Innovation and Creativity in HCI Education

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Abstract—**The present paper explores what creative thinking and design thinking could contribute to Human-Computer Interaction (HCI) education if included as a part of the curriculum. The investigations were carried out in the context of a mixed undergraduate and graduate course in HCI. The findings indicate that design thinking contributed to increased focus on innovation and creativity, as well as prevented too early fixation on a single solution in the initial phases of HCI design processes. More openness in design processes and changes in ways of learning required stepping out of the comfort zone for some students. However, increased creativity and adaptability may still be the best long-term benefits that HCI education can offer to students when preparing them for future work practices. The paper also addresses the organization of the course that, based on the empirical evidence from the past two years, fosters such processes in HCI education.**

Keywords-innovation; creativity; design thinking; HCI education.

I. Introduction

This paper is an extended version of the paper [1], presented at the Advancements in Human-Computer Interaction (ACHI 2015) conference. It, like its conference version, discusses the role of innovation, design thinking, and creativity in Human-Computer Interaction (HCI) education.

HCI is an interdisciplinary field drawing from diverse disciplines, including computer science, psychology, media studies, and design. Historically, the field developed in the early 80s as a specialty area in computer science, embracing cognitive science and human factors engineering. Although it has undergone strong development over the past three decades, it is still taught at computer science departments worldwide, usually as part of the core computer science curriculum. After graduation, the students who chose HCI focus during their studies tend to pursue many different paths, ranging from seeking further education and aiming for research careers to practicing interaction design, often also in design consultancies, or working as information system developers. Preparing such students for their future work is challenging. In addition to the diversity of career paths that they can choose, they always need to relate to changing technologies, interaction modes, and interfaces. These, in turn, affect people's work and leisure practices that HCI professionals design for. So, how and what to teach HCI students that will help them to have successful carriers?

HCI students, on the one hand, need to learn appropriate theories and research methods, as well as understand state-of-the-art research and the importance of scientific rigor and relevance. However, being a profoundly interdisciplinary field, HCI does not offer any unifying core theories, so this goal is hard to achieve once and for all. For example, entering a new application domain often requires the acquisition of new knowledge, understanding of the state-of-the-art research, as well as the ability to develop domain and context specific tools, techniques, and methods. Thus, constant learning is likely to be a part of the career path.

On the other hand, students need to be able to design new technologies and interfaces, using diverse design approaches, and usually, without any formal training in design. This is, in part, why design processes in HCI often depend heavily on engaging users and other stakeholders in participatory and co-design processes, described by Muller as the third space of HCI, see [2]. Participatory approaches that involve users and stakeholders in design processes are undoubtedly valuable, but they also carry with them certain limitations. For example, HCI design practitioners, in a co-design situation, share the design responsibility with participants, whom they often rely on as domain experts. Thus, the choice of participants may influence the quality of the results. As these results (prototypes), are frequently not intended to become use artifacts, but are tied to some research objectives, this is often not seen as problematic. This focus on research objective, in contrast to making a new artifact for use, reflects the major difference in approach to design between HCI and interaction design as taught in design educations. The latter, while utilizing human-centered approach, also relies on design practices that imply more open and creative approaches to design situations, with intent to make a novel product for use. The question we started investigation for this paper was: could HCI students benefit from the inclusion of design thinking and designerly practices as part of their HCI curriculum? If so, what kind of benefits/challenges would this yield?

Drawing on insights from the work presented here and our previous work [3]–[6], this paper argues that teaching about innovation, and engaging students in creative innovation processes such as design thinking, offers one possible answer to what kind of knowledge and skills the students could be taught in HCI. Adopting this approach may be successful in a long run because, while on the road to becoming an innovator within a design team, one usually experiences creativity (one's own or that of others) and need to adapt to new situations. Creativity and adaptability may offer greater permanent value to human-computer interaction education than many other kinds of knowledge and skills commonly considered to be part of HCI education. As reported in [5], all ten students in a graduate HCI course that made use of design thinking processes perceived themselves to be non-creative individuals at the beginning of the course. At the end of the course, all (excepting one student who felt neutral) stated that the design thinking affected them and that they now see themselves as more creative and confident in their skills. Thus, on a basic issue of whether the creativity can be taught, we can say that with proper tools and support, creativity can, at least, be nurtured [5]. We also observed an increased interest in invention among HCI students who participated in the course.

An additional indication that cultivating creativity could be a valuable asset was provided through a survey conducted at the end of a combined bachelor-master course in the fall of 2014. All design teams (18 teams in total, 3-4 students on each team) who participated in the class completed the survey. All teams reported that they now see HCI design as a creative process, and provided qualitative statements related to their experience of individual and group creativity. Some of these are presented later, in the discussion section of this paper.

In summary, the question this paper tries to answer is: what kind of knowledge and skills should be passed onto new generations of HCI students? While the complete answer remains elusive (many discussions around the HCI curriculum are already going on [7], [8]), our experience from the past two years of including design thinking and innovation (or, more precisely, increased focus on invention) in the curriculum shows that these benefit HCI students significantly. More open and creative processes seem to change how students that take part in such processes perceive themselves as HCI practitioners, and secondly, how they understand design processes, practices, and approaches to innovation.

The paper is structured as follows: the next section offers some arguments as to why HCI education should include innovation and creative thinking. In Section III, we show how these elements were introduced in a mixed bachelor-master HCI course. Discussion of the case is presented in Section IV, followed by the conclusion in Section V.

II. Focusing on Innovation

The ACM SIGCHI Curricula for Human-Computer Interaction defines Human-computer interaction as *"a discipline concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them"*, see Hewett et al. [9]. Teaching HCI typically includes the teaching of user-centered requirements analysis, design and prototyping, implementation, a design of experiments and evaluation. HCI's interdisciplinarity brings with it tensions between the breadth and the depth of teaching, diverse theories and practices, including the choice between contributing to science or to design (of new interfaces, products, services or interaction modes). Despite these tensions, HCI education is very much alive and doing well in practice, although still without generally agreed upon curricula.

Innovation, on the other hand, is known to be hard to achieve in practice, while it is very easy to understand the need for it, and the benefits it brings, see [10]. There are various ways to define innovation. The Oslo Manual [11] defines it as: *"the implementation of a new or significantly improved product (good, or service) or process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations."*

It is difficult to teach students to be innovative, creative and inventive. In particular, it is not easy to make good instructional frameworks for doing so. The processes related to innovation rely heavily on creativity, but also on both existing knowledge and on technical skills that are already present among the members of the design team and those whom they choose to include in the design processes. In particular, it is hard to define learning outcomes for such processes.

Within HCI, the creativity component is usually, at least partially, bypassed by two things: the framing of the process as a procedure that everyone can follow on the one hand, and relying on users and their participation in different stages of design processes on the other hand. The 'typical' design process consists of developing an understanding of the contextual domain first, and second, concretizing this understanding through practical work that involves iterative prototype design and evaluation, often in co-creation with users and other stakeholders. However, designerly and creative practices, a core activity of innovative design [12], [13] are, as already mentioned, harder to frame.

Purposefully managed innovation through design and creativity has been advocated in many different ways [14]. Design thinking is one of those options. Understanding design thinking is not straightforward. In [15, p. 13], Kimbell offers three different ways of understanding design thinking: as a cognitive style, as a general theory of design, or as an organizational resource. The last understanding lends itself well as an approach to innovation and real-life problem solving through human-centered design, employing empathy with users, rapid prototyping and abductive thinking as its main components. This understanding of design thinking has strongly impacted innovation in business, education, health and other crucial domains, see [12], [13], [16]–[18]. Many examples of how businesses and organizations could benefit from incorporating design thinking into their work and organizational processes were given in Brown's book [19], making design thinking into an efficient innovation engine emphasizing observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, synthesis and concurrent business analysis.

However, no approach solves all problems. Thus, only a few years after design thinking made a breakthrough in the world of business strategy and management, its limitations were brought forth in works such as Collins and McCullagh's works [20], [21]. The point made by

Nussbaum in [22], though, hits home best: *"From the beginning, the process of design thinking was a means to deliver creativity. But in order to appeal to the business culture of process, it has on occasion been reduced to a more linear process—presumably to eliminate the mess, conflict, failure, emotions, and iteration that are part and parcel of the creative process. In a few companies, CEOs and managers accepted that mess along with the process, and real innovation took place."* In short, the core of innovation is creativity, a messy and unstructured process. By framing design thinking in a particular, linear way, the creativity becomes limited, leading, in turn, towards failure to innovate.

Simultaneously, concerns are being raised around the failure of design processes currently applied within the field of HCI to support more radical innovation [3]. In particular, HCI design processes are held to lead mainly to incremental innovation and small changes. Innovation, radical or incremental, is a much more complex process than the design and invention of new products, systems, or interaction modes. It implies also their acceptance and use by people [11]. Upon careful consideration of design practices within HCI, one could argue that invention is common. However, a very small percentage of those inventions (prototypes) ever become finished products, and an even smaller percentage is adopted and used, see [4], [23].

Design thinking is only one approach to design, but it may be the one that is particularly suitable for non-designers and for multi-disciplinary collaboration. It employs, in part, steps similar to those often proposed in HCI: it frames its process in ways that have familiar overtones to those used in HCI, see Fig. 1.

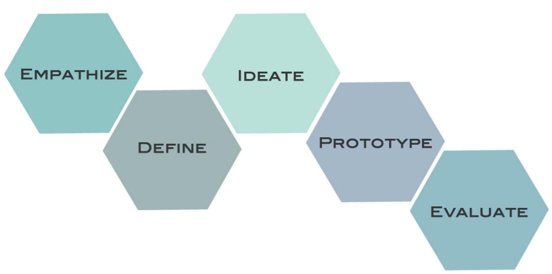

Figure 1. A process that may seem familiar to HCI students, as well as to those using design thinking. The image is adapted from [24].

Arguably, differences between design thinking and HCI should be sought by other means than comparing high-level design processes. One needs to consider differences in the assumptions, scope and aim of the design process – concerning, for instance, the role of research, the requirements specification, the questioning of assumptions, the consideration of organizational issues and the systematic exploration of design alternatives.

Design thinking stands on three main pillars: empathy with users and human-centeredness, rapid prototyping to generate a large number of alternatives in order to solve the correct problem rather than any given problem correctly (the creative part), and last, but not least, their synthesis leading to the best viable and feasible solutions that incorporate desired values, see Fig. 2 and [17].

IDEO [25], a design and innovation consultancy, has streamlined the process shown in Fig. 1 and made a 60 minutes version of it available to all, also non-designers. Although their process appears to be simple and short, its power rests on its capacity to initiate deeper engagement with the problem space and allow for organizational changes that support the engagement and creativity initiated by those short processes.

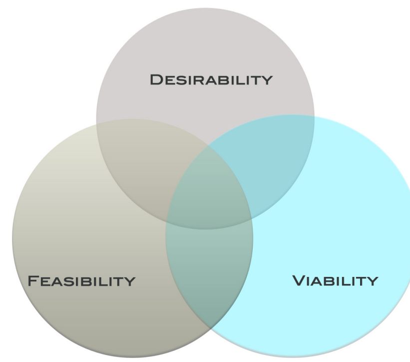

Figure 2. The solutions emerging from design thinking should be desirable, feasible and viable, i.e., belong to the intersection of the three.

As mentioned in the Introduction, HCI students need to master diverse types of knowledge and gain practical design experience. They are also expected to produce or develop new knowledge. In [26], Owen proposes a model for dual nature of knowledge production as depicted in Fig. 3.

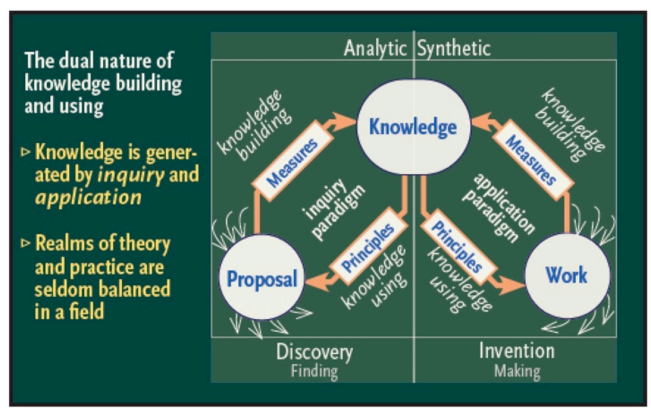

Figure 3. The dual nature of knowledge building, from Owen, [26].

Within interaction design, as practiced by HCI professionals, the research (finding, discovery) and design (prototyping, making) are often intertwined, involving knowledge of *techne* (programing, digital crafting), *episteme* (theoretical grounding) and *phronesis* (practical design knowledge). Production of new knowledge within these three (or any similar distinctions between knowledge forms) is also expected from students, especially those who are more advanced in their studies. Multiple roles that an interaction design student often assumes in any given project (that of a researcher, a designer, a programmer, or a crafter) further obscure the clarity of what this new knowledge is. In addition, he/she may have personal biases towards, or different levels of expertise in, either research, programming or design [27].

Fig. 3 makes another important point: realms of theory and practice are seldom balanced in a field. Papadimitriou's paper [28] discusses this topic in relation to the field of databasis; it considers the relation between theory and practice in the databases, summarizing what a good theory is and how applied science looks like during the 'normal' phase (referring to Khun's view on the structure of scientific revolution [29]). Papadimitriou searches for the equivalent of the concept of 'crises' in a non-natural, applied science field. As a possible contender, he proposes the lack of connectedness between theory and practice in the field of data basis. This is visually represented by a directed graph with very few paths connecting communities focusing on theoretical knowledge and those focusing on practical knowledge. At the same time, the theoretical community, as well as the practice-based community, had strong internal connections.

Similar arguments are true for HCI and its education. If the knowledge circle in Fig. 3 was further divided into diverse knowledge forms it would become even more transparent that there are too few connections between discovery and invention. A demand that the knowledge is relevant and rigorous exists within both discovery and invention. However, different criteria of relevance and rigor apply to different knowledge forms whose purposes, processes and contexts are also different [30], [31]. Navigating this landscape is particularly challenging for a novice HCI practitioners and interaction designers, HCI students among them, who wish to use HCI design and research through design approach, see [32] and [33], and who need to address knowledge production related to all these diverse knowledge forms and establish both relevance and rigor in their work.

So, why make the teaching of HCI, even more, complicated by explicitly introducing creative thinking, using design thinking and innovation?

III. The Case: Teaching HCI with a Creative Wree

A. *Previous Classroom Experiences with Design Thinking*

During the fall semester of 2013 two student project teams, from a combined bachelor-master course in interaction design, were introduced to design thinking. These teams worked with the design of new services for the University Library. They were introduced to design thinking and participated in workshops using service design methods and tools, such as service design cards, touch points and customer journeys, see [34].

Besides, during the same semester, a small graduate course of ten students, mentioned in the introduction, adopted the design thinking approach and studio-based teaching. There, three student groups were taught about design thinking and focused explicitly on nourishing creativity [5], [6]. They were also required to read articles like [33], [35]–[39], to gain a deeper understanding of research through design and designerly practices. In addition, successful examples of applications of design thinking were discussed [17], as was the work reflecting on the design practice and possibilities for understanding daily practices as a design material, see [30], [40].

Experiences from both classes strongly indicated that cultivation of creative thinking and making have a potential to contribute positively to the teaching of HCI.

B. *The Course Setup*

The teaching approach that we argue for in this paper was applied in the context of a combined bachelor-master course in interaction design. The course in question teaches traditional HCI research methods, using the textbook [41], and has two prior HCI courses as prerequisites. In addition to teaching research methods through lectures and small group learning sessions, the course aims to address real-world problems by offering a semester-long project in cooperation with external, local organizations. Usually, ten or more organizations (or large, funded research projects) are involved, offering two distinct project proposals each. Students, in small design teams of 3-4, select one of the proposals, based on a first-come-first-serve basis. The project work is, thus, anchored in the real needs of local companies and organizations. Sometimes, these needs are not clearly formulated. Rather, a company wishes to renew its offerings and engages student teams in looking for new, open and creative solutions. Some student teams have experienced such open requests as challenging. The insight that demand for novel and creative solutions could be challenging was gained through observation that proposals with a narrow scope and clear goals were almost always selected first while explorative problems were chosen last.

The students in the course were further supported (or challenged) in their learning efforts as follows: they were free to make mixed master-bachelor student groups, but master students needed to have a deeper focus on knowledge and knowledge production. Thus, they were required to read, understand, and actively apply previous research related to their projects. This implied finding published research of high quality and discerning its relevance to their projects. Both master and bachelor students needed to find examples of relevant previous design work. Furthermore, all teams had regular, hour-long design feedback sessions during the conceptual design and prototyping phases of the project (usually during the first 4-5 weeks). One senior researcher and a representative of a company, for which the students were designing, were required to participate in these sessions. Also, all groups made in-class, midterm presentations of their design efforts. The presentations were open to anyone, from interested organizations to other faculty members, professional designers, and junior students. They were also available online, see [42].

The course ended with a juried competition for the best student project, again with open access to the event. An independent jury consisting of three judges, recruited among HCI, design, and pedagogy professionals, judged the contest. Criteria for the jury were: novelty, clarity of presentation, the potential impact of the designed prototype (its relevance), validation of the prototype with users and the overall impression of the project work. This exact setup has been run for three consecutive years and has included a survey at the end of each semester. The surveys were individual and optional previously, focusing on cooperation with industry and research partners. Last year's survey was filled by all design teams and included questions about creativity, group or individual, and how design processes were affected by the introduction of creative and design thinking.

Although the course addresses real-life problems, which in non-academic settings would likely be solved by multidisciplinary teams, multidisciplinarity was not always possible to achieve in the context of this university course. In other words, teams could not invite others whose expertise could contribute significantly to the quality of designs and prototypes (for example, a highly skilled programmer, designer or engineer). Multidisciplinarity was anchored in the skills and knowledge that students had in addition to HCI, such as psychology, graphic design, or arts and in skills and knowledge of those that they collaborated with, such as librarians, museum professionals, software developers and others from participating organizations. Students were encouraged to understand the assemblages of skills and knowledge that they had within the team, and consequently organize work so that their skills could be used well, but also so that they could learn the most, from each other, organizations they worked with, and senior researchers.

C. *The Use of Creative Thinking and Innovation*

The teams were free to choose and follow an approach of their choice, as long as they complied with general course requirements described above. The challenge was how to best support the creativity within each team. A lecture on creative thinking and design thinking was given at the start of the course, introducing concepts of assemblages of skills and practices. The idea that one can design and adopt a set of practices that support creativity was also introduced in [5]. This was further practically demonstrated and re-enforced during design sessions.

In addition, all available external opportunities were sought out and used to motivate students. For example, last year, during the fall semester, the dean of the University extended an innovation challenge to all students at the University of Oslo, whether they study science, politics, social sciences or entrepreneurship. The most innovative idea was rewarded both financially and through support for its further development. The students participating in the innovation challenge had to go through several selection rounds, until the winner was chosen. All student teams in the course were encouraged to participate. Two teams took up the challenge. This has, in addition to the usual interaction-design course work, involved making a financial proposal and a business plan for implementation of the innovative idea/proposal, and a proof of the feasibility, essentially following the idea behind Fig. 2. Students did not have any prior experience with such processes yet managed to make a financial and business model for their ideas. Both teams were selected among the top four projects (although neither ultimately won the first place).

However, when judged independently in the context of the course and during the final competition, they won the first and the third place (from the total of 18 teams), indicating that they were highly motivated by the innovation challenge.

Each of the two teams in question consisted of four second year undergraduate students, and was supervised by a PhD student whose research focused on elderly living in a smart house. Thus, both projects addressed design for and with elderly users in that context, see [43] and [44] (projects were delivered in Norwegian, but one group also wrote a paper based on their project in English, and presented it at the HCII 2015 conference, see [45]). The latter project, see Fig. 4, developed a high fidelity interactive prototype utilizing low frequency-based technology (iBeacons) that helps elderly people with cognitive difficulties to navigate complex buildings indoors. Their system aimed to improve the well- being of elderly people and help them become more independent by introducing a familiar design on the tablet that was already in use as part of the smart house solution, and integrating it with a pre-existing aid, a walker.

The use of the smart-walker with the tablet that presented data from iBeacons, required mastery of the technology every time it was used. However, this task was made to be as simple as possible. SmartWalker enabled users with cognitive difficulties to move easier around on their own, giving them an increased degree of freedom of movement inside the complex building where they live.

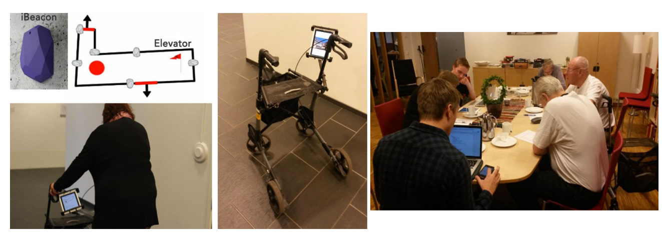

Figure 4. SmartWalker: a system co-designed with elderly and based on a low frequency technology and a simple visualization of the current position in the building on a familiar tablet interface. Photos from [44].

The second project [43], see Fig. 5, focused on self-management and bodily mastery through movement, see also [46]. It involved design of an exercise system for elderly users. The system was based on a motion sensor (Kinect), and wearable technology (a glove, powered by Arduino, that enabled more precise tracking of movements). The system provided feedback on whether exercise was performed correctly, and was designed to support bodily mastery and well-being in general, and in particular for those who needed rehabilitation and training after, for example, a fall.

This project involved 26 persons, 17 elderly, 3 physiotherapists and 6 employees in diverse homes for elderly.

Figure 5. An exercise system that enables correction of movements during the exercise session. Photo from [43].

Even though these two groups have achieved very good results, they were not the only ones that pursued the goal of being innovative and creative. Some other ways in which this focus on creative thinking and innovation affected the work of the project teams, with examples, is discussed in the next section.

IV. Discusion

The contextual differences among briefs presented to students by organizations that participated in this educational endeavor were substantial. Some teams were required to find new application domains for existing technologies, others to design new applications involving new technologies and yet others had to use old applications and old technologies, but find new ways of working with them. For example, a team had to work with the latest technology such as Google glasses and their potential use in crises situations by crisis management state bodies, such as the police, or paramedics. Another team had to work with complex web-based software used in the oil industry that required creative thinking around how to help users to customize it. What, then, about knowledge building and the best approach to it, for individuals, teams, and the class as a whole?

A. Arbitrage, Bricolage and Assemblages

Reflecting on alternatives and knowing why design processes involved certain tools, techniques and methods was a course requirement. This was seen as part of the knowledge production process, either in support of the scientific methods or in support of establishing reflective designerly practices, see [30]. Arbitrage was used to discuss what the 'new knowledge' is in each case, and how to communicate it.

Arbitrage is a concept used in economics and has to do with price negotiations where one capitalizes on striking deals that profit the most from imbalances between prices on similar items at different markets. Translated to interaction design, one might want to strike the optimal balance for similar work in terms of regarding differences in knowledge among practitioners and researchers working closely together. Over time, this strategy could increase links between research and practice in interaction design.

The issue of knowledge production has been a recent topic of discussion in interaction design and HCI communities. The discussion was concerned with how research through design in interaction design and HCI design, produces new knowledge. What forms this knowledge takes and how to frame questions around it has been a topic of a recent CHI workshop [47].

If students worked alone, arbitrage perhaps would not have been as effective, since they all have similar knowledge bases. However, the involvement of senior researchers and industry partners (most of whom are practitioners) was required, in part, to provide fertile ground for negotiations around knowledge production and design artifact created.

Bricolage and *assemblages* are terms used by Levi-Strauss [48], as well as by many others. We have experimented with implementing the practice of bricolage, both in the sense of using multiperspective research methods and seeing what 'fits' best in relation to the problem at hand, and as the practice of design and making that constrains design space in some way (in our case, material expenses needed to be minimal, and students were encouraged to use in-house resources). Assemblages of skills and practices were used as described earlier in the paper. With bricolage, also assemblages of materials were relevant. These concepts appeared to be useful in supporting creativity and a better understanding of a design practice in HCI education, see [5] and [49], while also improving students' analytic skills.

The practical application of these concepts in design processes was not yet carried out systematically. Both the assemblages of skills and practices, as well as arbitrage, were processes that could be applied where there was true multidisciplinary within the team. Then the participants were asked to explain their approaches or demonstrate their skills so that others could gain an understanding of what those are and include them actively in the decision-making process. This process was also beneficial in terms of preventing too early fixation on any given solution, having first to get acquainted with people's skills and practices, postponing the need to fixate on a solution fast, and instead, give time to consider the resources within the team and how these fit together. The bricolage was most relevant for projects where students were building or constructing an artifact using materials at hand and trying various techniques and methods in their work.

B. Design Thinking and Combining Approaches

The vast majority of teams benefited from being inspired by at least one of the three main components of design thinking: empathy with users, rapid prototyping, or abductive thinking. The use of any specific method, including design thinking, was never enforced, so teams could choose to use any component of design thinking, none or a combination of design thinking with other practices used in industry, and more traditional HCI approaches. Yet, as mentioned above, the negotiations needed to be done (arbitrage) as to which approaches fit best relative to the problem at hand.

Empathy is a multifaceted construct that includes emotional recognition, vicarious feeling, and perspective taking [50]. Empathy was 'new' for many HCI students. While students were used to conducting user studies, they seldom tried to take the place of a user themselves and develop empathy with users in that way (e.g. through role-playing). In part, this might be due to the perception that basing the design decisions on empathy, the 'scientific', objective component of the research is lost in favor of the subjective (emphatic feelings of the HCI designer). Another reason might be that the phenomenological perspective that is characteristic of the latest wave of HCI, is still lagging behind in HCI education. Regardless of the reason for empathy's 'newness', once it was tried, the students understood its benefits and could apply it creatively when working with conceptual development of their solutions.

As an example, two teams were engaged in designing for better waiting room experiences in children's wing of the hospital. Being empathetic observers in the hospital's waiting room brought insights that whatever it was that they would end up making, it had to respect young patients' right to have a quiet and safe (e.g., germ free) waiting room. They could engage young patients, alone or with others if desired, in technology-mediated interaction, but it had to be easy to choose a non-engagement as well. What students learned from empathic observations eliminated many of the initial ideas they had. They worked extra hard in order to find novel and engaging solutions that also meet all the above-mentioned conditions. The end results of design and research efforts were the following: the first team developed a water fountain, Fig. 6, and the second team a dress-up game. The LED lit fountain was controlled by in-air hand gestures, enabled by the Leap Motion sensor, not requiring any physical contact. It was fun to play with, nice to look at, and it had a pleasing and very soft sound, see Fig. 6 and [51]. The breakthrough for this group was achieved after they experienced empathy with young patients and understood how to translate this empathy, together with other findings, into a design opportunity.

Figure 6. The water fountain project. Photos from [51].

The second team utilized the Kinect motion senor to support their dress-up game, again requiring no physican contact with any objects in the room. The game, see Fig. 7, could be played by a single child, or by multiple participants. In the stand by mode, it was non-intrusive and easy to ignore. Attention was paid to special situations, such as players in a wheel chair, and players with otherwise different movements (for example, slower than usual, as a result of fatigue).

Figure 7. A dress-up game for young patients waiting for an appointment, see [52].

Rapid prototyping, the second pillar of design thinking, was also frequently used. Once students understood that they were to generate many simple prototypes, not just one or two, they found that communication of ideas became easier and clearer, in particular when group members had different backgrounds and levels of knowledge.

The following case demonstrates how the two teams working with service design for the University Library went about rapid prototyping. A workshop was organized by one master degree student, and apart from the two teams, two researchers, one designer and eight librarians attended the workshop. The participants were divided into two groups and engaged in bricolage and rapid prototyping, see Fig. 8.

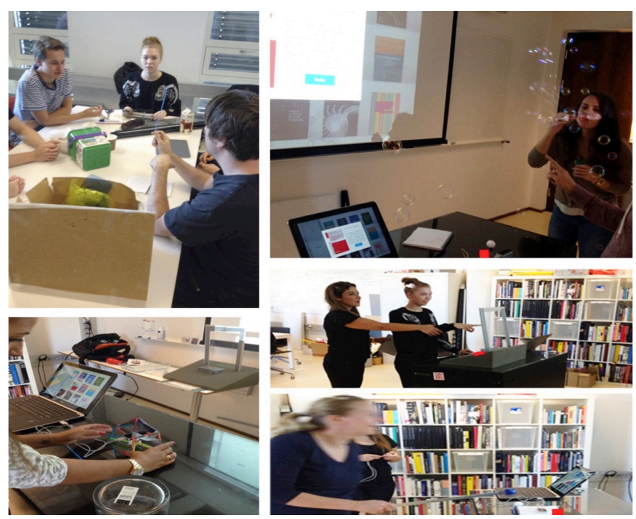

Figure 8. Making rapid prototypes of an intermediary surface in order to enable better precision when using LEAP motion for selection of books, see [53].

Everyone was to make as many prototypes as possible in the given timeframe. The problem they worked with had to do with reducing precision problems arising from the gesture-based selection when using the LEAP motion, in a multi-user situation. The second and longer part of the workshop was dedicated to discussion related to the prototypes made. The library experts could at once provide information on existing services, and how each of prototypes could fit with the existing services (or not), discussing the viability of proposals.

The last pillar of design thinking, abductive reasoning, was used to discuss how good parts of some of the prototypes could be combined to make a better prototype. The feasibility of diverse prototypes was a prominent part of this discussion. Abductive thinking and the ability to 'see' design opportunities by combining aspects of diverse proposals may be something that comes easier to people within design disciplines, rather than those using analytic way of thinking. The participating student teams clearly benefitted from being a part of this process, at least by gaining an understanding of what rapid prototyping and abductive thinking involve, as well as the relevance of concepts presented in Fig. 2.

C. Survey results

A short questionnaire, consisting of three questions only, was conducted after the initial 4 weeks of instruction, during which time the students were encouraged to remain open, not to "jump" to a particular solution, but instead, to take the time to feel the discomfort of not having a solution yet, and actually exploring the options. 30 students answered the questionnaire.

The first question was phrased as follows: *"In the design process you now have started, how did you feel about the request to keep the process open and resist the desire to use the first opportunity to define your solution and work towards accomplishing it"*. These are some answers to the question: *"I believe that this is more enjoyable and challenging. However, it can be tempting to jump right into solving a problem, and it is important to try to avoid this"*. *"It is difficult to keep yourself from starting to implement the first idea that one comes upon. One also thinks that if the solution is good enough, then one saves time and money by jumping over, maybe, an unnecessary process"*. *"Curious, hesitant at first"*. *"I actually think it is exciting. You know – the part of the process when everything can happen. I love being creative and I love creating ideas. For our group's work, my strategy was to make use of the small sketchbook our supervisor gave us. I used it to sketch ideas even if it was very early in the process"*. These answers reflect a willingness to engage in open processes. They sometimes expressed the discomfort and sometimes the joy of having an opportunity to do so.

The second question was phrased as follows: *"Can you think of anything that instructors could do to help you with keeping the process open and creative?"* Some of the answers here indicate a worry that they will somehow not have enough time to do the "real work", or lack of understanding of how they can accomplish all the goals laid out for the course: *"Even more real-life examples"*, or *"being clear about how much/what is expected of us"*, *"creative tools"*.

The last question was open, requesting *"Any comments on creativity in design processes?"* Most people did not answer this one, or answered it with a simple *"I like it"*. Some other comments included: *"It is hard, without knowing the defined possibilities"*, *"Tips about places one can find inspiration"*, *"Background differences are good"* and *"look to choreographers – they have an idea they want to explore – each dancer contributes with their movement material"*. This last remark expresses the same idea behind discussing the assemblages of skills, practices and materials.

At the end of the last semester, all teams filled a questionnaire, providing 18 sets of answers. Two questions were related to creativity:

1) Do you think that the kind of work you did in this course is also creative?
2) What do you think about group creativity?

All teams answered the first one in affirmative. As for the second question, here are some of the answers (the answers were given in English, as presented, only the very last statement was translated from Norwegian): *"It really helps. Quite often you have some ideas, but you need help to be able to explain them. So in our group we really understood how each other was thinking, and we could really help each other describe and realize our ideas and creativity."* Another team expresses it as follows: *"We have a group of different people with different ways of thinking, stirred together in a creative pot, it's awesome"!* The third considers that the *"group work increases creativity"*. The two most cautious expressions were the following two: *"We feel that the group works very well together, although this experience may vary"*, and *"Very good! Perhaps a bit too creative and ambitious"*.

D. Analysis

During the past three years, much experience was accumulated with project-based courses such as the one described in this paper. Lots of anecdotal evidence as to what works and what does not has been gathered and best efforts made to design a course that teaches HCI with a focus on creativity and innovation. Clearly, both theory and practice needed to be well represented in such a course. Things are not made easier by the lack of theory as to how interaction design produces new knowledge [47], what makes a prototype novel [54] or how to bridge (connect) diverse theoretical concepts and theoretical concepts and practice (see Fig. 3). Arbitrage (facilitated by a senior researcher or designer) helps discuss, understand and choose tools and methods that fit the context and design space. It is difficult to build directly on design and creativity in HCI due to the lack of design knowledge and frequently experienced insecurity among students in their capacity to be creative. Creativity is often confused with being artistic. However, through the work with the course, we see evidence that designerly practices, including bricolage and design thinking, are highly relevant tools for supporting creativity among students, conducting projects in the described setting. Multidisciplinarity is important, considerations of different practices often open up for new ways to be creative and learn in the process. The multidisciplinary exchange is facilitated well by looking at group composition and assembling all skills and practices in a short session at the start of the work on a project, which also facilitates getting to know other members of the project team. Students' answers to questionnaires confirm these findings.

The class as a whole learns to trust the process by having common presentations and demonstrations during the semester. Hearing and learning about different approaches, but also experiencing the results they produce, is very important. The close contact with the outside institutions, and a senior researcher or designer (often a PhD student), helps keep the processes within the framework of the course, as well as it utilizes their tacit or scientific knowledge for moving forward their work and learning through both classes and designerly practices.

V. CONCLUSION

The aim of this paper has been to inquire into the interplay between innovation, design thinking and creativity as educational channels that stand out as alternative or complementary to the ones traditionally used by HCI educators. The framework for learning about innovation, design thinking and creativity was introduced and explained. This setup has been repeated for the past two years and may be repeated by others. The concepts that have been helpful in the cultivation of creativity were assemblages of skills and practices within multidisciplinary settings, empathy, rapid prototyping and abductive thinking. At the same time, care was taken not to reduce working with them as a specific procedure. Rather, tools, methods and techniques needed to be reflected over and chosen in accordance with the problem at hand. Experimenting with, or, at least, negotiating choices of research methods and techniques was encouraged.

Further research is required regarding other frameworks and practices for supporting creativity and innovation in HCI curriculums, including a comparative analysis of outcomes.

The achievements and learning outcomes in the course described here has kept improving over the last three years, as frameworks for supporting innovation and creativity got better and clearer described. The students' understanding of processes has also increased over time. These findings indicate that design thinking contributed to increased focus on innovation and creativity, as well as helping to keep design processes wider and more open for a longer period, fostering increased flexibility and adaptability in learning processes. Added creativity and adaptability may be the best long-term goals that HCI education can add to its curriculums when preparing students for future work practices.

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