**	**Learning Outcomes**
Day 1: Manipulating Sound Waves	Students manipulated sound waves, recreated a piano note, and designed a speaker cabinet for functionality and aesthetics.	Audacity, Seeeduino Nano, Cardboard, Glue Gun	Reading circuit diagrams and use of a breadboard; graphical communication (sketching, CAD), design, teamwork, communication
Day 2: Synthesizer Assembly and Noise Cancellation	Students assembled and programmed synthesizers, explored synthesis techniques, and built noise-cancelling systems.	Arduino, Oscilloscope, Synth PCB, Microphone	Programming, introduction to microcontroller, introduction to circuit testing/validation

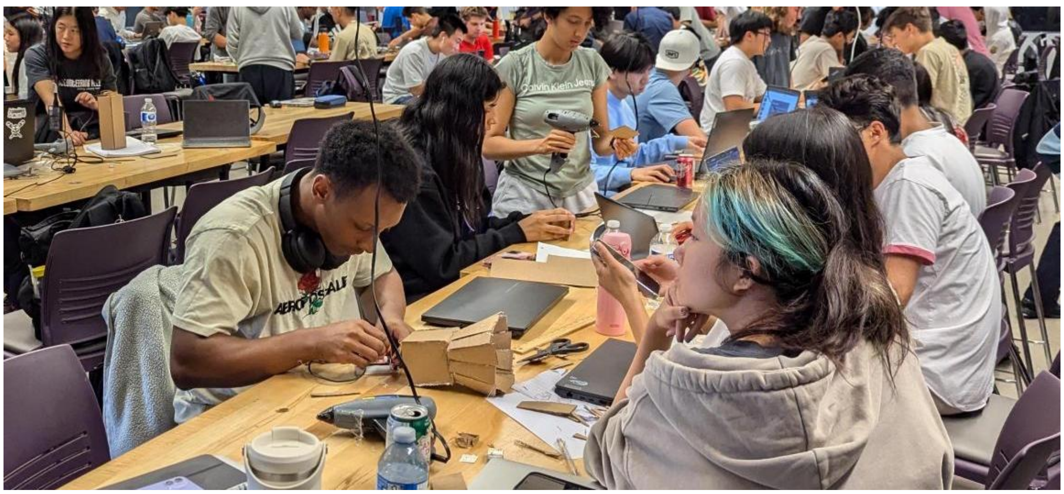


Figure 2 Students assembling their speaker cabinet, Tron Days 2024

4 Methods

To evaluate the impact of Tron Days on student motivation, students were invited to fill in a short, online survey (using Qualtrics), which included a series of demographics questions and the SIMS instrument at two points during the fall 2024 offering: at the start of the first day of the curricular hackathon, and at the end of the second day of the event held a week later. The demographics questions were adapted from the campus-wide student equity survey to ensure consistent language was used, and to facilitate comparisons to the university-wide student body.

Students also generated a unique ID code to enable the researchers to connect responses from students at the two measurement points during the event while maintaining participant anonymity. Initial data cleaning was completed in Excel and all statistical analyses were completed in Stata 15. Descriptive statistics and the Kruskal-Wallis test were used to describe and analyze the quantitative data. This study was approved by the institutional research ethics board (ORE#45461).

240 students were registered in Mechatronics Engineering in the fall 2024 term. Ultimately, 30 students completed responses to the first survey and only 15 responses were recorded for the

second survey. Unfortunately, only three students completed both surveys, limiting the opportunities to investigate how motivation changed over the course of the event.

Of the respondents to either survey who indicated their gender, five self-identified as women (13% of students who indicated a gender in the online surveys), 33 self-identified as men, and no students identified with the other gender options that were presented. No women completed the second, post-activity survey. The Faculty of Engineering reported that 23.7% of the incoming class of Mechatronics Engineering students in 2024 identified as women [22], so women are under-represented in this sample.

5 Results

The SIMS instrument consists of four questions that relate to each of intrinsic motivation, identified regulation, external regulation, and amotivation on a 7-point scale (1 “corresponds not at all”, 7 “corresponds exactly”). The internal consistencies of each collection of four questions for both the pre- and post-activity surveys were verified by calculating Cronbach’s alpha. The lowest Cronbach’s alpha value was 0.74 for the post-activity external regulation questions, indicating good internal consistency across all eight question groups. Generally, values in the 0.7-0.8 range are acceptable, and so the numeric scores for each motivation construct in both the pre- and post-activity surveys were averaged to obtain a single score for each of intrinsic motivation (Intrins.), identified regulation (Ident. reg.), external regulation (Ext. reg.), and amotivation (Amot.). The means and standard deviations of these values by participant gender are in Table 3 below.

Table 3 Average motivation scores, mean (std dev.)

	Pre-activity survey					**Post-activity survey**				
Pop’n	**N**	**Intrins.**	**Ident. reg.**	**Ext. reg.**	**Amot.**	**N**	**Intrins.**	**Ident. reg.**	**Ext. reg.**	**Amot.**
All	30	4.76 (1.3)	4.74 (1.1)	2.94 (1.3)	1.26 (1.1)	11	4.18 (1.4)	4.02 (1.6)	3.47 (1.5)	1.52 (1.35)
Women	5	3.9 (2.3)	4.7 (1.1)	2.45 (1.1)	1.4 (.72)	0	--	--	--	--
Men	25	4.93 (0.9)	4.75 (1.2)	3.04 (1.3)	1.23 (1.2)	11	4.16 (1.28)	4.05 (1.2)	3.86 (1.4)	1.45 (1.1)

As seen in Table 3, for the population as a whole and for the man-identified population, intrinsic motivation has the highest mean in both the pre- and post-activity surveys followed by identified regulation. This is not true for the woman-identified population, however, as identified regulation has the highest mean in the pre-activity survey, followed by intrinsic motivation. Intrinsic motivation and identified regulation were slightly higher in the pre-activity survey than in the post-activity survey, while external regulation was higher in the post-event survey than in the pre-event survey. Generally, amotivation was not present in either survey.

Figure 3 shows the mean motivational profiles for the entire population, as well as the breakdown by man and woman from the pre-event survey. The men exhibit a “truly autonomous” motivational profile, whereas the women, with the stronger presence of identified regulation over intrinsic motivation, might be more accurately described as a “moderately autonomous-controlled” profile [23].

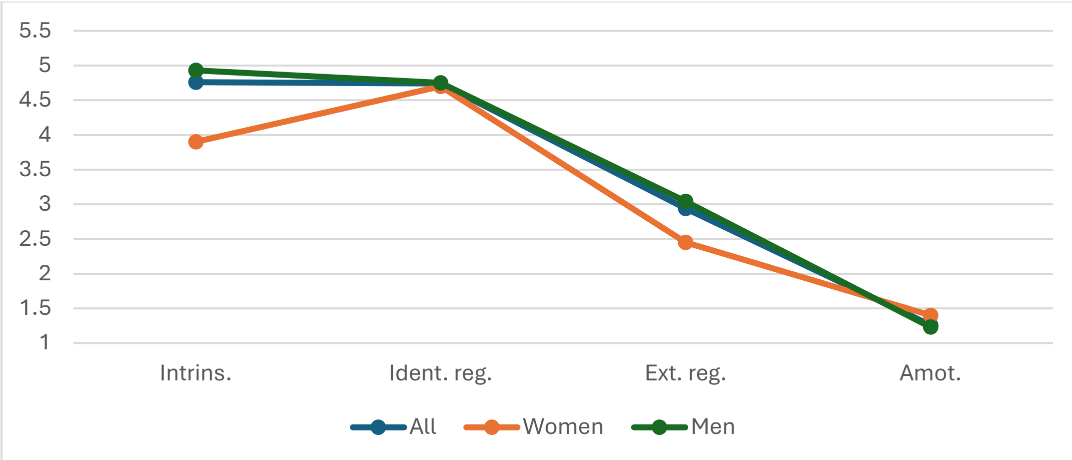


Figure 3 Motivation profiles by gender

The Kruskal-Wallis test (a non-parametric version of ANOVA) was used to investigate the differences in the means of the four motivation variables from the start of event survey by respondent gender. The differences in means were not statistically significant in any of these tests. As there were only three students who filled in both surveys, and no women who filled in the post-activity survey, a comparison between the respondent genders in the post-activity survey, and a comparison between the pre-activity and post-activity means were not conducted.

The post-activity survey also included three, 5-point Likert scale questions to capture general affective feedback on the event, including: "I feel like I am gaining knowledge through this event" (Gained knowledge), "I feel like I was prepared for this event" (Well prepared), and "Overall, I felt welcome at this event" (Felt welcome). The responses to these three Likert questions are found in Table 4.

Table 4 Summary of responses to Likert questions, post-activity survey (n=11)

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Gained knowledge	3	7		1	
Well prepared	3	3	4		1
Felt welcome	8	2	1		

Generally, the respondents to these questions (who all identified as men) felt that they were able to gain knowledge during Tron Days, slightly more than half felt well-prepared for the event, and nearly all respondents felt welcome at the event.

5.1 Results From Open-Text Questions

In addition to the demographic and SIMS instrument questions, participants in the pre-activity survey were also asked in an open-text prompt "What are you hoping to learn in Tron Days?". Of the 30 total responses to the pre-activity survey, 22 respondents (18 men, 4 women) provided some response to this question, typically one sentence or less. A summary of student responses is given in Table 5 (note: some students mentioned more than one topic in their response). The most common response was to learn to use a micro-controller, though a similar number of total students mentioned gaining, expanding, or applying knowledge in various forms.

Generally, women-identifying respondents seemed to list more general, or professional, skills whereas the male respondents had a higher emphasis on more specific, technical skills like using microcontrollers, electronics, or programming/coding.

Table 5 Summary of responses to "What are you hoping to learn in Tron Days", by gender

Response	**# of Men**	**# of Women**
Microcontroller	6	
Expand knowledge	3	1
Design	3	1
Teamwork	3	1
Domain knowledge	3	
Programming	3	
Electronics	2	
Time management	1	1
Hands-on Experience		1
Mechanics	1	
Creativity	1	
Industry skills	1	
Apply knowledge	1	

6 Discussion

Women who responded to the pre-event survey, on average, showed less intrinsic motivation to participate in the curricular hackathon than their man-identified peers, though the number of female respondents was low. This aligns with a similar finding to previous research using the same survey protocol in an extra-curricular setting [17]. In addition, the motivation profile of women in this study might be described as “moderately autonomous-controlled” – as opposed to the “truly autonomous” profile of their male peers [23] – as the female students had higher identified regulation than intrinsic motivation.

The responses from men in this study matched the findings from Stolk *et al.* [5] for non-traditional courses very closely. The women, however, reported lower intrinsic motivation, similar levels of identified regulation, and lower external regulation than was seen in Stolk *et al.*’s study. This may be a result of the persistence of gendered interactions in multi-gender groups, something that was reported in the study by Hirshfield & Koretsky [24].

The experiences of women and their self-reported motivation could also have been impacted by interactions with non-participants, such as the course instructor or teaching assistants [25] earlier in the term. While no intentional interventions to either highlight or draw attention away from gendered identities were made a part of this activity, the autonomous motivation of female participants may have been negatively impacted by “stereotype threat” [26] – STEM programs where there are low percentages of female students and professors can cause female students to endorse the gender stereotype that STEM is for men.

While the levels of intrinsic motivation reported by women in this study are lower than their male peers, it was nonetheless a positive result that intrinsic motivation and identified regulation are the dominant motivation scales reported by all Tron Days participants, as opposed to external regulation. Tron Days was a mandatory activity in a first-year design course and carried a small number of grades in the course (5% of the total course grades). However, these grades were earned through a post-event reflection report, and not through the project outcomes during Tron Days. In this way, the event was formative design practice, and not summative assessment (a longer, summative course project occurs in the second half of the term). It was perhaps this assessment structure that helped to control the external regulation present in the participants.

As described in section 5.1, women-identifying students tended to list general engineering skills (like design), or professional skills (like teamwork), when asked what they hoped to learn by participating in Tron Days. This was in contrast to the men-identifying students who were more specific in their response or more focused on technical outcomes. For example, six respondents, all of whom identified as men, mentioned that they were hoping to learn more about microcontrollers during Tron Days. It is not possible to say why the students responded as they did, perhaps there are gender differences in the expected outcomes of project-based learning, or perhaps the men were more familiar with the technologies in use in the event (like Arduinos).

These students must complete mandatory co-op work terms as part of the degree, and so it is possible that the women participants might not have been thinking of the technical skills they could add to their resumes in the same way as the men. This could also be a manifestation of stereotype threat, where the women participants are identifying skills that they're already confident they have developed to avoid having poor performance attributed to their gender [27].

Unfortunately, the response rates to the two surveys (the post-activity survey in particular) were quite low, and so it is challenging to draw generalizable conclusions based on the data presented in this paper. Women were under-represented in the pre-activity dataset and no women participated in the post-activity survey, and so statistical comparisons by participant gender were either not possible or lack statistical power. This study collected racial identity data from participants as well, but the populations of students were too small to conduct any meaningful analysis by participant race.

From past experience, it is challenging to obtain high response rates to surveys administered during these events as the students typically have staggered arrivals and once the activity has started, their attention is entirely focused on the design challenge. Future research could perhaps benefit from alternative research designs, including qualitative approaches to dig deeper into student experiences at these events.

7 Conclusions

This paper described the development and implementation of a curricular hackathon-style event in the domain of audio engineering. In the post-event survey, the majority of respondents felt they gained knowledge, felt welcome, and were prepared for this event, which were all positive indicators of the activity design and its integration into the academic semester.

An investigation into the motivations of student participants in the activity revealed that intrinsic motivation and identified regulation were the dominant motivators for both woman- and man-identifying participants, implying that students were predominantly internally motivated to take part in the activity. However, woman-identifying participants reported lower intrinsic motivation levels than the men. In open-text responses to the question of what students hoped to learn in this event, women-identifying students responded with more general responses like design skills, time management, and teamwork; whereas men-identifying participants more frequently mentioned specific technical outcomes like the use of microcontrollers.

This paper contributes to the study of gendered differences in active learning STEM pedagogies. Further research to explore these gender-based differences in motivation could perhaps identify the reasons for these differences and could offer suggestions to improve pedagogical design to ensure under-represented groups in STEM experience similar levels of motivation to their peers.

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