Senior-meter: A Hands-on Intuitive Approach to Teaching Electronics and Data-Driven Design to Undergraduate Students

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Abstract. This paper presents the development and implementation of a novel pilot course for undergraduate design students, with a focus on the integration of electronics and data-driven methodologies within the field of design. The course was structured around a real-world project that addressed the challenges encountered by senior individuals. It incorporated user-centered design principles, sensor-based data collection, real-world deployment, and data-based design assessment. The results demonstrated the successful application of data-driven methods, and an appreciation by students for the empirical foundation in design decisions. The pilot confirms that data-driven approaches can be successfully embedded within an undergraduate design program, offering valuable insights for educators interested in pursuing such integrative pedagogical methods.

Keywords: Data Driven Design, Interface Design, Physical Computing, Design Analytics, Design Engineering.

1 Introduction

In recent years, numerous industries have been disrupted and reshaped by the emergence of data-driven methodologies. The capacity to gather, analyze, and interpret vast volumes of data has heralded a new paradigm that emphasizes the use of empirical evidence in decision-making (Davenport & Patil, 2012). The field of design has not remained immune to this transformation, with examples now available across nearly all faces of design, from graphic design (Thornton, 2015) and product design (Feng et al, 2020), to architecture (Deutsch, 2015) and engineering design (Liu et al, 2022).

However, teaching these methodologies to undergraduate design students can be challenging due to the technical skills required, the analytical mindset necessary, and the limited availability of manageable real-world datasets suitable for beginners. As a result, data-driven approaches are often confined to graduate or specialized programs, despite the pressing need to equip young designers with these vital skills to meet industry demands.

To address this challenge, a pilot course was developed combining an overarching data-driven design approach with more familiar tools and processes for design students. This paper describes the pilot course structure, methods, outcomes, and post-hoc reflections, aimed at providing insights and guidelines for educators interested in implementing similar programs.

2 Methodology

2.1 Course context

The pilot was implemented by adapting an existing course on Interface Design within the undergraduate Design Engineering program at Universidad Adolfo Ibañez in Santiago, Chile. Based on the program curriculum, the course was formally focused on methodologies for designing and constructing physical computing interfaces from a user-centered perspective. This course was preceded by an introductory course on applied electronics where students learned to design and construct circuits using Arduino. The students were also trained on 3D modeling, digital fabrication, and design theory.

The course was co-instructed by a multidisciplinary team of professors composed by an electric engineer with expertise in electronics; a visual artist who specializes in digital interfaces, and an architect focused on data-driven design.

The course adopted a hybrid format, blending theoretical lectures with practical design studio activities. The time commitment for students was 3 chronological hours per week. About 40 students participated in the 16-week semester.

2.2 Course design and methods

The course was structured around a hands-on, real-world design project, with all lectures and practical activities tailored to support the progressive stages of project development. This was a usual approach in the design engineering program, making it familiar territory for the students.

The primary goal of the project was for students to design, fabricate, and test a product or service that addresses a challenge or issue encountered by senior individuals. The overall motivation of the project was the social phenomenon of population ageing, a topic that has been extensively documented in the literature (IAHSA, 2014).

To guide the data-driven design process, the project was divided in five phases:

In the first phase, students were introduced to the principles of user-centered design, and they were tasked with identifying challenges faced by the elderly using interviews, photographs, observations, and other qualitative data collection methods. Most of the students selected their grandparents as case study participants. Their findings were presented in class for open discussions with instructors and other students. By the end of this phase, students made groups of 3 or 4, and chose one particular issue they believed to be significant and wanted to explore further.

In the second phase, students were asked to design and build an electronic device equipped with sensors to sense, document, and describe quantitatively their chosen issue. This marked a significant shift from the traditional design process, where they would have immediately started by brainstorming potential solutions. Instead, they were asked to focus intently on the problem, defining one or more metrics to measure the extent of the issue appropriately, and developing custom sensing devices capable of gathering the empirical data. All devices were constructed using ESP32 boards and readily available off-the-shelf sensors, putting the emphasis on the device's ability to gather meaningful data, rather than in the technical intricacy of the electronics.

In the third phase, students deployed their devices to gather real-world actual data from their elderly case subjects. This involved installing the devices in the homes of the seniors and ensuring they worked properly. All senior participants consented to the data collection. All devices were connected to the internet, and students utilized the Arduino Cloud platform to remotely oversee the data collection process. The duration of data collection varied depending on the specific nature of each issue. After collection, students employed standard data analysis tools to interpret the results and subsequently presented their findings in class for collaborative discussions with instructors.

In the fourth phase, students were tasked with designing a solution to address the identified issue, either a product or a service. The solution could be as simple or complex as they deemed necessary based on the data collected. Regardless of the nature of the solution, all students were asked to provide a clear rationale as to why their proposed solution was relevant, how was it informed by the collected data, how was it tailored to the specific needs and challenges identified, and how it would make a significant impact on the identified challenge. Then, students were asked to prototype their solutions. Most students designed physical products and employed rapid prototyping tools available at the university.

Finally, in the last phase, students were requested to implement their product and use the same electronic device built in phase 2 to assess the effectiveness of their product in solving the identified issue. For this, students returned to the senior users to offer them their product or service for a test period while some data was being collected. Finally, students presented their project, findings, and overall data-driven process.

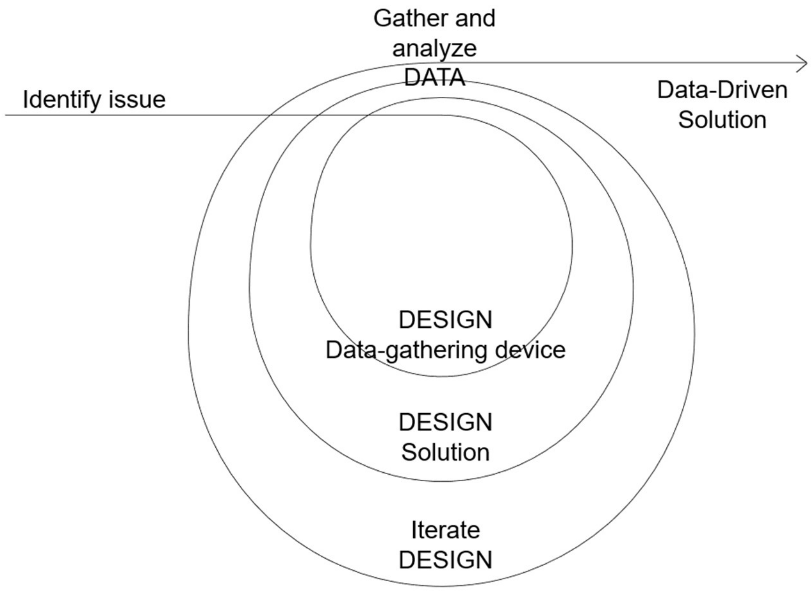

Figure 1. Closed feedback on data-driven design approach. Source: Own elaboration.

2.3 Pilot assessment

Throughout the course, students were evaluated based on their engagement, the robustness of their data collection devices and methods, the utilization of the data leveraged, and the creativity and relevance of their proposed solutions. Peer review and feedback were also incorporated at various stages to foster collaboration and critical thinking.

Additionally, mid-course and post-course surveys were implemented to gather feedback from the students regarding the course approach, data-driven methods, and overall learning experience.

3 Results

3.1 Project outcomes

The projects undertaken by the students addressed a broad spectrum of physical, social, and psychological challenges experienced by the elderly. A few exemplary issues and projects are the following:

- **Mobility Challenges:** Teams identified seniors experiencing mobility issues, particularly at night or when alone. Devices tracked transitions from bed to bathroom and time spent seated versus walking. The designs incorporated chairs to facilitate bathroom trips and canes equipped to detect falls.

- **Medication Adherence:** Recognizing that some elderly individuals often neglected medications, a team created a smart pill dispenser that counted the openings. Their solution involved an electronic alarm to remind users of medication times.

- **Excessive TV Watching:** One group observed that their elderly participants watched TV excessively, occasionally with the sound off. A custom measuring device utilized sensors to track the duration the television was on, volume level, and viewer movement. The response was a device encouraging alternative recreational activities.

- **Sleep Deprivation:** Students documented inconsistent sleep patterns and a lack of sleep hygiene. They used environmental sensors to track room conditions and bed sensors to monitor sleep movement. Their solution encompassed an ambient device that played soothing sounds and adjusted room lighting to enhance sleep.

- **Sensitivity to Hot Water:** The identification of some elderly individuals' lack of sensitivity to hot water, leading to potential scalding, prompted monitoring through water temperature sensors. The design featured a faucet attachment that changed colors in line with water temperature, providing a visual safety guide.

- **Unattended Active Appliances:** Students found that heaters or stoves were frequently left on unnecessarily for extended periods. They addressed the issue by monitoring energy consumption and flame activity. The design included lights and alarms that activated if a stove remained on, or unattended for an excessive time.

- **Neglecting Hydration and Nutrition:** One group identified dehydration as a significant concern and subsequently devised a smart water bottle that tracked fluid intake and issued reminders. Another team detected infrequent food intake through kitchen and refrigerator monitoring. Their solution was a device that released appetizing scents to induce hunger.

- **Social Isolation:** Utilizing household activity sensor data, social isolation was identified as prevalent. Indicators such as rare door openings and phone calls served as evidence. To mitigate this, students designed a community engagement app specifically for the elderly, fostering group activities and local community meet-ups.

Figure 2. Images of some measuring devices designed by the students. Source: [omitted for blind review]

Figure 3. Images of some measuring devices designed by the students. Source: [omitted for blind review]

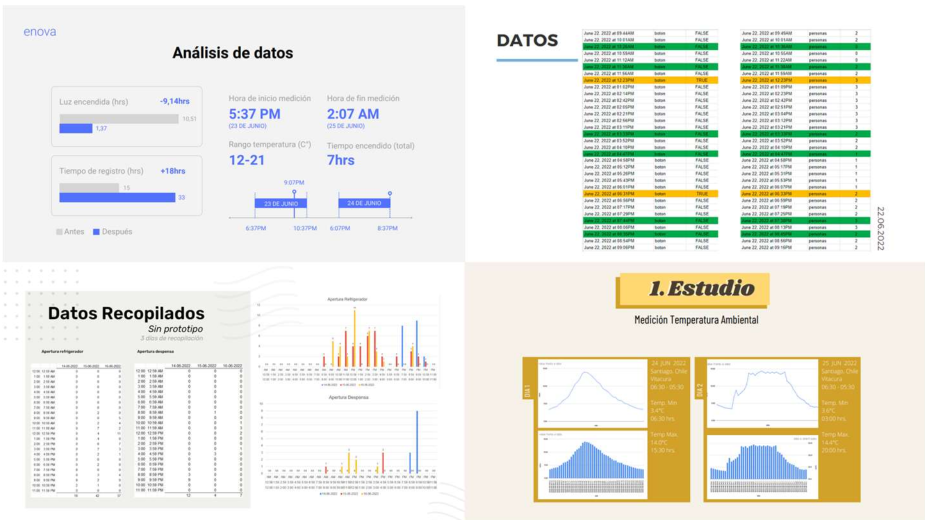

Figure 4. Screenshots of some of the quantitative analyses conducted by the students. Source: Omitted for blind review.

3.2 Student experiences

In general, students valued the overall data-driven approach. The survey responses indicate that students significantly expanded their understanding of data-driven processes and their practical value for design. The students also pinpointed some of the problems or limitations of this strategy. For example, some student comments:

"[Data-driven methods] allow us to corroborate the assumptions we have about the real world and people, and then approach the problems that affect us in a much more effective and precise way, thus creating projects that have a measurable impact, all based on verifiable information."

"I believe that [data-driven methods] greatly benefit the designer when carrying out a project, since the data and its correct analysis allow for constant feedback in real time and reveal the true needs and optimal strategies to develop the project."

"I think the use of these techniques is good, since in the end, what validates that a product works is hard data. This strategy allows us to prototype and evaluate based on concrete information to know if it is working or not."

"I think that [the data-driven approach] is a good strategy as it eliminates possible biases. However, it is very important to have the abilities and knowledge to correctly interpret the results."

"I believe that [the use of data-driven design methods] can be somewhat hindering when it comes to introducing creativity; I feel that it somewhat limits creative design. I struggled to fall in love with my project."

"Although in general, measuring quantitatively is beneficial for a design as it allows an objective analysis of the situation, there are possible scenarios that are not so pleasant that may occur with the misuse of automation and big data."

4 Discussion

In general, the projects demonstrated how students effectively utilized data to identify, validate, and address challenges. The diversity of issues, topics, and types of data collected was surprising even to the students, who appreciated the varied themes and solution approaches.

Initially, the students encountered difficulties in understanding the data-driven design process, particularly the role of the data collection phase. This methodology was not only unfamiliar but also distant from their traditional understanding of design. However, post-course reflections revealed that students were able to grasp the approach and value the empirical foundation of their design decisions.

While the use of data was generally appropriate, in some instances, the analysis of the datasets was superficial. This was mainly attributable to the fact that some students lacked advanced quantitative analysis skills. As some comments pointed out, the success of the data-driven approach depended on the ability to accurately interpret the collected data, and deficiencies in this area could be a significant obstacle.

The employment of Arduino boards and the Arduino Cloud platform was well-suited to the students' technical preparedness. The technical complexity associated with creating and deploying custom sensing devices presented a significant challenge for some. On certain occasions, the difficulty of managing wireless data and the unreliability of the network in the homes of the elderly participants had a negative impact on data collection. It is worth emphasizing that such technical demands can sometimes overshadow the central design focus, so careful consideration is needed to ensure that technology supports rather than dominates the design process.

The opportunity to engage with real-world challenges was cited as a valuable aspect of the course. Students felt a sense of responsibility and purpose in their design work, making the experience more authentic and meaningful. However, the specific emphasis on the elderly population felt remote and less inspiring to some students.

An important point to highlight is that some students expressed concerns regarding the potential constraints that data-driven methods might place on their creative design processes. This apprehension is understandable and, in fact, echoes an ongoing academic debate around the interplay between data-driven approaches and intuition in the design process. While this is not a resolved issue, learning experiences such as the one described here enable students to firsthand explore this creative tension.

In conclusion, the pilot course, albeit experimental, affirmed that a data-driven approach can be successfully incorporated within an undergraduate design program. Students were capable of developing, deploying, and analyzing data from custom-made devices, leading to the design and execution of real-world solutions. By melding hands-on projects, accessible tools, and a systematic approach, undergraduate design students can effectively cultivate a robust understanding of data-driven design methodologies and recognize their practical utility for decision-making in design. Furthermore, the favorable results of this pilot course endorse the inclusion of data-driven strategies in undergraduate curricula, thereby equipping future designers with essential skills that will be progressively needed in the coming years.

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