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A pedagogical framework and a transdisciplinary design approach to innovate HCI education

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Abstract. In the current work, we introduce Applab as a pedagogical framework and a transdisciplinary design approach to innovate HCI education. Students do not work for a client, but work together with urban stakeholders to better frame the problem in order to deal with societal challenges. In this way, Applab embraces design thinking as an approach to leverage a cross-disciplinary collaboration between research, government, industry, and HCI and design education. Results are described as well as lessons learnt. Consequently, the elaborate Applab model is discussed. Interestingly, the corresponding transdisciplinary design approach enabled a successful implementation of Applab into HCI education. Students learnt a lot, as did the urban stakeholders. The designed artefacts greatly leveraged their mind-shifting and meaningful learning experiences.

Keywords: collaborative design, design thinking, HCI, higher order skills, meaningful design, multidisciplinary, societal challenges, transdisciplinary design.

1 Introduction

Design thinking is increasingly seen as the answer to tackle today's societal challenges such as climate change, the ageing population, and reducing inequality and social exclusion [1]. Governments and funding bodies increasingly stress the importance of creative skills as well as design thinking in their research agendas, which call for new ways of thinking and doing to deal with these challenges [2,3]. Technology is seemingly integrated in our society, and therefore, plays a crucial role in almost all major changes in society, including education, research, and innovation. Technology is no longer the expertise of an engineering elite, people increasingly need to be data literate in order to participate in society. Also the fields of HCI and design are transforming towards society. HCI scholars have identified and discussed changing paradigms of HCI [e.g., 4-6]. Whereas the first and second paradigms discussed broad areas of topic, varying from human-computer interfaces and interaction towards communication and information sharing, the third paradigm of HCI explicitly addressed the situated context and looked for ways to include human values into meaningful design [6-8].

Similarly, the design discipline has moved from the designing of things to interactions to systems, and from designing for people to designing with people and by people [9]. Or differently phrased, moving from design 1.0 towards design 4.0, where the latter refers to a transforming society [10]. Product design has turned into product service systems design and becomes more and more intangible, ubiquitous computing goes into the city, and people have multiple devices, which are increasingly connected. Brynskov and colleagues [11] elaborate on this and motivate how research strands from art, technology, and society currently come together in one emerging field of Urban Interaction Design, and conclude that the making of the city is no longer the only concern of urban planners. Similarly, the Maker Movement [12] is enabling that anybody can be a maker, while providing all kinds of people around the world with the tools and infrastructures to unleash their intrinsic ability to create, make, and innovate. This spreading trend of learning-by-doing has the potential of empowering people in doing things previously unthinkable, through the potential of 3D printing, laser cutting, Internet of Things, electronics, and so on. The unleashing of creative processes can be coined as 21st century skills, which refer to amongst others digital literacy, creativity, critical thinking, problem solving, as well as collaboration and communication skills. It is commonly accepted that these higher order skills are essential for successful participation in society. "Numerous efforts have been made to identify 'key competencies' and 'employability skills' over the past decades. However, apart from the universally acknowledged importance of basic literacy and numerical skills, there is little hard evidence of what other skills are required for workers to obtain better labour outcomes and cope with a more fluid labour market" [13].

The on-going debate on the future of work [14], long-life learning [15] and the changing skillset generally agrees that higher order skills are essential for successful participation in society, though the question remains where and how the knowledge and skills can best be learned [3,14,16]. The current article aims to contribute to this debate and therefore, explores *where* and *how* such higher order skills can have a place in education. In the next section we describe the context of our study and introduce the physical space created for doing design as a collaborative process. Also the research program *Meaningful Design in the Connected City* is briefly introduced, which provides the context for the student projects.

2 Chaordic education as a learning space for 21st century skills

In response to the increasing pressure and changing demands from the environment, higher education tends to fall back on the traditional quality and efficiency thinking. This not only leads to more rules, guidelines, and order, but also has the effect that motivated, creative teachers and students feel less and less in place. The last trend report of the SURF's Scientific Technical Council [17] interestingly pleas for a *chaordic teaching and research environment*, an environment that provides both structure (order) and space for educational innovation (chaos). Such a *chaordic* environment that allows for both *chaos* and *order* can be seen as an ideal playing field for learning higher order skills.

Our lab grew out of that vision; it is a chaordic teaching and research environment, which connects research and education. Citylab Rotterdam is a lab for applied creativity, a FabLab extended with a strong emphasis on electronic and sensor devices, the Internet of Things, and Open Data. The lab has been designed as a technical workshop, where students learn about the latest digital technologies that challenge the curriculum [18]. Next, the lab connects students with the research program *Meaningful Design in the Connected City*, which investigates the role of design in transforming society and explores the dynamics in the city by using the urban space as a living lab. More specifically, it studies how the design process on an urban interaction level can be people-led, opening up the scope of a stable educational institute, which is training students in the field of digital communication, interactive media design, and computer science. Consequently, students can practice their HCI and interaction design skills on an urban interaction level.

Working in multidisciplinary teams on realistic projects with external clients is often commonplace in higher education. Realistic projects are key to providing a rich and challenging learning environment; such projects are problem-based, enrich prior learning, and provide the ability to apply knowledge and skills in a real context. However, implementing such multidisciplinary and effective learning spaces is not easy [19]. Best multidisciplinary practices are oftentimes extracurricular or embedded in the elective space, as the recruitment of multidisciplinary realistic projects takes a lot of effort, and puts high demands on flexibility and availability of external partners, due to dynamics in disciplinary participation, learning goals, and interests of students. Moreover in the execution, multidisciplinary education projects frequently result in a division of tasks among the different students – one does the conceptual design, another the interface design. And still too often, outcomes remain at the level of ideation. Our students explicitly indicated that they liked to work as a multidisciplinary (or even interdisciplinary) team and elaborate upon other projects in order to make meaningful design happen in Rotterdam. Driven by the students' desire to leverage their interdisciplinary work into transdisciplinary learning experiences as well as their desire for contributing in a meaningful way to the design challenges in their city, Applab emerged.

3 Applab as a pedagogical framework to innovate HCI education

Realistic projects are driven by contextual questions from the city, and are also applied again in the real context. Our lab shares this ambition, though Applab, the proposed pedagogical framework goes even a step further. Students do not work for a client, but for city challenges. They work together with stakeholders in a multi-helix consortium, in which education, research, creative industry, business, governmental organizations, interest groups, and local residents are represented, to better frame the problem in order to deal with societal challenges. In keeping with Carayannis and Campbell [20] who describe how the triple helix (existing of organisations, governments, and universities) can be extended with a fourth helix to a quadruple helix that acknowledges the important role of the (media base and culture based) public or civil society, we use a citizen-centred collaborative design process. With

this fourth helix, knowledge of culture, values and life styles, multi-culturalism, creativity, and media, are brought into the process. The fourth helix represents and warrants designing with a human scale. The pedagogical purpose of the Applab is not only to teach meaningful design in keeping with the third wave of HCI, and developing breakthrough applications in co-production with local stakeholders, but especially to brings design thinking into HCI education, along with a rich variety of design methods and techniques stressing human values and ethics, creative methods as well as providing the latest digital techniques, such as laser cutting, 3D printing and the Internet of Things. Design thinking has been used broadly as a sequence of diverging and converging of solutions, or differently phrased as a continuous process of creating choices and making choices [1]. Students learn how to account for the diversity of values while dealing with the different partners and stakeholders involved in framing the problem space. In this way, Applab trains a new generation of students, which recognizes different perspectives, has an open and entrepreneurial attitude, and is willing to embrace complexity and wicked problems. Applab is a learning and development environment for the training of higher order skills, such as teamwork, creativity, data and ICT literacy, communication, problem solving, critical thinking, and social and cultural skills, as well as gaining a social responsible, entrepreneurial, and open attitude. In this way, Applab embraces design thinking as an approach to leverage a cross-disciplinary collaboration between research, government, (creative) industry, and HCI (design) education.

3.1 Connect, co-create, and share

Applab stands for: connect, co-create, and share. The Applab methodology *connects* institutes, courses, researchers, teachers, and students with local stakeholders such as government, industry, design agencies, and IT companies through multidisciplinary crossover projects. This creates a synergy in which students of different disciplines and different cohorts *co-create* together and pick each other fruit, but also continue each other work, complement, or finish. Students *share* knowledge and learn from each other. A physical space benefitting from the facilities of the citylab but also providing additional cliniques and workshop kits, enables ideation, making, and realisation. Sharing of the insights and outcomes is supported in a physical and digital way, and enhances the collaboration of students and staff across different courses, cohorts, and institutions.

3.2 Objectives and ambitions

In accordance with the collaborative attitude of Applab, a kick-off session was organised to discuss what Applab should be and what it should not be, in order to guarantee and to ensure the aforementioned ambition, the following objectives have been embraced:

- Applab connects education and research with the city in order to design in a meaningful way for a transforming society.

- Applab offers an inspiring environment in which students are given space to learn by experimenting in multidisciplinary teams.
- Applab is a dynamic development of an innovative education and research methodology in line with the developments in the digital network society.
- The Applab organizational model is dynamic and based on self-organization in networks. As a result, the constellation of projects and participants is constantly changing over time.
- Applab is an open digital platform for project co-creation among students, teachers, researchers, and local stakeholders (both business and government).
- Applab enables a sustainable embedding of research into the regular curriculum, and contributes to other disciplinary research centres as well.

3.3 A chaordic space in the curriculum

Multidisciplinary student teams are supported throughout the curriculum, and working closing with (urban) stakeholders in the research program *Meaningful Design in the Connected City*. Figure 1 shows the Applab space in the several bachelor courses in the School's curriculum. The first year is largely reserved for theoretical learning and emphasises low order skills [21].

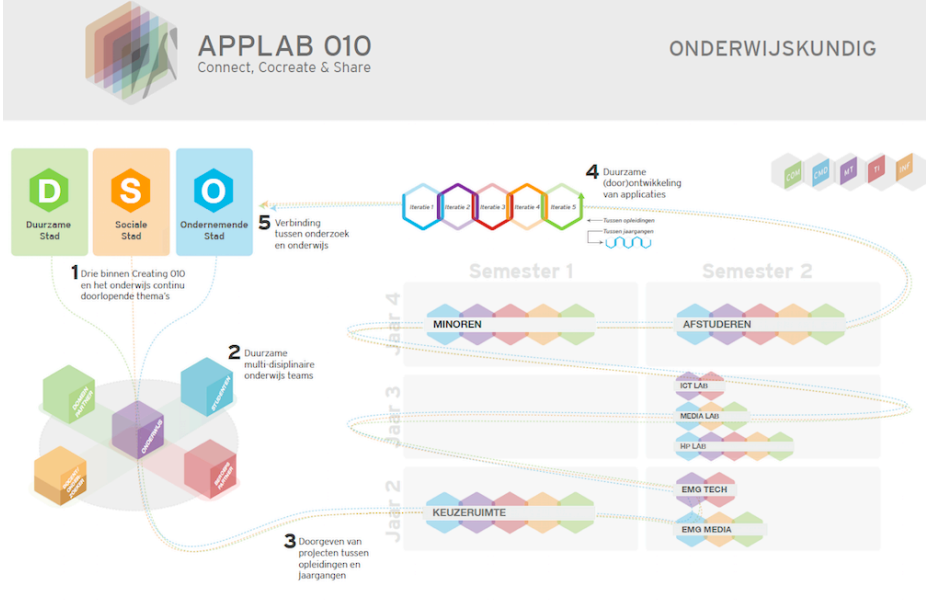

Fig. 1. Applab as a pedagogical framework embedded in the curriculum of bachelor courses in the domain of human-computer interaction, interactive media design, creative technology, and computer science.

Although some students already have their first encounter with the research program during electives in the first semester of year 2, such as the elective courses on human values, envisioning information, research for design, or creative research tools, for most students the emerging media and emerging technology courses in the second semester of year 2 enable their introduction to the Applab methodology; these are roughly 400 second year students each year. The first semester of year 3 has no Applab opportunity as students are not in the school due to internships. At their return, they continue working with creative industry in either a medialab or ICT lab; students that particpate in the Honoursprogramme (HP), however, work in a HP-lab, which is usually connected to the research program. Several labs are executed in the Applab space. Then in the fourth year, some minors work closer to the Applab than others; for example the minor Urban Interaction Design is hosted by the research program *Meaningful Design in the Connected City*. In the final semester of the bachelor program just a few students participate in the Applab, as the graduation projects is on an individual basis.

4 Method

The objective of the current work is to see whether the proposed Applab framework could be implemented in the School's broad HCI curriculum, which is already in keeping with the third wave of HCI, and whether the Applab objectives are met.

In keeping with the intentions of a chaordic learning environment, Applab projects are initiated bottom up, and therefore open to both students and teachers who are willing to work with the research centre on air quality. The learning goals are consequently set by the course the students are following, the teacher, who is coaching and lecturing, is responsible for the assessment. This guarantees that the students meet the requirements of their main bachelor discipline in the first place. It also enables collaboration across cohorts; thus students from different years can collaborate in Applab.

In other words, participating in Applab leverages the context of the course, and provides a meaningful design challenge that comes with involved co-creative partners. A researcher will be responsible for the link with the research program and the corresponding partners (*connect*). Where necessary, the researcher also brings additional design research methods and tools to the table. The students, however, frame and reframe the problem space, and are responsible to debrief to all partners involved. In the *co-create* phase, the students take the lead, and communicate accordingly. This is however, already a common practice in their regular education. At the end of their course, they *share* their results and bring new issues to the Applab community inviting other students or other courses to continue with the challenge.

The next section reports on a series of Applab projects that embrace the challenge of air pollution.

5 Results – Applab Practices on Air Quality

Air pollution is one of the many societal challenges a mundane city faces that are affecting the quality of life of its residents. The design-oriented Applab approach connects various urban stakeholders in the design process, among others citizens, municipal officials, and businesses. Several multidisciplinary teams have developed concepts to improve air quality and to reduce health risks. Some exemplary projects regarding air quality that leveraged each other as a relay race are introduced below to illustrate the Applab implementation in the curriculum.

5.1 What do I smell?

'What do I smell' started as an 'Emerging Media' project together with the Regional Environmental Protection Agency. In this project second year bachelor students in media technology designed for the control room of the future. They studied how citizens can use social media to communicate with the control room. The environmental protection agency wants to involve citizens in their activities and to the lower threshold to think along with them. The resulting design is an interactive platform including a website and an app (Figure 2). Citizens can easily give feedback on what they smell, share their scents, and find more detailed information about odours in the area. Using the app, citizens can send their feedback including a GPS location directly when they smell [22].

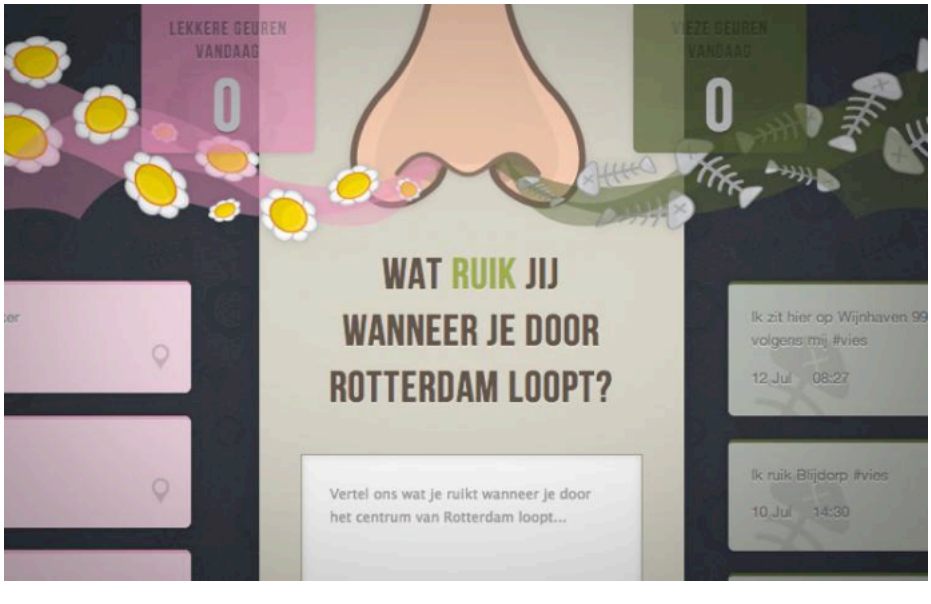

Fig. 2. What do I smell?

5.2 Sustainably Sniffer

In the next semester, a team of students with backgrounds in industrial product design, electrical engineering, and computer science continued the project in the context of their minor Innovation Engineering & Design hosted by the School of Engineering and Applied Sciences. Their particular focus was on how to motivate citizens to collect data for the purpose of better understanding of air quality and awareness of the air pollution in their immediate vicinity. Several teams have worked together and developed a 'Sniffer': a compact and simple air quality meter that measures air quality elaboration upon a professional sensor of the Holst centre that measures substances affecting air quality, such as particulate matter, nitrogen dioxide, temperature, and humidity. Consequently, the sniffer informs citizens via Bluetooth, and an app on their smartphone on the current air quality level. A map shows the current location and corresponding measurements as well as those of other sniffers in their vicinity. Students were mainly interested in the real-time measurement of air quality and the ability to transmit data wirelessly to a (open data) server for further processing (see Figure 3).

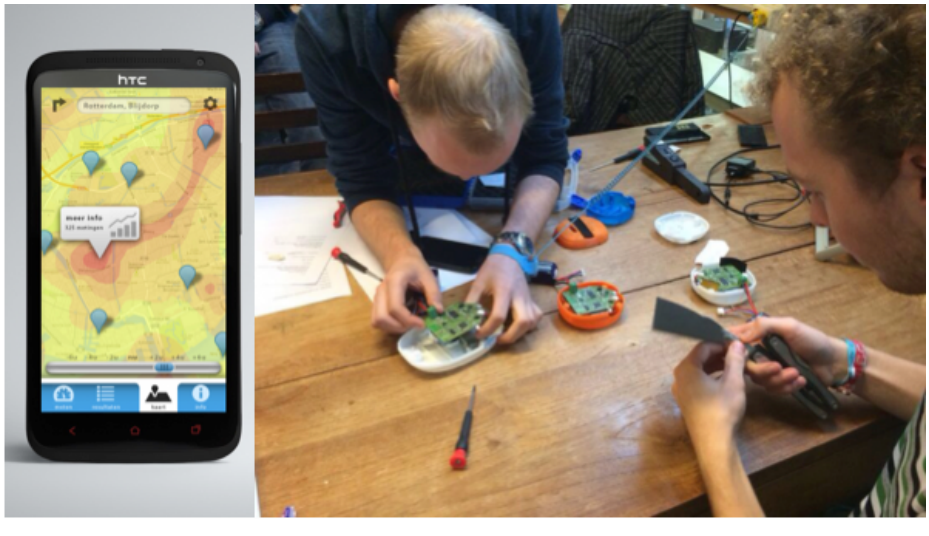

Fig. 3. Students working on the Sustainably Sniffer.

5.3 Citizen's awareness of air quality – QFit and Pollie

When the first prototype has been developed, two new students groups of the Honours Programme-lab (HP-lab) embraced the business potential of the Sustainably Sniffer. These multidisciplinary groups investigated various ways to motivate citizens to use the Sniffer, and studied whether and how citizens could be motivated to gather data, which could be re-used by the environmental protection agency, in order to provide citizens more awareness and insight in actual air quality circumstances. Students

collaborated with the Municipality, the environmental protection agency and, of course, citizens. Both QFit and Pollie emerged from this follow-up.

QFit is a small wooden cube – inspired by the iconic local cubic houses – that can be used as a keychain or can be attached to a bag. QFit is a further development of the initial Sniffer; it is not only smaller, but also more focused on a specific target group. QFit responds to modern citizens who like the 'quantified self' movement. QFit tracks movements such as the number of steps, traveling modes, locations, and measures air quality. Citizens become more aware of the local air quality. A persuasive game element of collecting points which can be reused for local discounts aims to motivate citizens to continue their measurements, but also stimulates them to be more active. QFit is a so-called 'appcessory', a wearable, which is in contact via Bluetooth to a smartphone. Thus, the data is sent to the app that records the measurements and anonymously sends these to the Rotterdam Open Data store. The network of QFits are visualised as a heat map that shows which locations are most and least polluted. It empowers citizens to decide on the healthiest route to school or work. In addition, the app gives feedback on exercise behaviour. The multidisciplinary team consisted of interactive media design and digital communication students. They actively asked for technical knowledge through working together with other students working in the lab, for example, the Sniffer team. After several brainstorming sessions, street interviews, and forecasting techniques, students have finalised their concept, and consequently, built the prototype in the citylab and evaluated it with citizens.

Another group of electrical engineering students from the School of Engineering and Applied Sciences elaborated upon the findings of QFit and found a more efficient way to measure particulate matter and managed to make the Sustainably Sniffer smaller. Figure 4 illustrates QFit, and Figure 5 Pollie.

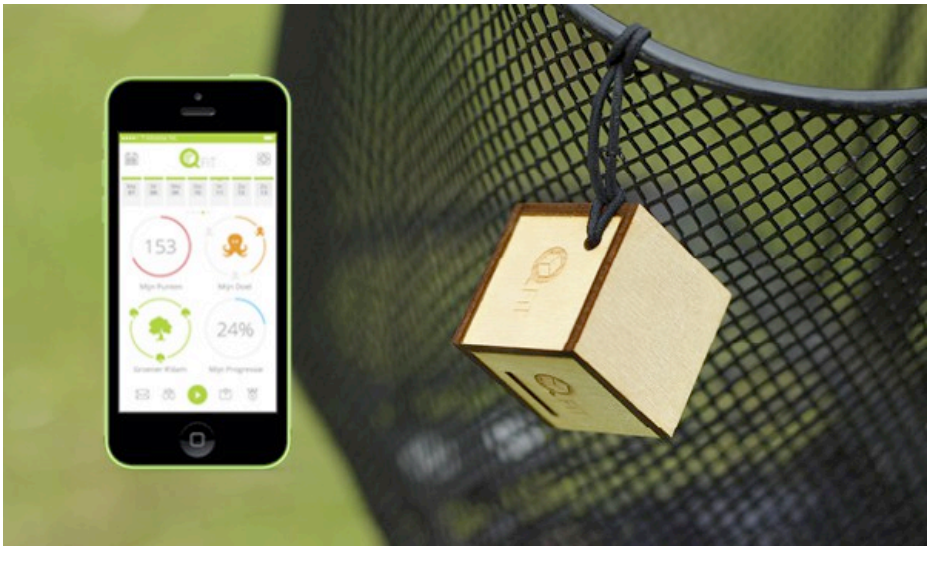

Fig. 4. QFit, see also the corresponding concept video [23].

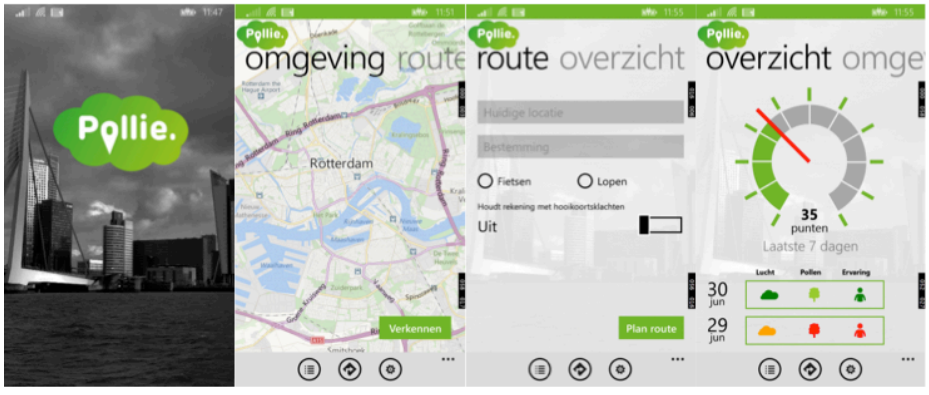

Fig. 5. Pollie.

Pollie is the results of another group of the HP-lab that has chosen to associate Sustainably Sniffer's air quality measurements with available data on green spaces from the Rotterdam Open datastore and combined it with actual weather data. Pollie allows hay fever sufferers to adapt their itinerary to local and actual circumstances. The application is a route planner in which you can opt for a clean route or a route where you suffer the least from hay fever. The application is interesting for people who want to understand the quality of their living environment and people with hay fever (Figure 4). The multidisciplinary team of Pollie consisted of Honours students following undergraduate courses in Media Technology, Communication, and Communication & Multimedia Design. To learn from each other, the team members have presented their professional ambitions and specialisations. The students reflected as follows. "*Because everyone followed another course and had a different background, it was an informative experience to watch along with each other and learn from each other*." They worked in close collaboration with the second Sniffer team that elaborated upon the initial prototype, which was a constellation of product designers, electrical engineers, and embedded systems engineers. Students researched and learnt a lot regarding air pollution, materials, sensors, potential competitors, and trends. For example, they involved an expert in hay fever from the Leiden University Medical centre and worked in collaboration with the developers of Allergy Radar. Allergy Radar provides a current and nationwide survey of the extent hay fever sufferers experience symptoms of nose, eyes, and lungs. Participants in this survey register at least once a day the intensity of their complaints on a scale of 1 to 10. All registrations are processed immediately and visualised on a geographical map of the Netherlands. The more people participate the more detail can be displayed (http://www.allergieradar.nl).

In addition, user research was done with potential target groups. The many creative sessions included a broad variety of urban stakeholders. The team has been positively surprised by the value of this co-creative effort: "*The beauty of this project is that the main wishes of all external stakeholders are embraced by the final design*." In order to elaborate upon what is technically possible and to increase their ideation, the team participated in a hackathon on Internet of Things and Open Data. The team practiced iterative prototyping and evaluation with users on a weekly basis.

6 Discussion and Conclusions

In the current work, Applab has been introduced as a pedagogical framework to innovate HCI education. Students were trained in higher order skills and worked together with urban stakeholders on design challenges for social innovation and a sustainable future. The chaordic space in the HCI curriculum enabled experimenting within accredited education, which is not always easy to pursue. The implementation of Applab in HCI education clearly contributes to the current discussions on transdisciplinary design - how design transcends disciplinary boundaries – which can be seen as the fourth paradigm of HCI [24, 25].

It can be concluded that the six Applab objectives have been achieved largely. Having an established connection with the research program *Meaningful Design in the Connected City* from start, Applab's ambition to connect research and education in order to meaningfully design for a transforming society was already in place.

Applab indeed offers as well an inspiring environment in which students are given space to learn by experimenting in multidisciplinary teams. Not only was the strategic advisor to the university's Board of Directors convinced of the uniqueness of Applab: "*it provides a concept for defiant and challenging education as well as a collaborative approach to team up with urban stakeholders*", but also learning through experimentation, or better: learning through design doing had an inspirational effect on the students. Students easily moved out of their comfort zone. Space in the sense of freedom as well as creative environment, even enhanced students' ambitions. This was evidenced in the quality of their work as well as their time investments.

Applab is also a dynamic development of an innovative education and research methodology in line with the developments in the digital network society. The Pollie team joined for example an Internet of Things hackday, which was addressing the opening up of personal data and its combination with meaningful use of the available public sector information. The jury welcomed their contribution in particular because they managed to develop meaningful apps, which do use open data, and at the same contributed to the on-going debate on the value of open data. "*With this contribution, your grandmother understands what data is, and will even start asking for more data, to benefit more*" the jury explained.

The Applab organizational model is dynamic and based on self-organization in networks. As a result, the constellation of projects and participants is constantly changing over time. Learning through experimentation gives students the space and inspiring. Students engaged various collaborations, which were not initiated by their course leaders. The student teams involved differ in background and size and are often multidisciplinary. Though collaboration within and between such teams ask for more preparation and transfer of lessons learned. Therefore, Applab needs an open digital platform as well enhancing collaboration among students, teachers, researchers, and local stakeholders (both business and government). Embedding such a platform in a cross-institutional context needs more time. However, the continuous collaboration with the quadruple helix clearly contributed to achieving higher order skills.

Interestingly, learning by collaboratively designing not only worked for students, but also the involved urban stakeholders learnt. This is not a trivial observation. In

earlier work on collaborative learning in ad hoc design teams we focused on the process of shared meaning making [26]. We referred to collaborative reflection as 'co-construction of knowledge' when team members learnt as a joint reflective action, however, the transcripts of the design teams' communications did not show any collaborative reflections. Without having studied the current process in similar detail, both students as well as urban stakeholders spontaneously expressed collaborative reflections, i.e., used statements that fit the earlier assessment of 'co-construction of knowledge' as assessed in [26]. The attention of design thinking in the HCI curriculum and training students as reflective practitioners [27] might have made students more aware of reflection in action as well as reflection on action, and consequently, better prepared to collaborative reflection and shared meaning making.

Moreover, the designed artefacts leveraged the discussions among all participants, and likely have encouraged the co-construction of knowledge as well. The corresponding 'complex' collaboration with innovative design agencies and ICT companies speeds up bringing innovation and new technologies into education, and enabled a successful implementation of Applab into education. The success of Applab, however, also attracts traditional clients that like to have a cheap solution for their defined problem. Requests like this are unfortunately not rare: "*we are looking for someone who could develop an app for patient education with regard to specific diagnosis. We have a project for writing a storybook with recognizable stories about the disease and the development of a number of products related thereto. In addition, we thought of an e-book and app where patients can look up things. Can the students do it, we are out of budget*." While the equal partnerships and collaborative problem framing are the strengths of the Applab model, the shift in culture requires continue and consistent communication, from and to all colleagues and collaboration partners.

Applab has also spurred spin-off projects. One of the workshop platforms been made accessible to school dropouts in a low social and economic status community and provided them with a broader skillset enhancing their participation in society. Some youngsters, during the course of this particular spin-off-project, had a mind-shifting experience and demonstrated that it is indeed possible to transform dropouts into engaged and successful individuals, who are role models for their peers [28].

It can be concluded that Applab indeed enables a sustainable embedding of research into the regular curriculum, and has contributed to other disciplinary research centres as well as spinoff projects.

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