Data-Enabled Design: Hands-on Teaching Activities to Onboard Design Students in the Use of Sensor Data as a Creative Material

CARINE LALLEMAND [1,2*], ROY VAN DEN HEUVEL [1*], LOES VAN RENSWOUW [1], SANDER BOGERS [3], PEPIJN VERBURG [4], CAROLINE HUMMELS [1]

[1] Eindhoven University of Technology, Industrial Design Department
[2] University of Luxembourg, Human-Computer Interaction Research Group
[3] Philips Design, Data-Enabled Design
[4] Bureau Moeilijke Dingen

* Both authors contributed equally to this work / Corresponding author: r.v.d.heuvel@tue.nl

This contribution presents two hands-on teaching activities introducing the use of sensor data to design students. We designed two sequential workshops to educate on why and how to use data as a creative material in the design process and provide students with the technical means to quickly prototype connected data-collecting probes. Workshop 1 (Human Sensors) consists of a role-play exercise where teams of students simulate the collection of data in-situ by acting out various sensor types. In workshop 2 (Coffee Cup Challenge), students build their own data-collection artefacts using sensors. Modular, both activities can be adapted to any similar course that uses sensor technologies and data to conduct user research and extract insights to be used in the design process. We describe the activities in detail, provide generalizable materials, and reflect on their use, supported by student reflections and insights from our teaching practice.

CCS CONCEPTS • **Human-centered computing ~Interaction design ~Systems and tools for interaction design**

Additional Keywords and Phrases: Data-Enabled Design, Physical Computing, Sensors, Design Education, Pedagogical Method.

ACM Reference Format:

Carine Lallemand, Roy van Heuvel, Loes van Renswouw, Sander Bogers, Pepijn Verburg, Caroline Hummels. 2022. Data-Enabled Design: Hands-on Teaching Activities to Onboard Design Students in the Use of Sensor Data as a Creative Material. In *4th Annual Symposium on HCI Education (EduCHI'22), April 30–May 1, 2022, New Orleans, LA, USA*. ACM, New York, NY, USA, 12 pages.

1 INTRODUCTION

Interaction design students are usually introduced to classical user research methods (e.g., surveys, interviews, or diary studies [11]) to investigate users' motivations and needs, as well as the context of use. However, physical computing and sensor data are playing an increasingly important role in design, offering a myriad of opportunities to enrich the design process and outcomes. For instance, it can support the investigation of user behavior over prolonged periods of time or in a non-obtrusive way or provide contextual and behavioral data to triangulate with self-reported experiences. Where most existing design approaches consider data as plain output that can be evaluated, we postulate that data can be seen as a creative design material that can enrich the user research and design processes in more open ways [6]. Introducing students to physical computing and teaching them to see and use sensor data as a creative material in a design process is a challenging endeavor, requiring a new mindset and new skills, both engineering and methodological-wise. By collecting and playing with real data, students can start understanding the richness and nuance of real life through that data, and use the data and insights later on during their design process.

Over the past few years, several creative pedagogical methods and tools have been developed to help teach the design of interactive, data-oriented products, services and systems. Boer and Bewley [1] shared their practice of teaching physical computing through 'smörgåsbords', boards that display collections of physical computing components available in-house, in an organised and interactive way to support the initiation of interaction design projects. This works well due to their practical and hands-on approach. Similarly, Zheng showcases the design of custom toolkits to teach design students about technology integration [13]. These approaches work great for scaffolding quick prototyping but are quite specific to tangible interactions. The focus on data collection and connected digital interactions requires students to also learn to deal with sensors, data-processing and connecting to cloud-based platforms.

In this contribution, we share two hands-on teaching activities that can be used to introduce interaction design students to the use of sensor data as a research- and creative material in the design process (inspired by the Data-Enabled Design approach [10]). These teaching activities are hands-on, modular, and are aligned with current trends in experiential and challenge-based learning. They can be adapted to any similar course that uses sensor technologies and data to investigate users' needs and use contexts to gather design insights. We describe the activities in detail, provide transferable teaching materials and reflect on their use, supported by student reflections on the course and insights from our teaching practice.

1.1 Learning Objectives

Personal informatics models [8] have an increasingly important influence on design processes. Such models are often implemented with stages of data-collection, visualization, reflection and action [5]. They enable designers to gain a deeper understanding of user behaviors through data and consequently develop more effective interventions. Inspired by these models, the HCI community has developed processes where interventions are not just directly derived from data (data-driven), but rather created by using data as a creative material in the design process [10] (data-enabled). Through our earlier experiences of teaching physical computing and especially data-enabled methods to students, we found that students have difficulties to come up with simple ways of collecting data and can be intimidated by the technical implementation of making their own sensing devices. We developed two hands-on workshops to change students' minset about data, and support them early in the design process to both develop tangible engineering skills and methodological experience.

Our workshops are based on the Data-Enabled Design framework (derived from [10]), which consists of a double loop. Following the first 'everyday life' loop, students learn how to collect data about the user context and use of products through ecosystems of sensors. The objective is to get students familiar with different ways of situated data collection on human behaviors. In the second 'design-research' loop they are asked to make sense of the collected data in order to derive insights which will be used as ideation material. Through this, they also learn the limits of what sensor data can tell us about the world, and how they might use qualitative user input to draw a richer picture of the context. By introducing students to the benefits, challenges and limitations of using data as a creative material in the first workshop, we hope to change their mindset about data by providing hands-on experience that helps them steer their design process. In the second workshop, we teach them to quickly prototype connected data-collecting probes, to kickstart their design process. We discuss the teaching activities presented using student feedback collected after the course.

1.2 Institutional Context

The activities we described were conducted at the Eindhoven University of Technology (Industrial Design). Squads are learning and research communities where students, scientific staff, experts, and industrial partners work together on projects in a specific application domain. The Vitality Squad has expertise in the design of interactive systems for preventive health and wellbeing, with some members conducting research projects around Data-Enabled Design [2,7] and sensor kits for office vitality [4,6,12]. Student projects typically run for one semester, with key milestones and a final design exhibition. Guided by a coach, students receive a project brief and learn to conduct user research, extract insights from different sources to ideate and conceptualize, create prototypes and conduct user studies to evaluate their designs iteratively. During the semester, we conduct a variety of pedagogical activities (e.g., workshops, lectures, site visits, inspiration shots) supporting students' design processes. We mainly rely on creative, hands-on workshops to let students explore specific design(-research) techniques. This Teachable Moment contribution focuses two of these activities.

2 TEACHING ACTIVITIES

2.1 Workshop 1 – Human Sensors (3 hours)

Workshop 1 introduces students to the potential of sensors in user research and ideation, through a data-collection and sensemaking exercise, without needing any technical skills. It aims at bringing awareness on what data sensors can bring, how to select and calibrate them adequately to gather insightful data and how to eventually use sensor data as a creative material in the design process. In this activity, students are invited to act out scenarios in a living lab; a fully equipped 'home', with living room, kitchen, bathroom and bedroom. This location is the context of the 'everyday life loop' of the data-enabled design model. The workshop can take place in any setting, as long as it mimics a 'real', everyday situation. The workshop is organized in 3 main stages (Figure 1), with short breaks. We describe the workshop as we conducted it, but most elements, like the design brief, size of the teams and the setting are customizable to the needs of a lecturer.

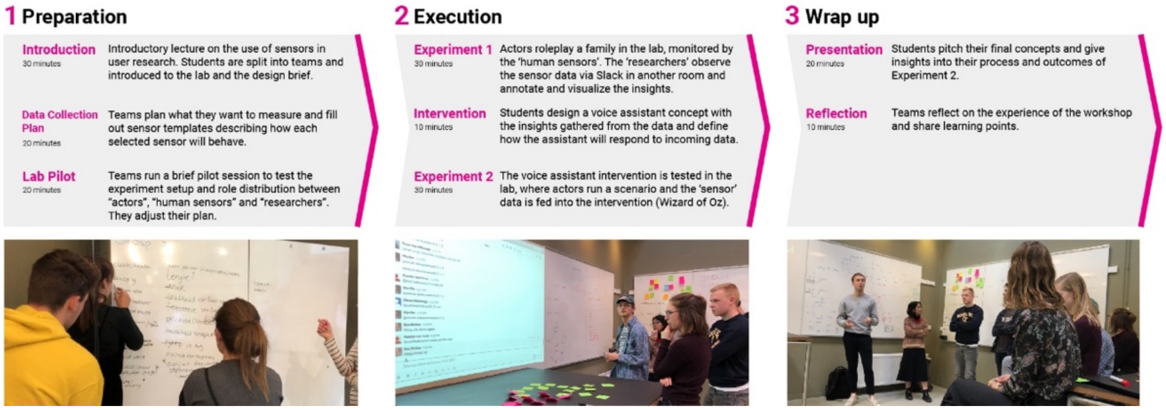

Figure 1. Overview of workshop 1 including the stages and activities.

2.1.1 Introduction: Instructions and Distribution of Roles

At the start of the workshop, students are welcomed in the lab and given a 20-min introductory lecture on Data-Enabled Design including examples how the method has been used in real case studies [3]. Then, students are split into teams of 6 and instructed on their first assignment. The design brief focuses on the design of an intelligent voice assistant that helps people to take care of themselves. The context is a family home setting. Within each team, part of the students are assigned to the role of being a human sensor in the living lab, while others act as the design researchers gathering and analyzing the sensor data in a separate room (Figure 2). Moreover, a few students are the actors, playing the family members. In case one has access to additional lecturers or teaching assistants, these people can playing the family members.

The roles and tasks are the following:

- *Design researchers*: prior to the experiment, the research team defines what sensor data will be collected and create sensor mission sheets. During the experiments, they gather the sensor data sent by the human sensors via the messaging platform and represent and/or analyze it to extract insights.
- *Human sensors*: observe and manually log events and share them through chat with the research team
- *Actors* play the role of family members in the lab and freely act out a variety of family situations

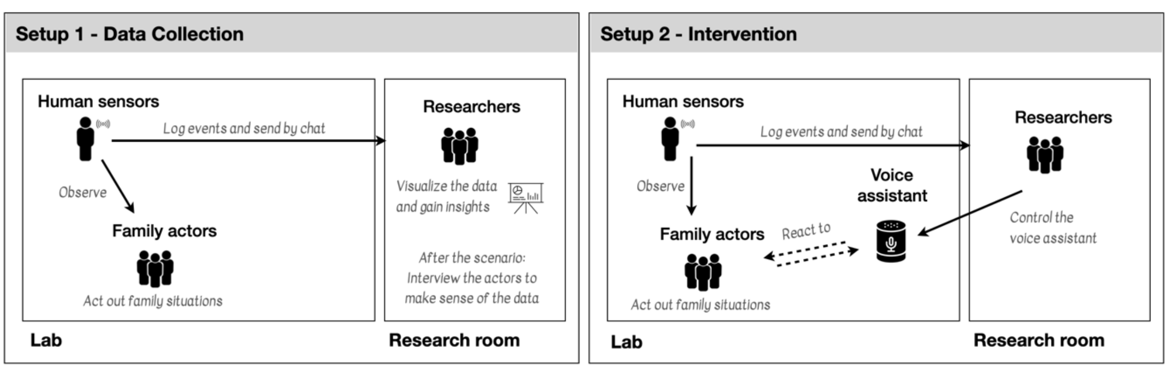

Figure 2. Workshop setup for experiment 1 (data collection) and 2 (design intervention)

2.1.2 Data collection planning (20 min)

Before the role play starts, the entire team is asked to sketch an initial plan for what they want to measure in the living lab and why. For example, they can be interested in how users use multimedia devices or how users interact with furniture when given a certain task. Noteworthy here is to let students anticipate the knowledge that they expect to gain through sensor data. A sensor can for instance measure when and how long the TV is turned on, but not what programs are being watched. Based on this initial plan, each team comes up with several sensors that they deem interesting to deploy. They then selected the most insightful ones to be deployed in the lab and filled out a sensor mission card for each (Figure 3). The sensor mission card defines what type of sensor is deployed, what measurement is made, and at which calibration level. The team distributes the sensor plans to the human sensor subgroup (ideally from another team, so they have no knowledge on the research goals apart from what is indicated on the mission card) by making it manageable for a single person to report on the number of events requested. Let's imagine that a student represents a TV power sensor: they monitor TV activity, sending the 'sensor' data (TV on or TV off) to a dedicated messaging channel using their phone (Figure 3).

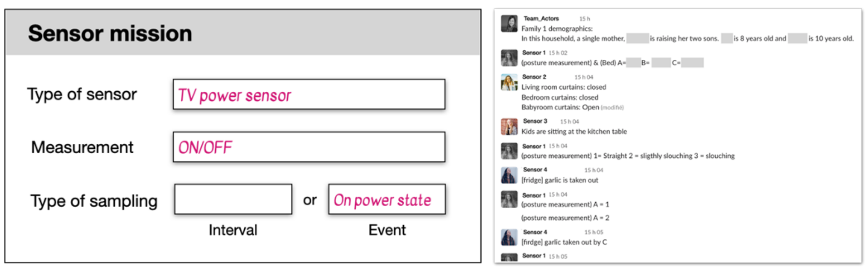

Figure 3. Sensor mission card (left) and sensor output sent by the human sensors on the messaging channel (right)

2.1.3 Lab observation pilot test (10 min)

Before the students run the main experiments, we first do a brief pilot session to test the experimental setup. All human sensors move into the home lab to observe the 'families' and use the messenger app to transmit their data to the researchers. They then reunite with their team to discuss what went wrong and what can be adjusted before starting the experiment. Key problems identified during the pilot test were usually linked to calibration or sensitivity of the sensors, with some events being too scarce to be meaningful during the short duration of the experience, or too frequent and overwhelming for the human sensor to keep track of them. Other problems were about data modelling, structuring and what semantics to use in the communication protocol. Interestingly this shows strong similarities when working with the actual technologies.

2.1.4 Experiment 1: Data collection (30 minutes)

The teams are now ready for their real data collection experiment. Since interpersonal (family) differences are a key source of inspiration revealing the common denominators and individual uniqueness, the actors will portray three different families, each family being in the lab for 10 min.. The human 'sensors' are deployed and report to the researchers via the messaging app (Figure 3). Based on the data collected by the 'sensors' in this experiment, the remote researchers try to sketch a scenario and deduce what is happening inside the home. Students typically plotted data points under the form of graphs to make sense of it. At the end of the session, researchers have the opportunity to interview the 'families' (actors) about their experiences during the experiment, using the data collected from the sensors. For instance, inquiring who in the family is watching TV or who is usually brushing their teeth less than the recommended time. At the end of this step, the team has collected insights about the behavior of their users in context, which they can use to design an intervention.

2.1.5 Intervention Design (10 minutes)

The team conducts an ideation session to design a concept of voice assistant that can play a meaningful role in the lives of the family. An example is a voice assistant helping you to adopt a healthy sleeping routine. Based on this, the team must decide how the voice assistant will respond to different types of 'sensor' input. The sleeping routine assistant can for instance suggest stopping viewing screens 10 minutes before recommended bedtime.

2.1.6 Experiment 2: Test intervention (30 minutes)

The family members (actors) and human sensors return to the home lab and roleplay the situation with the intervention triggered by the design students acting as researchers. Teams can now explore (although superficially) the experience of their intervention, using a remote-controlled Amazon Alexa to send the voice assistant's spoken feedback, based on the collected 'sensor' data as input. We did not include an additional debriefing interview with the family member at this stage, but we emphasized that this would be again needed to triangulate and make sense of the data from this intervention stage.

2.1.7 Presentation and Reflection (30 minutes)

After experiment 2, the student teams refine their concept and prepare a 2-minutes pitch to describe their final concept and share reflections on the experience with the entire class.

2.1.8 Insights from students' reflections

In the first workshop "Human Sensors", the main goal was to introduce students to the use of gathering sensor-data in a real context and what insights they might derive from it to design meaningful interventions. By acting out as 'human sensors', students have learnt about the limitations of sensors (e.g., numerical data does not show emotions) or the calibration (binary on/off states or multiple options of use?). As one student notes: "*You have to set clear boundaries on what you want to know and leave out the rest*" (EL). Sensor data can also quickly be overwhelming due to its volume and pace, requiring the team to filter what is relevant: "*It was difficult to keep track of everything that was happening.*" (EL). For most students, the workshop was the first time where they were using data as a creative material in their process: "*Seeing live data come in about a situation involving users in an everyday life context was new for me. I only worked with saved data before.*" (LU). This observation of live data helped students 'debug' the 'sensors': *"You can immediately see if something goes wrong when no data comes in."* (LU). In understanding how people behave around an intervention, students recognized the benefits of access to live data: *"An advantage is that you still see a lot of spontaneous reactions, you see their immediate responses to IoT devices (e.g., Alexa output)."* (LU).

2.1.9 Insights from teachers' reflections

As lecturers, we enjoyed the hands-on and engaging way of teaching, especially for students with no experience in sensors or a low level of understanding of design processes. We believe that such an implementation of Kolb's cycle of experiential learning [9], where one starts a project with a concrete experience is important in a hands-on field as HCI.

The experience also builds well towards Workshop 2 (and eventually their own project within the course), where students after reflection, conceptualization and experimentation can apply what they have learned in a new situation.

The simplicity of the workshop was key in letting students focus on the intended experience and the role of data in a design process. We purposively got rid of the technical complexity and 'fear of technology' that sensor technology inspires in order to make students enthusiastic about the opportunities of this approach. Although simple in technical feasibility, students still were triggered to ask the right questions about data, such as the types of sensors, data fidelity and volume, and the (im-)possibility of measuring subjective experiences. This practical introduction into the complexities of using sensor technology opened their eyes to the power of combining quantitative and qualitative data. Acting out a single sensor was fairly easy, but when making the transition to a multi-sensor ecosystem that needed to work together it was more difficult to work out how different things interact. Often this required a high degree of focus from all group members. Making the transition to multi-sensor ecosystems is crucial in understanding relations between data where nowadays many of our products rely on.

We initially aimed to compress the workshop in ~2 hours, but that resulted too often in us cutting short on interesting discussions. A ~3-hour workshop is a more comfortable format. Additionally, the situations acted out were often too playful and cliche, and it is difficult to detect many patterns in a situation that you only observe for 10-15 minutes. Providing the family members actors with some sort of a script (where we would deliberately include some identifiable patterns) and perhaps representing chunks of a day in a fast-forward fashion might help. Lastly, conducting this workshop in collaboration with industry was an asset, as students could see the practical and business value of implementing certain design processes to design products that were later put on the market.

2.2 Workshop 2 – Coffee Cup Challenge (5 hours)

The second workshop introduces students to building their own connected sensors and data-collection artefacts. After the first workshop, students are more familiar with the use of data as a creative material in the exploration of a user context, so the second workshop focuses on the required prototyping skills to construct their own sensors. In their project, students often need custom sensors to observe something specific to their design brief. Through our experience in HCI education, we have often seen that students experience a high threshold (and/or fear) towards the use of sensors and the technological skills required for building their own probes. This often leads to design projects that use technology towards the realization of the final prototype, rather than as a means of inquiry throughout the design process.

The main goal of this workshop is to demystify the making of connected (IoT) systems, data-collection and sensor components. At the same time, the workshop aims to stimulate collaboration and students supporting each other as a result of a shared knowledge of the technology and the data-enabled design approach. The workshop alternates between hands-on activity and brief lectures explaining the next steps (Figure 4). We recommend short breaks between the stages.

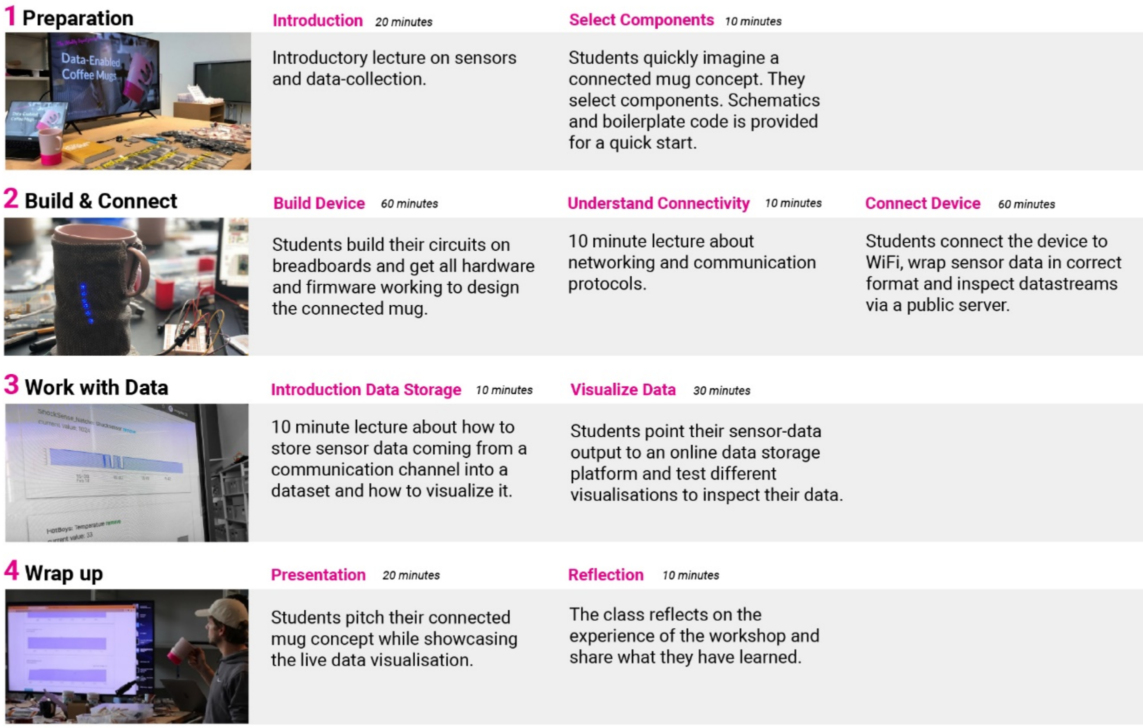

Figure 4. Overview of workshop 2 including the stages and activities

2.2.1 Instructions and Selection of Components

Before the workshop starts, we share instructions for students to prepare the installation of the necessary software. For this activity, we use accessible electronics and code that can be changed depending on teacher preferences. Before the workshop starts, we ask students to install the Arduino IDE, ESP8266 drivers, libraries (ArduinoJSON & OOCSI) and set up a cloud-based database account. In our department, we use the in-house developed Data Foundry platform (https://data.id.tue.nl), but other cloud-based platforms such as Adafruit.io, Particle.io or Thingspeak.com are suitable as well. All materials and instructions can be found in this GitHub repository: https://github.com/royovic/educhi.

The workshop starts with a 20-minutes introduction on sensors, wireless networking and data collection. Students are then invited to collect components (~10 minutes) from a selection we provide. We offer the same basic components for everyone, to stimulate collaboration and students helping each other. The component list consists of an Wemos D1 mini with battery shield, 200mAh LiPo battery, breadboard, jumper wires and an array of Arduino sensors (pressure sensors, temperature sensors, accelerometers, light-sensitive resistors). Offering a variety of sensors has pedagogical advantages, as it helps students explore different capabilities and levels of complexity.

Next to the electronic components, students receive a mug, which will act as the 'probe' on which they attach a variety of sensors. The mug is optional in the process of the workshop and other everyday objects could be used as well. Not every everyday object is suitable though. The mug was chosen because of the richness of underlying interactions and human behaviors. First, a mug can be held in a variety of ways, which impacts the sensory capabilities. Second, a mug is used across a variety of social contexts; it is about a daily pattern for an individual (e.g. when someone is drinking behind their desk), but also social in a group context (e.g. when you are joining a queue in front of the coffee machine).

2.2.2 Building and Connecting the Device (1 hour)

First, students are asked to setup their devices, select a sensor and make the circuit on a breadboard. We provide the students with schematics on the basic setup of every sensor. We also share basic boilerplate code, so even students without experience in programming can use their devices. Importantly, we have technical staff in the room (or students with more experience with electronics) to support students with any problems such as missing software, connection issues or code bugs. We recommend one supporting person per 10 students.

2.2.3 Work with Data (1 hour)

After students have connected their electronics and managed to read out sensor values in the Arduino IDE serial monitor, we introduce connectivity options to facilitate remote data collection by means of a 10-minute lecture. Students are instructed to connect their devices to Wi-Fi and are introduced to communication protocols. For our workshop, we used our in-house OOCSI system (https://github.com/iddi/oocsi), a MQTT-style protocol. It is easily swapped with MQTT itself (or a HTTP API, such as Adafruit.io if you cannot access a MQTT-broker). We recommend using mobile phone hotspots, 4G access points or IoT-capable Wi-Fi networks, as WPA2-Enterprise encryption in universities prevents IoT-devices connecting. Boilerplate code is supplied, so everyone can get connectivity and data communication up and running. The logging system of the public OOCSI broker (similar to a public MQTT broker) is used to check whether their device is correctly streaming data. After students have completed this step, we introduce students in a 10-min presentation to the data-storage platform where they can save their sensor data to a dataset. Furthermore, we offer options for quick data-visualization on the same platform so they can easily make graphs of their results. An alternative could be to use visualization engines of cloud-platforms, or export to .csv to use Microsoft Excel for visualization.

2.2.4 Presentation and Reflection (20 minutes)

At the end of the workshop, we invite students to demonstrate their working prototype in a two-minute pitch. They show how they tackled technical challenges, present a live data visualization on screen or present how sensor-output could help them in exploring a certain context or user behavior. Additionally, they are asked to reflect on the experience and what they have learned.

2.2.5 Insights from students' reflections

The main goal of the Coffee Cup Challenge workshop is to introduce students to the technical implementation of their own sensor systems, so they can use this knowledge in their Data-Enabled Design processes. They are shown, step-by-step, how to build and program data-collection probes and visualize the output. The workshop also aims to stimulate collaboration and support within the squad. Overall, students appreciated this second workshop and the knowledge they gained from it: *"Here it really started to make sense for me, because sensors and data was always very abstract for me."* (AN). They recognized how it logically followed Workshop 1: *"In Workshop 2 it was a lot of fun to kind of implement Workshop 1 with your own sensors; how can you collect actual data in a quick way"* (EL).

Some students found it intense and sometimes difficult: *"I think it's a good exercise for people not familiar with tech, but it was quite fast (1 day) and can still be difficult for people without experience."* (LU). However, that intensity and focus on individual practice also showed benefits: *"I was never involved in coding, we always had one person responsible for that in the projects which made it hard to collaborate and none of the project prototypes really worked. In the workshop, the pressure of having to do everything yourself really forced you to go through all the steps."* (AN). We see this reluctance to work on technology more often in projects, as shared by another student: *"Usually, I think tech is 'scary', I'm quite* *paranoid that something goes wrong, so I tend to avoid it."* (LU). Students expressed that such activities can really kickstart working with technology: *"This shows that it doesn't need to be all that complicated and that you can achieve a lot and gain insights based on data in just one afternoon."* (EL). Besides the reflections on technology, students also appreciated to be confronted with the challenges and limitations of translating human behavior to structured data. Remarks such as "*I could not understand why the data wasn't grouped in a way that made more sense, forcing me to evaluate with my team members*" were great examples of a process where two mental models of the data were complementary to each other.

Quite some students shared that they used the knowledge from the workshop in later projects as well: *"I used knowledge from the workshop in my later prototypes (e.g., OOCSI)"* (AN) and *"I did use some insights from this workshop in my later projects, such as using off-the-shelf sensors to investigate a user context early in the process."* (LU). Others found that while the knowledge from the workshop was worthwhile, they also realized how it did not fit their process: *"However, in the time and (my process of) user research this did not really fit. So, I made the choice not to try and force fit it"* (AL).

2.2.6 Insights from teachers' reflections

The hands-on and practical nature of this workshop was very valuable. Getting students to use technology as a means of inquiry at the start of projects is often difficult due to a 'fear of technology' as well as a lack of experience in what data can bring to the creative process. The format of this workshop asked every individual student to go through the entire process of (briefly) conceptualizing an artefact and implementing it from sensor to real-time cloud-based visualization. We organized it in such a way, that even though everyone had to do it by themselves, all students could support each other. Usually in project teams, students delegate the technology-part of prototyping to the student with existing experience or affinity, and refrain from developing that competence themselves. We were satisfied that students now had a more equal level of understanding of the technology and can collaborate better on key design decisions in their own projects. What struck us was that this process was seen as 'impossible' by many in such a short amount of time. By doing this process hands-on and individually rather than theoretically and in a group really changed the perspective of students how fast it is possible to achieve such outcomes by themselves. We were proud to see students with a low self-esteem excelling. Noteworthy, some more technological skilled students were trying to overachieve and in the end achieved less than most.

Running this workshop is not possible without the continuous and well-prepared support from staff members, besides the support from expert students or student assistants. Preparing the electronics and software took more effort from students than expected, mostly due to a lack of understanding of software libraries and microcontrollers. Support staff was necessary to help students that were stuck in setting up software and devices. It is recommended to do an end-to-end test of all hardware and latest software versions a few days before, so issues are solved before the workshop starts.

Even though most students were able to complete the workshop with a working prototype, we realize that a fundamental understanding of the technology (e.g., reliability of sensors, communication protocols) is not an outcome of this workshop. We see however that it can give a push to inexperienced students to see how quick one can build and deploy a working, data-streaming sensor-probe in their design process. And that this push makes them interested in learning more about the technological fundamentals of such an approach. To further help removing some of the temporal and technical barriers we later invested in off-the-shelf sensors (e.g., commercial motion sensors and smart buttons), which students can now borrow from our lab. This may help inexperienced students, who still feel uncomfortable in building their own sensors, to nevertheless use data in their design process. While easier, it still might cause some difficulties due to the intricacies of the different IoT ecosystems and (proprietary) interfaces.

There is also room for improvement to let students reflect on how this impacts them as a designer, rather than as an engineer. Most of the collected data in workshop 2 was not put in perspective of interaction design or how to translate it to insights to inform your design decisions. The link with workshop 1 thus has to be reactivated during discussions. The use of a common object (mug) was interesting to compare the approaches between students, yet we would be interested to adapt the workshop format to allow students to directly use the knowledge on their own designs, instead of a generic object.

3 CONCLUSIVE REMARKS

With this Teachable Moment contribution, we have shared two teaching activities that successfully introduced students to the use of (sensor-) data as a creative material in a design process. Our main goal was to provide a hands-on, experiential educational format that conveyed the practical use of data for design purposes. The two workshops we described can be generalized to different contexts and technical implementations and can be adapted to fit the needs of other HCI-educators.

Based on students' reflections we have seen that the workshops were perceived as useful, bringing a new mindset about data through the DED approach as well as practical skill-based knowledge. They expressed that the format was fun, educational and that they were able to leverage the learned insights in later projects and courses. Most students recognized the practical value of the workshops, but still quite some of them failed to implement it in their respective design projects. We observed later in the semester that some students were still afraid to lose time on technical details and were hesitant to jump immediately into concrete solutions instead of using data to explore novel opportunities for design. This also gives us the challenge to not only provide workshops, but to better scaffold the data-enabled design process throughout the course. One approach is to provide commercial off-the-shelf sensor products to speed up the initial context discovery process. An alternative for Workshop 2 could also be a format where students can directly work on their own projects and replace the mug with their own design artefacts and look for opportunities in terms of sensing capabilities.

We see that most educational goals were achieved but that there are still some practical implementation lessons that we take into next iterations of the workshops. The time-planning is crucial to allow insightful discussions and not generate stress to properly prepare and execute the intense activity schedule. Making the transition from one sensor to multi-sensor ecosystems is crucial in understanding relations between data where nowadays many of our products rely on.

As a conclusion, we hope that these educational activities leveraging the use of sensor data to enrich the design processes will open new opportunities for design students and practitioners alike. We are enthusiastic to see how other lecturers will appropriate and adjust the format of our teaching activities to their own practices.

ACKNOWLEDGEMENTS

The authors would like to thank all students, teaching assistants and staff members of the Vitality Squad at TU Eindhoven, for their contributions and constructive feedback. A special thanks to Philips Design for hosting the first activity and inspiring the students.

4 REFERENCES

[1] Laurens Boer and Harvey Bewley. 2021. Smörgasbords for Physical Computing. TEI 2021 - Proceedings of the 15th International Conference on Tangible, Embedded, and Embodied Interaction. https://doi.org/10.1145/3430524.3446077

[2] Sander Bogers, Janne Van Kollenburg, Eva Deckers, Joep Frens, and Caroline Hummels. 2018. A situated exploration of designing for personal health ecosystems through data-enabled design. In DIS 2018 - Proceedings of the 2018 Designing Interactive Systems Conference, 109–120. https://doi.org/10.1145/3196709.3196769

[3] Sander Bogers, Janne Van Kollenburg, Eva Deckers, Joep Frens, and Caroline Hummels. 2018. A situated exploration of designing for personal health ecosystems through data-enabled design. DIS 2018 - Proceedings of the 2018 Designing Interactive Systems Conference: 109–120. https://doi.org/10.1145/3196709.3196769

[4] Tjeu van Bussel, Roy van den Heuvel, and Carine Lallemand. 2022. Habilyzer: Empowering Office Workers to Investigate their Working Habits using an Open-Ended Sensor Kit. In Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems (CHI EA '22). https://doi.org/https://doi.org/10.1145/3491101.3519849

[5] Daniel A. Epstein, An Ping, James Fogarty, and Sean A. Munson. 2015. A lived informatics model of personal informatics. In Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '15, 731–742. https://doi.org/10.1145/2750858.2804250

[6] Roy Van Den Heuvel, Tjeu van Bussel, and Carine Lallemand. 2022. Habilyzer: A User-Driven Open-Ended Sensor Kit for Office Workers. In Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems (CHI EA '22). https://doi.org/https://doi.org/10.1145/3491101.3519884

[7] Roy Van Den Heuvel, Pierre Lévy, Steven Vos, and Caroline Hummels. 2020. Exploring public playgrounds through a data-enabled design approach. In DIS 2020 Companion - Companion Publication of the 2020 ACM Designing Interactive Systems Conference, 1–6. https://doi.org/10.1145/3393914.3395865

[8] Elisabeth T. Kersten-van Dijk, Joyce H.D.M. Westerink, Femke Beute, and Wijnand A. IJsselsteijn. 2017. Personal Informatics, Self-Insight, and Behavior Change: A Critical Review of Current Literature. Human–Computer Interaction 32, 5–6: 268–296. https://doi.org/10.1080/07370024.2016.1276456

[9] David A Kolb. 2014. Experiential learning: Experience as the source of learning and development. FT press.

[10] Janne van Kollenburg and Sander Bogers. 2019. Data-enabled design : a situated design approach that uses data as creative material when designing for intelligent ecosystems. Eindhoven University of Technology.

[11] Carine Lallemand. 2021. Creative Pedagogical Activities for User Evaluation Methods Courses. In 3rd Annual Symposium on HCI Education (EduCHI'21). In 3rd Annual Symposium on HCI Education (EduCHI'21), April 30–May 1, 2022, Virtual. ACM, New York, NY, USA

[12] Sjoerd Stamhuis, Hans Brombacher, Steven Vos, and Carine Lallemand. 2021. Office Agents: Personal Office Vitality Sensors with Intent. In Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems (CHI EA '21). https://doi.org/10.1145/3411763.3451559

[13] Clement Zheng. 2018. Unfolding an industrial design approach to physical computing. TEI 2018 - Proceedings of the 12th International Conference on Tangible, Embedded, and Embodied Interaction 2018-Janua: 721–723. https://doi.org/10.1145/3173225.3173344