How design students select maker technologies in their undergraduate projects

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ABSTRACT

The choice of technology for the prototyping phase is one of the most common issues relating to the use of maker technologies, particularly for students. The factors influencing students' choices of technology when learning about interactive prototyping have not received much scholarly attention. Therefore, this study investigated these factors. We applied grounded theory to the analysis of students' artworks and discussions. When selecting components, it is crucial to consider the socio-technical context in which pupils are studying as well as the electrical and communication qualities of the parts. Our results shed light on the need to conduct further research and redesign boards and component parts for educational practitioners.

CCS CONCEPTS

• Social and professional topics;; **• Human-centered computing;**;

KEYWORDS

Design, Education, Interactivity, Selection, Practices, Prototyping Tools

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1 INTRODUCTION

The choice of technology is crucial to interface design [1, 2, 6, 11, 15, 17]. By utilizing the learning obstacles framework [14], Booth [10] has shown that selecting difficulties are frequent and negatively impact the development of maker systems. According to a recent study on the subject [13], the selection of sensors is influenced by various factors, such as protocol complexity, component size, kind of connection, documentation, and the measurement of comprehensible real-life phenomena. Mellis reported that in a study based on PCB construction, the selection of components among amateur volunteers was influenced by factors such as robustness, availability, and ease of interfacing. Due to the subjects' need to make numerous early judgements, the projects' definition were complicated. Furthermore, the selection of the components was challenging due to the complexity of the information and the challenges associated with understanding how to use it [16]. Karvinen claimed that the large assortment of components electrical kits, many of which call for sophisticated skills, could be the cause of selection difficulties [13]. Mellis also argued that the selection process is challenging due to the abundance of components [16]. A study of the use of creative technologies in higher education in developing nations found that the availability and transferability of skills, the learning curve and learning objectives all influenced the technology chose by teachers [18]. In a study on the prototyping of interactive artefacts by design students, teachers chose the RBB board [22] because of its compatibility with Arduino, the cost and the need to be assembled [9]. Remarkably, a study conducted on engineering students discovered that teachers were more likely to believe that choosing electronic parts was difficult compared to students [12].

The above-mentioned studies show that selecting the right technology for interactive prototyping requires a variety of abilities and socio-technical supportive contexts. According to these analyses, which were conducted using technology selected by the teachers, peers and tutors assist in selecting, experimenting with and assembling interactive prototypes. While these works offer initial evidence concerning the process of choosing technologies for interactive-prototype development, they do not elucidate the process by which design students choose technologies for interactive-prototype creation in real-world scenarios. The significance of technological features and teaching in design students' choices of technology for interactive prototyping has not yet been fully clarified. It is also unclear what data support these processes and what kinds of decisions might be drawn from them. In addition to offering educators insights, our work clarifies technology-selection practices and helps the design of new prototyping components that optimise these dynamics.

2 METHODOLOGY

This section explains the study's background, research methodologies and data analysis approach. The study was conducted with design students enrolled in a final-year design course at the Design Department of the University of Dundee in the United Kingdom. The purpose of the Personal Honours Project module was to give the students a way to integrate the knowledge they had gained by developing personal projects. Using the knowledge and abilities they had acquired during the curriculum, the students created unique design outputs for their project briefs. Each student had a designated area in the design studio, which served as a common learning place for all the pupils in the class. The specialists in the studio and the workshop technicians also helped them. During the

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two semesters, each student had to produce certain deliverables as part of their assignments, including an expert-day presentation, an idea presentation, presentations regarding the mark 1 (MK1) and mark 2 (MK) prototypes, a personal folio, a project booklet, a blog, one image, a one-minute video and a final presentation.

During the four years of the curriculum, the students learnt core design skills, people-centred research approaches and design briefs across interface and product design. In their second year, they took classes on Arduino and Processing. By the time they reached year 4, every student had two years of experience creating digital prototypes, mostly using Processing and Arduino. In the final year, students working on projects have to show that they can prototype independently. Numerous specialised technologies and tools were employed to carry out the projects. The hardware boards, Processing, Arduino, and many input and output actuators (e.g., buttons and LEDs) were used. Several databases, server services and software libraries were utilised in the projects.

Prototype analyses and semi-structured interviews were conducted as part of the study. We developed seven questions, and we employed them to initiate the conversations around the creation of the students' prototypes. Questions were designed to investigate the technologies and tools used in the projects, the degree of knowledge with which the technologies and tools were applied, and the development of solutions to problems regarding the composition of the technologies. Each interviewee was also asked to draw a functional diagram of the system on paper, emphasising the techniques used to connect the various parts. Nineteen out of the 57 students who responded to our email volunteered to be interviewed. Eleven participants were men, and eight were women; their ages ranged from 23 to 27. Every respondent had a single in-person interview in the studio, lasting from 40 minutes to two hours. With the participants' consent, all the interviews were videotaped; the researchers also took written notes.

We transcribed and arranged all the audiovisual material. All the information concerning the methods, equipment and technologies employed to build the prototypes was highlighted. We analysed the interviews through thematic coding. To make the assertions easier to identify, we coded each text segment by adding one or more keywords to it. Instead of starting with pre-developed codes in mind, we employed data-driven coding. We started with no codes and created them as we gained an understanding of the subject matter. To capture the entirety of the experiences under study, we combined the coding and the created categories. We categorised the coding to measure the frequency with which particular topics were addressed. This frequency was then contrasted and associated with other themes. A saturation of substantive understanding and interpretation resulted from our shift in focus from a descriptive to a more theoretical level during the analytical phase. The data's reliability, as well as the discrepancies among the data examples, was continuously assessed.

3 FINDINGS

University students of design must choose appropriate technologies to construct prototypes of interactive artefacts. This study shows that the primary factors influencing their choices of technology were its unique features, availability and popularity in the socio-technical practice setting. The participants selected the technologies they would use for their projects early in the design process. During four major prototype-interaction milestones, each lasting roughly two weeks, we saw that the participants' study of various technologies and tools developed over time (Figure 1). The four milestones were the expert-day presentation, the MK1 and MK2 prototypes, and the final prototype. After finishing each prototype iteration, the students presented their works to the panel of tutors, who had backgrounds in computer science, cognitive science, design, engineering, psychology and crafts. During the early stages of concept generation, the course's instructors encouraged the participants to think about the tools and technologies they wished to use to build their prototypes. During these sessions, the students received guidance on enhancing their prototypes in terms of design and user interaction. In an early presentation to professionals, the participants shared their ideas for their projects and the technology they intended to use. When the students began using technology, they frequently began with well-known platforms (e.g., Processing and Arduino) because they were more at ease with them and believed that using them would teach them to respect other technologies. Some of the first widely used technologies for physical prototypes were Arduino, Processing, basic sensors and actuators. In the MK1 phase, the students had to create mock-ups that looked at basic materials, tools and technologies. In terms of technology and user interactions, this phase still lacked clarity and resolution. At this stage, the students evaluated the use of technology for personal advantage. During the MK2 phase, materials, technologies and procedures that were more advanced and refined than those employed for MK1 were employed to produce the artefacts and the intended user interactions. This resulted in more sophisticated design decisions and interactive outcomes. During the MK2 phase, which included the creation of the prototype architectures, the primary functionalities of the prototypes were determined. At this stage, it was evident that the participants had come up with a variety of creative solutions to address the technical difficulties encountered during the design process. The technologies and materials used for the MK2 prototypes were significantly enhanced in the final-prototype phase. In this phase, the technologies, materials and interactions were fine-tuned and constructed to provide the most genuine and natural user experiences. The tutors judged the final prototypes during the students' formal presentations.

The tutors offered considerable help to the participants when they had to choose their technologies, especially when it came to building and configuring the components. For example, A1 said that he received permission to purchase the two components that were most crucial for their project thanks to the tutor: *"Every time I had to buy something, I just went upstairs and asked him [the tutor]."* A9 had the following to say: "*I bought this [a Bluetooth module], and he said, 'Come in when you get it.' He showed me how to set it up."* Moreover, the instructors furnished necessary materials, as indicated by A8: *"He gave me some electronic parts. Here is a player for the SD card."* A4 offered the following example: *"He ended up having some copper tape, which was great. So, I moved to that, and I think I have a part. It is like a tape with strips of copper."* (Figure 2) These quotes highlight the importance of the tutors' guidance

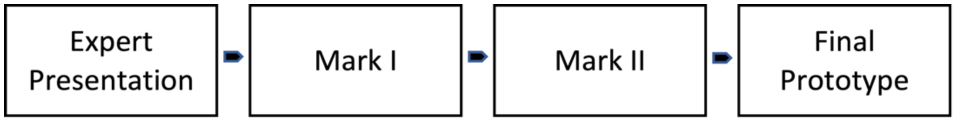

Figure 1: Design Process.

in assisting the students when they had to select the technologies they wanted to use.

According to our research, the adoption of new technologies in a community of practice can depend on their availability (including commercial availability) or on reverse-engineering processes. The students believed that the most popular technologies were the most appropriate for developing interactive prototypes since they were more frequently used in communities of practice. For example, A7 said, *"I could have used another micro. There were a lot of things I could have used, but I knew I had that [Arduino], and if I got stuck, I would get support. There are tons of projects. If one part of the project gets stuck, you find the answer."* A14 explained the following: *"I found that one [a pulse sensor], and I went with it. I bought two. I just tried them, and they work very well. I can't really find many others."* (Figure 3). A1 stressed that the decision-making process was also influenced by the commercial availability of the technologies: *"There is a website called Cool Components, and I knew that it sells Arduino and all the shields and the speakers. I go on the website and look at what is available, so I know what I can work with."* According to A16, the reverse-engineering technique occasionally determined the choice of technology. This participant found the most important components for his project by taking apart a shake lamp. As these excerpts demonstrate, design students' choices when building their interactive prototypes are influenced by the increasing usage of technology in education and communities of practice.

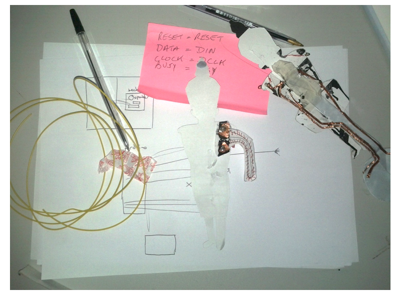

Figure 2: Copper tape explorations (A1).

Figure 3: Pulse sensor (A14).

To build interactive prototypes, it is necessary to understand the technologies' primary features; in particular, their circuit and communication qualities are essential for developing interactive systems. The words of A9 show that several technological features meant for communication were not as successful as the participants had thought. *"I did have an application called Amerino, which you need for the Bluetooth module, and the Bluetooth site was ok. I think I could get it to do something on my tablet, but I don't think I could constantly listen to the value changes..."* According to A14, a microcontroller could not speak to another microcontroller using a serial connection: *"With that one [Gemma], it's mostly about the serial. In the serial of the [Arduino] Uno, I can see exactly the values coming in from the sensors."* However, in other cases, communication means that were deemed elementary proved to be unexpectedly useful in developing the prototypes. As A7 explained, *"I choose radio frequencies instead of Wi-Fi because they are smaller and easier."*

A4 stated that contrary to what she had first believed, a number of the technologies used in the development of the electronic circuit were unsuitable: *"While making the prototype, I discovered that conductive ink didn't actually work. When the pup up was like end and stand up would break the circuit of the conductive ink."* However, in other cases, fundamental characteristics were surprisingly suitable for developing the interactive prototypes. As A7 said, *"So, it [microphone] is accurate, but not terribly accurate. It registers analogue values, but it doesn't register sound. You can use it for audio recognition, but it's not very good at it. Still, because it could really do audio detection, it made me feel that it was less intrusive."* A14 explained that his microcontroller supported both a 3.3-volt output and a 5-volt output. *"So, this [Gemma] has a 3.3-volt output. I don't know which component it is, but it steps up to 5 volts."* These examples demonstrate how some elements that were initially thought to be necessary were found to be insufficient for developing the interactive prototypes, while other features that were thought to be unnecessary were found to be useful.

4 DISCUSSION

Design students' choices of technologies to create interactive artefacts or system prototypes may vary depending on the availability and popularity of a board or component. Furthermore, taking apart a product to discover how it is made may have an impact on the components that students choose to use when creating interactive artefacts or systems. Students' choices of technologies for prototyping interactive systems or artefacts are also influenced by the guidance of tutors.

These results are consistent with those of previous studies. [5, 7, 8, 16, 18, 19]. Our study adds to this body of knowledge by demonstrating the significant influence that technology and tutoring have on design students' choices of components. This suggests that it is important to begin equipping university students of design with the most fundamental technological skills and selection tactics to help them build critical awareness for the informed use of maker technologies. Educators should teach students about electronic and computational ideas, as well as how to identify and locate boards, parts and artefacts for disassembly. Current technological developments should also be taught. When building prototypes of interactive artefacts or systems, the electronic and communication properties of boards and components may have an impact on the decisions made by design students.

Contextualising the electrical, physical and sensory features of the components with the imagined coupled materials and imagined ambient settings of use would be beneficial for their integration. These findings align with prior research [3, 4, 6, 9, 16] that has detailed how teachers' choices of technology are influenced by component compatibility and ease of interface. Our study contributes to this understanding by elucidating how circuitry and communication properties influence the boards and components that design students choose to utilise in the construction of interactive artefacts and system prototypes. The results of our study suggest that students should acquire the electrical, electronic and physical skills necessary to make informed decisions when selecting technologies. Moreover, teachers should discuss with students the advantages and disadvantages of the electrical and physical aspects of toolkit systems and breakout boards. Furthermore, the designers of toolkits and breakout boards should provide students with access to complete documentation as well as examples and illustrations of how specific protocols for sensors and actuators interface with different platforms (e.g., Arduino and Raspberry Pi). They should also explain the features of the components with concise contextual information. Engineers who invent sensors and actuators should clarify the sensors' sensitivity in an intelligible manner and offer examples of electrical connections or combinations with materials and physical learning environments [20, 21].

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