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UTILISING HACKATHONS TO ENHANCE THE DESIGN PROCESS FOR ELECTRONICS & PROGRAMMING LEARNING WITHIN PRODUCT DESIGN EDUCATION

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ABSTRACT
The demand for enhanced technical competencies in graduates of product design (PD) and product design engineering (PDE) courses continues to grow year on year, with industry now requiring students to not only have an appreciation of design and manufacturing, but also a practical understanding of electronics and programming. However, traditional electronics and programming education, especially in product design courses, is often received negatively by students, especially by students that are solely driven by the creative aspects of the industry. At Nottingham Trent University (NTU), we identified that students saw a disconnect between their design education and their electronics and programming teaching and learning, yet there was a desire to understand more about how products function. Within the BSc Product Design course at NTU, there was a desire by the academic team to explore different pedagogies that would have a positive impact on electronics and programming learning, whilst also helping students see a more direct connection with this topic in relation to their future employment. As such, we sought to leverage the use of hackathons to provide an intense practical delivery approach for electronics and programming learning, whilst combining this with a focussed design activity. This paper explores the process of developing hackathons to complement electronics/programming curricula by encouraging students to combine all their skills in a product design context. Student feedback is presented based on their learning experiences. The paper concludes with a series of recommendations for the future use of "Hackathons" in product design education to help engage students.

Keywords: Coding, electronics & programming, hackathons, intuitive design, product design education

1 INTRODUCTION
Hackathons are short events, usually one to three days in length, where participants motivated by a common challenge work in groups to build a software or hardware prototype/output [1-2]. The hackathon methodology often focusses on specific design challenges linked to software or hardware development with the aim of realising a new functional outcome. Hackathons have been utilised in software engineering education for many years [3] and are typically utilised as a method of rapidly designing mock-ups, prototypes, or solutions which aim to solve a very specific goal or brief. Hackathons have also been utilised within the product design and engineering education realm as a form of design exploration [4], for design research [5], for project-based learning [6] and for technology focussed, business focussed, and social issue driven challenges [7]. Hackathons provide an opportunity to engage students in quick paced, experiential learning approach with the ultimate target of having a suitable outcome that is presentable. Hackathons present challenging workloads for students, as such cultivating the desired environment either online or face-to-face is important.

This paper explores the process of developing an electronics and programming curriculum that encourages students to explore the realms of the subject within a product design context whilst engaging with hackathons. The aim of this research was to investigate how the Hackathon methodology could be applied and to test whether this has any impact in the product design education curriculum. Furthermore, this research sought to investigate whether it was possible for students to apply their sketching, CAD, electronic and mechanics learning into one piece of work. This paper also explores the implementation of hackathons, identifying successes and challenges of using the methodology. This paper presents collected student feedback and is reviewed based on the learning experience for product design students with aim of implementing hackathons into the curriculum. Industrial partners have also identified the relevance of the activity in relation to a student's degree and future career/professional practices.

2 INTEGRATING HACKATHONS INTO THE PD CURRICULUM

At NTU, we integrated our first single day hackathon into the BSc Product Design course at the end of the 2020/21 academic year in an attempt to help students contextualise and apply electronics and programming learning into a product design focused outcome. This hackathon was received positively by students allowing them to connect their electronics/programming learning from their taught sessions via a focussed design challenge. Subsequently, in 2021/22 academic year our first two-day hackathon was implemented, whereby student groups competed against each other and were set the challenge to design, manufacture, and programme a remote-control vehicle (RC vehicle) using Arduino kits. The developed range of RC vehicles were then judged on their aesthetic design, quality of manufacturing and programming before being ranked based upon their ability to navigate a predetermined time trial course. The development of the hackathons and electronics curriculum is discussed below:

2.1 Electronics Curriculum Re-Development & Initial Hackathon

Due to the impact of the COVID-19 pandemic the traditional first year ten-week electronics syllabus had to be redesigned. As such this was split into two elements. Firstly, all students were provided with an electronics and Arduino kit on loan from NTU. Each student was required to complete a series of curated LinkedIn learning courses which were supplemented by academic recorded asynchronous online Tinker CAD videos/activities. Adherence to this program of work was extremely variable, with novice electronics users/students citing significant struggles. Second, the students were provided with six weeks/sessions of socially distanced classes on the development of simple circuits, an introduction to Arduino, basic programming, digital inputs/outputs, analog inputs/outputs, and motor drivers. To check student learning on the taught blended electronics/programming content, a one-day hackathon was developed. The hackathon focused on students working in groups of three or four and were tasked with designing, building, testing, and racing a designed cardboard vehicle which utilizes basic Arduino kits and motors. Size parameters were set for the vehicles. The judging/racing criteria was as follows:

1. **Quality Of Build & Aesthetic Appeal:** The cars were judged and ranked first to last based on the quality of the construction and its aesthetic appeal and use of additional electronic components to elevate the designed vehicles appearance/performance i.e., flashing lights, head lights, audio, etc.
2. **Speed Challenge:** A straight line race of the vehicles was conducted in a round robin system whereby vehicles were ranked first to last place based on the number of races won.

2.2 Expanding The Electronics Curriculum & Developing A Two-Day Hackathon

In response to the return of face-to-face teaching, the electronics curriculum was refreshed and increased to sixteen weeks of electronics and programming classes in groups of 15-18 students. This was broken down into six weeks of introductory electronics classes exploring fundamentals such as breadboards, soldering, simple circuits, and the use of multimeters. Ten weeks were dedicated to the teaching of programming microcontrollers (Arduino) and exploring topics such as motor control, sensors, switches, inputs/outputs, pulse width modulation etc. Based on feedback from students from the 2020/21 academic year a more challenging hackathon was developed and run over two days. The possibility of running a more challenging hackathon with a greater number of elements was possible due to absence of COVID-19 restrictions. The hackathon challenged student groups of three/four members to design, build, test, and race a wired robot controlled (RC) vehicle which utilises Arduino kits and motors/motor drivers. Students were required to use Arduino kits to control the directional control of the designed vehicle. This challenge allowed the students to put into practice the previous sixteen weeks of electronics and programming learning as well as implement the learnings from the eight-week mechanics curriculum too. The hackathon challenge required students to produce vehicles of set size parameters using 2-4 wheels. The students needed to balance the creative development of their vehicle alongside the functional performance and were judged based on the following criteria:

1. **Quality Of Construction & Electronic Capabilities:** The designed RC vehicles were judged and ranked first to last based on the quality of its construction and the vehicles electronics capabilities.

As such the student groups needed were required to use the electronics available to increase the overall aesthetics/function of the designed vehicle i.e., flashing lights, head lights, audio etc.

2. **Aesthetic Appeal & Creativity:** Students vehicles were ranked first to last based on the RC vehicles aesthetic appeal and creativity. They were challenged not to just build a car, but explore other vehicles that could developed, built and tested whilst not compromising functional performance.
3. **Obstacle Course Time Trial Challenge:** The RC vehicles were time trialled over an obstacle course which included ramps, multiple terrains, and several obstacles whereby the vehicles are ranked first to last based on the finishing time achieved. Missing obstacles, skipping obstacles, or removing obstacles resulted in pre-determined time penalties based on the course.

3 METHODS

Forty students took part in the forty-eight-hour hackathon at the end of the 2021/22 academic year. Students were split into groups of three/four and tasked with designing, building, testing, and racing the designed wired robot controlled (RC) vehicle which utilizes Arduino kits and motors/motor drivers. The student group with the highest number of points based on the rankings of the determined criteria would be crowned the winner of the hackathon and provided with a small prize to help further their electronic and programming learning. Post the hackathon judging, thirty-two students (response rate of 80%) voluntarily completed an end of hackathon survey which was constructed of twenty-four questions comprising of basic demographic questions, open-ended feedback questions, 5-point Likert Scale questions and overall event rating questions. This survey was delivered through Microsoft Forms. The collected data provided insight into the effectiveness of the hackathon teaching and learning approach. Student feedback and the findings from the hackathon were ultimately collected to demonstrate the effectiveness/impact of combining the students design, manufacturing, CAD, electronics, programming, and teamwork skills. A summary of the key results and findings are presented in section four.

4 RESULTS

The winner of the first hackathon challenge in 2020/21 was the group that got the highest combined score from the two challenges; examples of produced vehicles can be seen in Figure 1. Student feedback from the first set of hackathons was overwhelmingly positive with all groups able to produce functional vehicles. The hackathon helped underpin the taught electronics and programming content and provided a basis for the electronics and programming work to be completed in year two alongside industry partners; this is based on the development of electronic vehicles using modules. The winners of the second set of hackathons, run in 2021/22, demonstrated a higher level of electronics and programming skill as well as increased manufacturing and electronic integration (Figure 2).

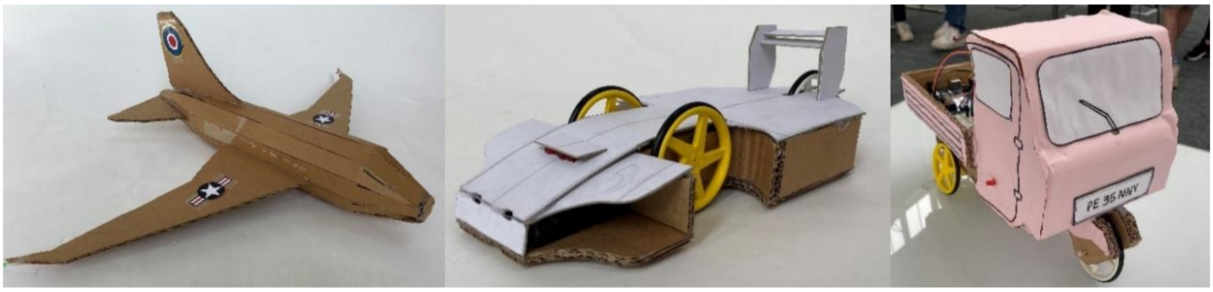

Figure 1. Assortment of developed Arduino vehicles during the one hackathon

Figure 2. Assortment of developed RC vehicles during the two-day hackathon

Feedback from the student survey presented to the 2021/22 cohort identified that only four students had taken part in a hackathon before. Prior to undertaking the hackathon, students identified how interested they were to learn about and experience a hackathon; seven students stated they were 'extremely interested', twelve 'mostly interested', ten 'moderately interested', two 'slightly interested' and one 'not interested at all'. Student groups identified that they spent a variable amount of time working on the hackathon challenge, typically identifying that they spent 9-12 hours or 13-16 hours engaging with the activity. However, other students identified that they spent 20+ hours engaging with the hackathon. Collected student feedback highlighted several areas that they found useful when undertaking the hackathon including rapid ideation, electronics and coding through trial and error, assembly of multiple electronic components and the transfer of circuits built on breadboards to stripboard.

Rapid prototyping and idea generation/development alongside mechanical development for the steering system. (Participant 26)

I found it really useful to make something that actually has a function using electronics rather than just making LEDs turn on and off, it was also very useful incorporating the electronics into a physical model, having to design around the space available in the car and having wires go through the car. (Participant 27)

Electronics & programming were weak points of mine, being stuck & forced to understand code & electronic pathways has certainly been useful. (Participant 30)

When asked to reflect on what aspects of the hackathon the students found most enjoyable, a number of areas were identified ranging from ideation, rapid prototyping, designing within constraints, applying electronic and programming to a design solution, quick problem solving, amongst others.

I enjoyed the wiring, being able to see my product work and seeing the wheels spin was great, especially combined with the coding for the buttons to allow different types of movement. (Participant 10)

Enjoyed working in a team and rapidly creating a complex CAD model. Short time constraints have allowed for much quicker idea generation and generally a more efficient approach to the process. (Participant 29)

You always felt pushed for time which made the Hackathon more chaotic than other projects like the design sprint. I enjoyed having to design the product and the controller as part of it. (Participant 32)

Student feedback captured a wide range of feedback in relation to the level of preparation, training and support provided (Figure 3). Student feedback captured their perception in relation to product design focused electronics and programming hackathons and how important they felt these types of events related to their future professional practice. Two students identified the hackathon as 'extremely relevant', with thirteen stating it was 'very relevant', fifteen 'moderately relevant' and two 'slightly relevant'. Students were also asked whether they would be prepared to take part in product design focused electronics and programming hackathons in the future with fourteen students stating that they would be 'very willing', ten 'somewhat willing', six 'undecided' and two 'somewhat not willing'. Student feedback highlighted that to improve the hackathon experience, they would have liked some benchmarks/targets to achieve by certain times within the forty-eight-hour time-period.

Conversely other students requested that more of the weekly electronics and programming sessions to be tailored more directly to the hackathon activities to help them prepare more effectively. Feedback also suggested that a pre-event launching them into the project would have helped them prepare more effectively for the hackathon. Although the above points are valid, hackathons are supposed to be pressurized challenges set over a short time-period with the hope of navigating, exploring, and producing a solution or outcome that meets the requirements. Providing a pre-launch or providing additional time as requested would go against the ethos of a hackathon and take away the pressures designed to be applied in this setting. This hackathon was an opportunity to encourage students to test, trial and fail in a non-assessed environment, thus promoting opportunities for experimentation, whilst working under pressure without an academic grade being assigned.

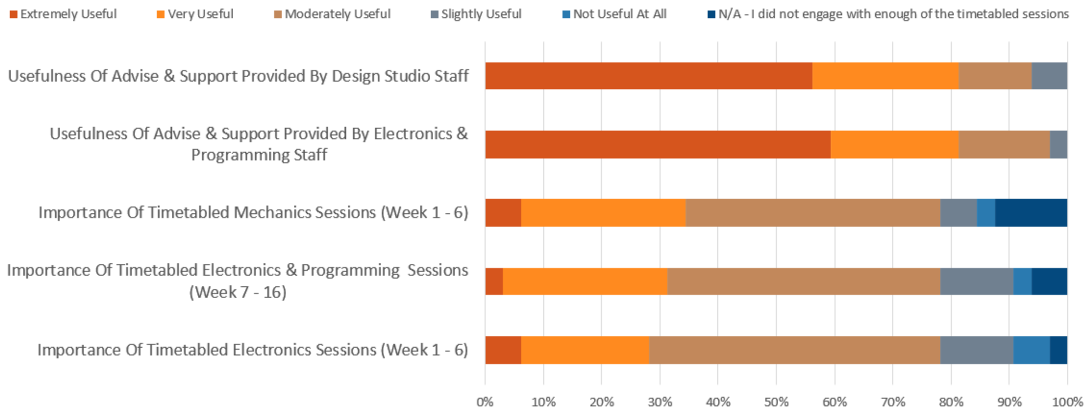

Figure 3. Student response regarding the level of support and preparation linked to the hackathon

Feedback collected also asked students to identify aspects of the hackathon which they found particularly challenging and why. Student responses varied from challenges with teamwork, achieving the task within a pressurized time scale, challenges associated with assembling code together and general electronic issues such as transferring circuits from breadboard to stripboard to produce a more reliable and complete circuit suitable for the obstacle course.

Coding the car was challenging but the support of the tutors was greatly appreciated. (Participant 5)

Teamwork was quite challenging as everyone had different ideas of what to do which made it hard to communicate within a short time. (Participant 28)

Arranging the components on the breadboard as well as transferring it over to the blank stripboard. (Participant 31)

Based on the hackathon experience students were asked to rate the perceived importance of a range of skills and activities used/conducted throughout the hackathon; the results are presented in Figure 4.

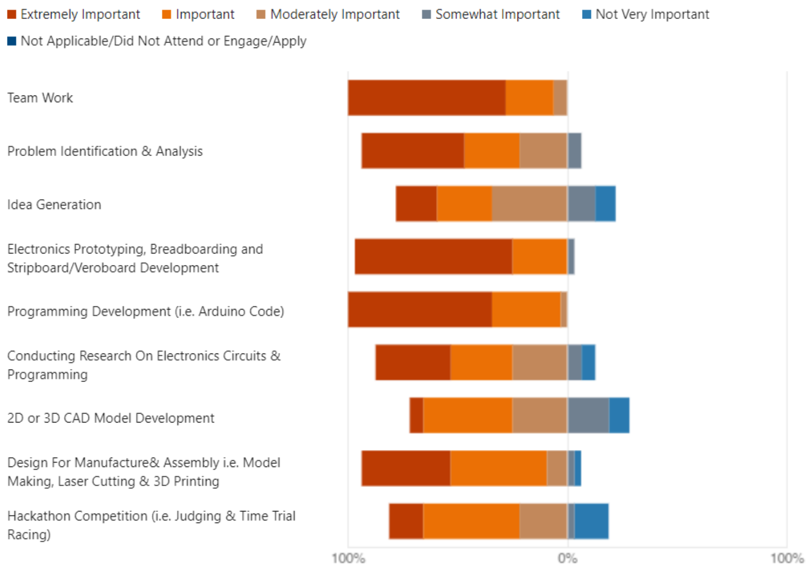

Figure 4. Student response to the perceive importance of hackathon skills/activities

To conclude, the student group rated their overall hackathon experience. Five students stated they were 'extremely satisfied' sixteen 'very satisfied', 'ten 'moderately satisfied' and one 'not satisfied at all'. The results suggest that the Hackathon experience had the desired effect by encouraging students to implement their electronics and programming learning into a real-life problem/context, which is often a barrier for students engaging with electronics and programming learning consistently over their studies.

5 CONCLUSIONS & RECOMMENDATIONS

From the feedback collected it was evident that small changes are necessary, in particular, providing further resources to students when preparing for a hackathon. More focus/teaching on translating circuits from breadboards to stripboard is needed as is further time experimenting with motor drivers. No demographic or nationality issues were noted during the deployment or delivery of the electronics teaching block or the hackathon. International students however identified that the recordings of sessions and the supporting captions and handouts helped with any confusion around terminology.

The deployment of the hackathons across the last two academic years has demonstrated how the delivery of an electronics/programming curriculum which is reinforced with a real-life challenge has helped student groups contextualize their learning and put into practice their developed skills. Challenges still do remain with regards to the different speeds for which students understand and grasp the topics of electronics and programming, however the extended teaching block supported by hackathons has without doubt reduced the number of students struggling and failing electronics assessed content.

Based on the implementation of hackathons in the product design curriculum at NTU, and the student feedback received, the following suggestions are made when planning to run/implement hackathons:

1. Provide students with the opportunity to select their own grouping, however, provide clear parameters based on the length and complexity of the hackathon challenge being set.
2. Provide collated kits or standard equipment which all student groups must use as the basis of the hackathon challenge, whilst also ensuring they have access to a plethora of additional resources.
3. Provide clear and designated workspaces for student’s groups both in a design studio environment and within an electronics laboratory environment.
4. Provide clear/explicit guidelines where groups should be at during the hackathon timeline to help keep the student groups focused and on task.
5. Ensure that a diverse staff team is available and engaged within the hackathon environment, in particular ensure that multiple electronics and programming tutors/technicians are on hand to support the event whereby student questions/queries will inevitably be frequent.
6. Ensure student groups do not focus too early on perfecting the design output, rather encourage them to experiment with the electronics and programming as soon as possible to maximize their chances of having functional outputs come the judging/assessment.
7. At the end of the hackathon ensure that all student groups irrespective of the success or failure of the outcome are involved in the review and presentation of the designed outputs produced.

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