

Ubiquitous Computing Education: Why, What, and How

Edited by

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Abstract

This report documents the program and the outcomes of Dagstuhl Seminar 19232 “Ubiquitous Computing Education: Why, What, and How”. The workshop gathered 26 faculty members and one undergraduate student to discuss the current state of ubiquitous computing education, and how the training and education in this domain should evolve. We provide the motivation for the seminar and an overview of the activities. The outputs of the seminar include laying out the challenges of teaching ubicomp (WHY), proposing a ubicomp curriculum based on various types of students (WHAT) and innovating active learning methods for ubicomp (HOW).

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1 Executive Summary

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This document summarizes the insights gathered during the seminar. We first provide an overview of the motivation for this seminar before presenting an overview of the activities that occurred during these five days. We then provide a series of outputs that we gathered in addition to the list of abstract provided on the website.

1. Motivation

Interactive systems are becoming increasingly complex and diversified, often comprised of multiple interconnected devices, with many different functionalities. They are slowly merging within our everyday objects. Such systems are becoming ubiquitous. Ubiquitous computing, or ubicomp, is a multidisciplinary field of study that explores the design and implementation



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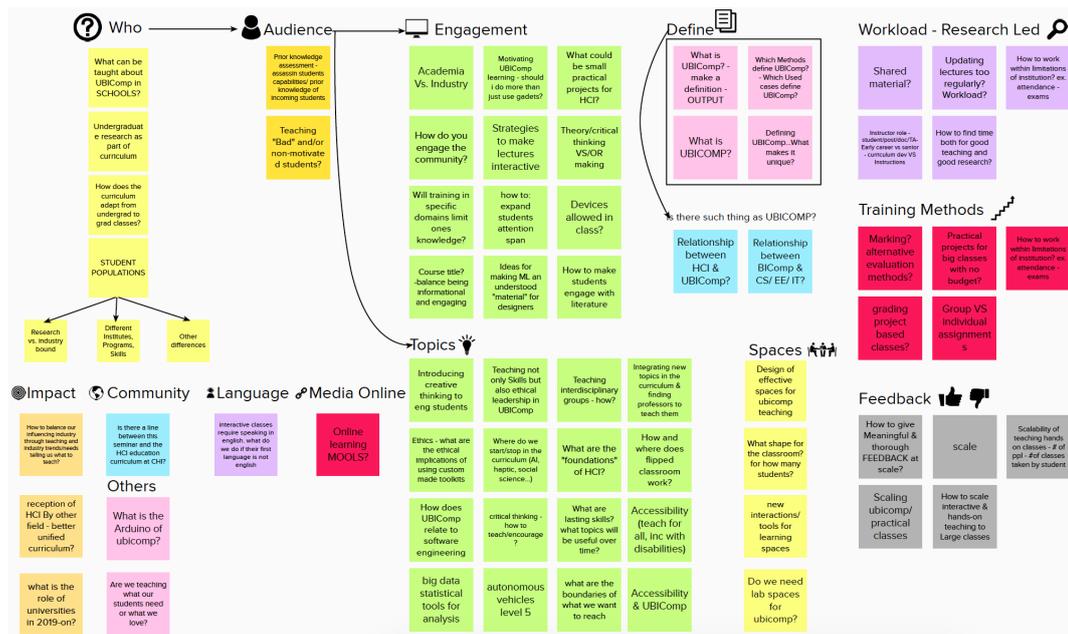
of such embedded, networked computing systems. Due to the novel aspect of the technologies involved and the multidisciplinary nature of skills needed to design such systems, teaching and training new innovators in this field are not well addressed through traditional programs and instruction. Consequently, it is important to ask several questions about the training and education needed to help students become valuable members and leaders of ubicomp teams. Three central questions about ubiquitous computing education emerge: why, what and how, with the goal of enhancing ubicomp education through interdisciplinary perspectives:

- **WHY** is training in ubicomp needed? Is it enough to train experts in narrow domains (e.g. those who can create low-power embedded circuits, or those who can make usable applications), and then bring them together in teams that will tackle ubicomp problems? Or do we need specialized training that targets ubicomp in addition to domain expertise? There is broad consensus that we do need specialized training, but often this argument is based on intuition and anecdotal evidence. We approach this question by first asking: what are the grand challenges that we expect our students to tackle in the world (e.g. privacy, sustainability) by inventing and developing ubicomp solutions? Next, we ask: who can better address the challenges: teams of domain experts, or teams where at least some team members have specialized ubicomp education? Answers to these questions will clearly identify problems that might exist with current ubicomp educational approaches.
- **WHAT** should constitute training in ubicomp? Once we identify the grand challenges, we need to ask further questions. What are the values, knowledge, and skills we should train students in ubicomp? What are the topics that should be covered? How do these depend on the background of students or their degree program? Answers to these types of questions will allow us to set goals for ubicomp education.
- **HOW** should we teach and engage a diverse body of students? Once we identify specific goals for ubicomp education, we need to ask ourselves how those goals can be achieved. How does the unique nature of ubicomp challenge the current pedagogical approaches? How can we create new pedagogical approaches for teaching and training in ubiquitous computing? Answers to these types of questions will help create the appropriate tools to reach our ubicomp education goals.

2. Overview of the activities

Our goal was to create a community to support new forms of teaching, training, and learning in ubiquitous computing. Our activities were centered on our main questions:

- Day 1, we explored the **WHO** and **WHY**. Each participant presented briefly their research and current teaching, and highlighted what they see are the main challenges for teaching ubicomp in the morning. We then brainstormed and discussed why it is important to rethink the way we teach ubicomp material and what are the grand challenges associated to this change.
- Day 2, we explored the **WHAT**. In groups, we defined the curriculum for Ubicomp education for different types of students, different degree levels, as well as identified what are the learning goals. One discussion that came up relating to the limits of Ubicomp material, specifically how complex it currently is to define what is ubicomp.
- Day 3, we explored the **HOW**, and particularly brainstormed about the challenges related to ubiquitous education. Participants generated a list of their current active learning methods or tools and exchanged them in a speed dating fashion with each other.



■ **Figure 1** Grand challenges of teaching Ubicomp (from a motivation point of view).

- Day 4, we explored further the HOW. In groups, we developed and experienced new active learning pedagogies on ubiquitous computing topics. We also discussed pedagogies for academic ubicomp programs.
- Day 5, we wrapped up the seminar and plan for concrete actions for the future, in particular, ideas for the next Dagstuhl seminar.

3. The challenges of teaching Ubicomp (WHY)

Figure 1 illustrates the grand challenges of teaching Ubicomp from a motivation point of view. We have identified several themes including (1) who is the audience in terms of diversity, motivation, population; and how (2) these aspects particularly impact their engagement and what methods can we use to better engage with students. We also talked about the difficulty that Ubicomp brings in terms of being a multi-disciplinary field and we highlight the fact that it is difficult to choose (3) which topics should be covered and which ones should not be covered in a particular case. What are the boundaries of Ubicomp? In fact, our discussions highlighted that there is not a clear (4) definition of Ubicomp. We talked about (5) issues with the high workload of both teaching and learning about ubicomp, and how research-led teaching could alleviate some of these issues. We discussed (6) scale issues, i.e. how to teach to a large number of students (and provide feedback) when it seems that certain aspects of Ubicomp teaching (e.g. workshop activities) can only be taught to smaller groups. We pointed out the issues of (7) space and that Ubicomp teaching is based on traditional classroom but also new types of spaces such as workshops, hackerspaces, and maker spaces. Furthermore, we discussed other media types such as (8) online lectures. We also discussed more general topics such as (9) the impact of ubicomp (e.g. on business and industry) and the future of universities and how this relates to ubicomp education.

4. The Ubicomp curriculum (WHAT)

Table 1 illustrates the topics central to Ubicomp Education brainstormed during the seminar. We split the participants (including the organizers) in four groups designing curriculum (standalone lecture or program) for different students (undergraduate UG or postgraduate PG) and technical (Computer Science) or non-technical (Interdisciplinary) background). We wish for this document (that we also plan to put onto our online web platform) to be used as guidelines for teachers in order to provide a better and unified Ubicomp curriculum across different institutions and countries.

5. Existing active learning methods for Ubicomp (HOW)

Figure 2 illustrates the grand challenges of teaching Ubicomp from a method's point of view. This was the result of a brainstorming with participants following the curriculum creation. We found that (1) managing the workload was a theme recurring again (as we also mentioned it in the initial brainstorming in Figure 1). We noted that one difficulty of teaching Ubicomp was (2) the lack of differentiation with other CS, HCI or Design teaching material. We also thought this could create issue in (3) attacking certain types of students and that possibly, depending on the demographic, different terminology (Ubicomp, Interactive Systems, Interaction Design etc.) might be used. We raised issues in (4) evaluation and assessment potentially raised by (5) the interdisciplinarity of the community which makes it hard to assess student but also to teach so diverse material. We discussed issue in (6) engaging with students and enforcing skill acquisition (surface vs. deep learning). Finally we also add other issues such as (7) scaling of students, (8) project styles, (9) reaching to real end-users, (10) having input from industry and the (11) format of the lecture (e.g. online). We finally discussed about the issues raised by (12) admin and physical resources.

To build on participants' past and current experience regarding education, we also asked them to share both memorable experiences as well as active learning methods. For the former, we wanted to gather memorable educational moments, anecdotes that stayed with participants long after, as means to both remember the impact that we have on others, as well as get inspiration when designing new activities or methods.

We finally asked participants to share three teaching active learning exercises or methods, ones they currently use in their teaching materials, or ones they experienced in the past. They shared their methods, in a one on one, speed-networking format. In two minutes, they explained one of their ideas to another participant. After the speed-dating, participants placed their basic descriptions on a board and voted for the ones that seemed relevant to their courses. This activity sparked interest for material sharing among participants and ideas on how everyone could implement some of the approaches in their own contexts.

6. Innovative active learning methods for Ubicomp (HOW)

The next main activity focused on generating new educational material that may be difficult to generate, or missing, from a current curriculum. Participants formed six groups, they selected a topic, and investigated new active learning methods as well as initial teaching material related to the topic. The specific topics for each group were selected from topics and challenges highlighted earlier in the seminar. Next, groups formed pairs of groups, and

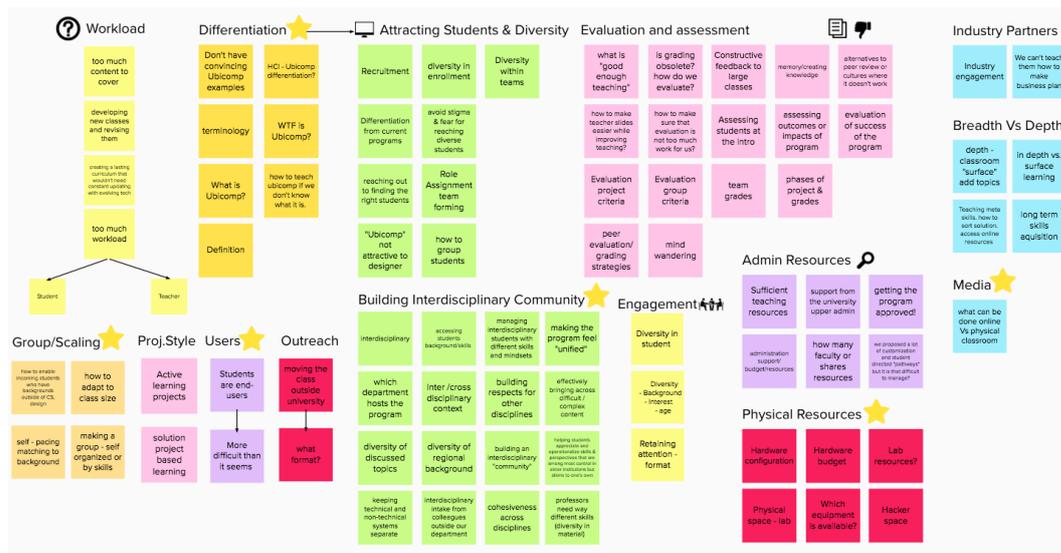


Figure 2 Grand challenges of teaching UbiComp (from a method point of view). A star corresponds to a challenge specific to UbiComp while other are general to teaching.

each group tested their content and methods on other group and received feedback, before iterating on their design. Finally, teams presented a summary of their new materials to the group (Table 2).

From the discussions following up the presentation we also noted some actions to do:

- Create a repository or playlist (youtube) or videos that can be used within the community and define what is UbiComp.
- Ask participants to upload a 2 minutes video of their definition of UbiComp that can be used in class to show the variety of what people think is UbiComp.

7. Future Steps

Although this seminar addressed many questions the organisers had originally highlighted, it also opened new exciting directions to explore and new challenges. To start addressing them we identified the main following avenues for future work and future events:

- Follow-up Dagstuhl seminar on writing a textbook
- Follow-up Dagstuhl seminar focussing on the industrial side, e.g. what skills do students need for the society we will built in 5/10/20/50 years?
- Using the website to keep the community alive as well as the access to material, and also create a video channel to create a repository of ubicom examples.
- We also have discussed about 3-4 follow up papers to be written among participants and organizers.

■ **Table 2** Innovative content and activities for Ubicomput education.

Topic	Content	Activities
What is Ubicomput (Ellen, Jakob, Michael)	<ul style="list-style-type: none"> Multi-media video presenting Ubicomput and that the whole community can use + show examples of real life Ubicomput (or fictional life on movie) Have a good and bad example of Ubicomput repository video They showed a video of the construction worker in traditional set up and new (with new digital tool) Introduce key concepts (e.g. calm technology, Weiser, disappearing computer etc.) ILO: Identify concepts in showed example / explain the example using appropriate terminology What is Ubicomput? let's people define HCI. It is too big to propose a definition because the edges are so blurry. But this is may be not a bad thing (although students may ask us what it is). What is Ubicomput? May be it is about designing interconnected devices while removing the stress of having so many devices to deal with. (from a user point of view) 	<ul style="list-style-type: none"> Make them watch videos and read paper and write a definition of Ubicomput (plus sketch) Definition of terminology (e.g. Cliff notes or cheat sheet) Give examples of categories of things that can disappear (e.g. task, physical computer) and ask students how would you make it disappear. Repository of video or youtube playlist?
Electronics (Tim, Brygg, Thomas)	<ul style="list-style-type: none"> Use three examples ("schools") of building new Ubicomput devices using simple electronics and use these examples all along the course. Three layers of increasing complexity to focus on are sensing, actuating, computing. Having a 30 minutes version of this as well. 	
Electronic (Nicola, Jessica, Jeremy, Andrea, Simon)	<ul style="list-style-type: none"> 110 minute lecture about sensors part of a more general course on physical computing Here focus is on hardware so code is not the focus and is prepared (download and pre-assemble circuit). Basic of resistors (sensing as a variation of resistance) 	<ul style="list-style-type: none"> Before class: they get material and they assemble and glue together a sensors (plus papers material). They will end up with different sensors Motivating by showing famous consumer devices and show how it is inside and this is "sample" Show what's inside a resistor Find out about the mapping between the sensing value we are getting and the actual response (e.g. acrylic overlays to change the light coming to a sensor) Collect all broken device and identify things inside.
Interfaces (Aake, Michael, Sylvain, Donald)	<ul style="list-style-type: none"> Design space to describe the dimension of interacting with Ubicomput. Show example of Ubicomput visions and show where they are in the design space. It may be good to show old video trying to predict the future to show what things are changing. may be why defining Ubicomput is hard. Are they future of the past? 	<ul style="list-style-type: none"> Activity 1 "understanding possible ubiquitous interfaces: gave existing material and let students place them in the design space" (the mock up activity show this may be a good activity). Activity 2 "Dismissing with ghosts" (Donald use it already): This is kind of a wizard of oz design where two students are ghosts and actuated things around and the user is blindfolded. The ghost help them through the world by actuating things around. Bank of videos example
Research methods (Caitlin, Miriam, Vicky)	<ul style="list-style-type: none"> For interdisciplinary class (40 min) ILO: Identifying research question, making a hypothesis, identifying variables, operational definition and study design. 	<ul style="list-style-type: none"> Give hypothesis example, e.g. "the time of the day will improve your grade". Ask "Is your hypothesis falsifiable"? Activity around what is measured in terms of the dependant variable and how to make sure the measurement fits with the hypothesis. Watch a short video, come up with a question "does self driving cars cause more accidents". Giving example of wrong design or wrong set up and make them find why and where are the problems.
Implication (Aurelien, Eva, Rizanna)	<ul style="list-style-type: none"> Use integrated approach to talk about the implication during the entire course rather than in a single lecture Topics as dimensions to discuss within a diagram they proposed (see Radar diagram in the reading list) Show the "what our smart devices know about you" (TED talk) 	<ul style="list-style-type: none"> Use case studies to discuss impact of technology or architecture choices on impact topics (from the diagram) as well as other factors. Exercise with critical review of certain system can be done. Repository of use case examples (e.g. Amazon dash video, google glass, autonomous cars, Alexa etc.) "Common thread" with a visual so students know when the implication is discussed during an entire program.

8. Reading list

We collected a reading list that addresses the why, what, and how of ubicomp education, designed for educators.

- Pervasive Computing Education, Audrey Girouard, Andrew L. Kun, Anne Roudaut, Orit Shaer, and Andrew L. Kun, IEEE Pervasive Computing, Oct, 2018.
- Teaching Pervasive Computing in Liberal Arts Colleges, Orit Shaer, and Evan M. Peck IEEE Pervasive Computing, Jul, 2018.
- The Fuzzy and the Techie: Why the Liberal Arts Will Rule the Digital World, Scott Hartley
- Fixing Tech’s Ethics Problem Starts in the Classroom, Stephanie Wykstra, The Nation.
- The Pervasive, Embedded, and Mobile Computing Curriculum – Preparing Computer Science Students for the Technology of the Future, Jakob Bardram, 2012
- Bridging the Gap Between Teaching and Research: A Case Study for Engineering & Applied Science, Anne Roudaut, Higher Education Pedagogies 2019
- Krumm, J. (Ed.) Ubiquitous computing fundamentals. CRC Press, 2010 (fairly outdated by now)
- Rowland et al. Designing Connected Products. O’Reilly 2015 (on Design of IoT products, with a broad range of topics ranging from networking aspects, architecture to product design)
- Landay, J. A., & Borriello, G. (2003). Design patterns for ubiquitous computing. *Computer*, 36(8), 93-95.
- Electronics books from “Make” .
- The radar diagram <https://scottwhyong.com/teaching/information-ethics-privacy-spring-2018/>

2 Table of Contents

Executive Summary

<i>Audrey Girouard, Andrew Kun, Anne Roudaut, and Orit Shaer</i>	26
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Overview of Talks

Reflections from Michael Beigl on ubicomp education <i>Michael Beigl</i>	36
Design patterns for Ubicomp? <i>Andrea Bianchi</i>	36
Teaching Ubicomp in different countries and for different students <i>Anke Brock</i>	37
Reflections from Jessica Cauchard on ubicomp education <i>Jessica Cauchard</i>	38
Interactive Socio-Technical Systems (or what's next for Ubicomp) <i>Ruzanna Chitchyan</i>	38
Situating UbiComp Education within or distinct from HCI? <i>Jeremy Cooperstock</i>	39
Creating Magic– reflections on ubiquitous computing <i>Ellen Yi-Luen Do</i>	39
Reflections on the need to discuss ubiquitous computing education <i>Audrey Girouard</i>	40
Reflections from Eva Hornecker on ubicomp education <i>Eva Hornecker</i>	41
Integrating Ubicomp in undergraduate education <i>Miriam Konkel</i>	41
Ubicomp as a vehicle for teaching students to generate new knowledge <i>Andrew Kun</i>	42
Is Ubicomp here? <i>Sylvain Malacria</i>	43
From Weiser to Now: The Search for Ubicomp <i>Nicolai Marquardt</i>	43
What is Ubicomp?: A Student's Perspective <i>Amanda McLeod</i>	44
Reflections from Donald McMillan on ubicomp education <i>Donald McMillan</i>	45
Reflections from Tim Merritt on ubicomp education <i>Timothy Merritt</i>	45
Ubiquitous computing: Accepting a fuzzy field <i>Caitlin Mills</i>	46
Reflections from Simon Perrault on ubicomp education <i>Simon Perrault</i>	47

Leveraging the multidisciplinary aspects of Ubicomp <i>Thomas Pietrzak</i>	47
Reflections from Michal Rinott on ubicomp education <i>Michal Rinott</i>	47
Reflections from Anne Roudaut on ubicomp education <i>Anne Roudaut</i>	48
Strong Disciplinary Skills are Key – Ubicomp Teaching is then the Multidisciplinary and Practical Application of these Skills in Context of a Realistic Problem <i>Albrecht Schmidt</i>	48
Reflections from Oliver Schneider on ubicomp education <i>Oliver Schneider</i>	49
Reflections from Orit Shaer on ubicomp education <i>Orit Shaer</i>	50
Scoping Ubicomp for interdisciplinary students <i>Jakub Sypniewski</i>	51
Reflections from Aurélien Tabard on ubicomp education <i>Aurélien Tabard</i>	51
Reflections from Brygg Ullmer on ubicomp education <i>Brygg Ullmer</i>	52
Reflections from Vicky Zeamer on ubicomp education <i>Vicky Zeamer</i>	52
Participants	54

3 Overview of Talks

3.1 Reflections from Michael Beigl on ubicomp education

Michael Beigl (KIT – Karlsruher Institut für Technologie, DE)

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The reflection on what Ubicomp is has taken much of discussion about teaching Ubicomp:

- how much should it include knowledge from other CS and non-CS areas. Is Ubicomp just all of computing (I don't think so)
- in general, does Ubicomp really exist as a topic separate from the rest of CS? (I think so)
- what is the focus, e.g. focusing on systems that are of low (perceived) complexity (calm computing, etc.)? (I think: yes: the core of Ubicomp is about methods (design) and technology to make computers calm and stay in the background)
- Is the Smartphone a legitimate Ubicomp device? (I think yes, but..) What is the difference to Mobile Computing, IoT, etc.? ? (concept vs. technology centered)
- is Ubicomp a subset of HCI? (I don't think so, as e.g. all of tech is missing)
- should there be a development of Ubicomp towards modern times (data-centricity, more complexity)? (yes, but how?)

I see this as positive, as a debate helps shaping an area. And it is always good to reflect on the basics.

3.2 Design patterns for Ubicomp?

Andrea Bianchi (KAIST – Daejeon, KR)

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This seminar had the ambitious objective to try to understand the role of Ubiquitous computing in contemporary society and current educational curricula around the world. We started by trying to define what is Ubicomp, and how it differs from HCI education or other multidisciplinary programs. Furthermore, we attempted to define a list of topics that span under the umbrella of Ubicomp. One of the common elements that were highlighted is the fact that Ubicomp does not require the direct attention of users, but it works in the periphery and background (“calm technology”). We further elaborated on this point, and we all seem to agree that it is not a matter of technology, but a matter of user’s consciousness and overall context. For example, mobile devices such as smartphones, despite requiring the users’ full attention and engagement when used, can also be seen as Ubicomp devices because the usage is transient. For example, using a mobile device to check the time or as an alarm clock are examples of short burst of transient activities that should not be read as isolated independent actions, but in a broader context. Under this light, Ubiquitous computing is not technology driven, but rather depends on the users’ consciousness about the activity at hand (i.e. a “background” task when contextualized in light of the “broader” task at hand).

The second half of the seminar is mainly focused on trying to determine the means (HOW) and ultimate motivations (WHY) for teaching Ubicomp in universities. Participants highlighted that the multidisciplinary and generalist competencies usually required in current Ubicomp classes might not be enough for real world products (where instead specialized

multidisciplinary teams work together). Furthermore, we can also assume that many of these competences will become more common places for future generations, or might even disappear. The question hence becomes again WHAT type of knowledge Ubicomp can additionally provide to a CS or Design curriculum, or, in other words, what general knowledge will remain in the students considering that specific technologies might become obsolete or common knowledge over time. One of the suggestions that seems to be shared among many participants was that perhaps Ubicomp educators should attempt to distill domain specific knowledge using design-patterns. As many professional fields such as software engineering, interface design and security, attempt to transfer knowledge by building unit-blocks of knowledge in the shape of patterns, so perhaps Ubicomp education will require the same level of abstraction – patterns that go beyond technology, but are specific enough that can be implemented using the current available tools and technology. I personally think that defying these patterns will be next big challenge of the field.

3.3 Teaching Ubicomp in different countries and for different students

Anke Brock (ENAC – Toulouse, FR)

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We were lucky to have participants from many different countries and universities across the world in our Dagstuhl seminar 19232. One interesting observation was then how teaching environments and situations vary across these different countries and institutions. This may impact the number of hours which could be attributed to a new Ubicomp course or program, the availability of hackerspaces and hardware, or the background of students (e.g. their prior training). A new Ubicomp course or program would need to be adapted to all these factors. In our working group, we first worked on designing a new Ubicomp course for computer science students, which could be integrated into an existing program (for instance in my case the Master for HCI in Toulouse, France, <http://www.masterihm.fr/>). Since we aimed at technical students, we expected students to meet certain prerequisites (e.g. programming skills, software development methods, statistics). Our course would then encompass lectures and exercises on topics such as concepts of ubicomp; methods; sensing, data & communication; hardware; interaction techniques; and system. We identified skills and knowledge that should be taught in parallel in general HCI or CS lectures (e.g. user-centred design). We agreed that current students would enter a Ubicomp course without necessarily having knowledge on electronics (e.g. Arduino), but that it might become prerequisite knowledge for students in 10 years from now (similar to the increase of CS teaching in high schools which we currently observe). An interesting exercise was to adapt this course to a different student population. In our case we discussed how such a lecture could be adapted for architecture students who would be interested in learning ubicomp for the design of smartphones. Such type of students would look at ubicomp from a different perspective than CS or HCI students: rather than learning how to build systems from scratch, they would be interested in learning how to make use of existing systems and toolkits. As a consequence, the focus of the lectures would shift from a technical perspective to a more applied perspective. On the other hand, topics such as sustainability would gain more importance, since architects are already trained in considering aspects such as energy consumption in the design of spaces. To sum up, the design of a Ubicomp class or program needs to be adapted to the specificities of each university. However, this Dagstuhl seminar hopefully lays the foundations which will help us implement such a course or program at our own institutions.

3.4 Reflections from Jessica Cauchard on ubicomp education

Jessica Cauchard (Ben Gurion University – Beer Sheva, IL)

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While the discussions started around what and how to teach Ubiquitous Computing, we realized that we couldn't fully define how Ubiquitous Computing differs from Human-Computer Interaction education. In addition, we believe that within the next decade or so, Ubiquitous Computing will become the norm in terms of computing. As such, what are the skills required and how large is the scope of university education in the field? One of the discussion topics was around whether data science should be part of Ubicomp teaching curriculum or not. We also wondered how the background of students will change within the next 5,10 and 20 years and how early their education in the field will start.

Following these discussions, we started establishing curriculums for both undergraduate and graduate programs in Ubiquitous Computing. The programs we focused on were targeted for both technical or multidisciplinary students. We found that the programs that were designed by the different groups ended up with many similarities, all including a large range of topics from software and hardware engineering to design and creative skills. The undergraduate programs had a focus on practical skills and industry placements while graduate programs had an emphasis on research skills and research methods. We also had discussions around institutional support and constraints for courses, such as budget for class equipment. When designing classes, most classes comprised active learning activities for students to engage with the content and better understand the concepts.

3.5 Interactive Socio-Technical Systems (or what's next for UbiComp)

Ruzanna Chitchyan (University of Bristol, GB)

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URL <https://energysystems.blogs.bristol.ac.uk/author/r-chitchyan/>

Can a single curriculum can deliver teaching and training for all knowledge and skills necessary to deliver the newly emerging generation of UbiComp systems? Let's consider that that to get driverless cars (as an example system) to “disappear into the fabric of everyday” (that is to become ubiquitous) we need to draw on skills and knowledge in: mechanical, electrical, electronics, and software engineering, networking and telecommunications, as well as, ergonomics, aerodynamics, product design, HCI, psychology, cultural context, regulations and laws, to name a few (not even mentioning aerospace related issues for getting the GPS systems in place).

It is then difficult to see how a single curriculum for a UbiComp systems can be arrived at. Neither do we try to get only UbiComp graduates to work on driverless car systems today. In practice, when developing and deploying such ubiquitous solutions, teams of specialists collaborate to draw in the required skills and knowledge.

Then maybe we could agree that **Future-Focused UbiComp Curriculum** does not limit itself to Hardware and Software Prototyping, Programming and Networking, and Creativity modules, but is taught as a **programme where specialists** in Software Engineering, Networking, Electrical Engineering, HCI, Human Anthropology, Psychology, Business, Law,

and other disciplines textbfwork in teams to build large, complex, situated, usable systems that become the infrastructure of tomorrow. In other words, the learning to build UbiComp (or to be more precise, Interactive Socio-Technical Systems) is not accomplished through graduating from a specific degree, but by “graduating” through working on collaborative *interdisciplinary projects with focus on interaction of human (both individual and societal) and technical aspects*. In other words, I suggest that such projects should form the “heart” of the curriculum on UbiComp/ Interactive Socio-Technical Systems, while the specific curricula would continue to deliver HCI, Communications, Software Engineering, Law, Phycology and other similar modules, depending on the flavour of the courses provided.

3.6 Situating UbiComp Education within or distinct from HCI?

Jeremy Cooperstock (McGill University – Montreal, CA)

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Ubiquitous computing education faces a hurdle of differentiating itself from that of general HCI education, and perhaps more importantly, demonstrating its relevance and importance to society at large. Despite the clear definition of UbiComp as provided almost thirty years ago by Weiser, there is no clear consensus as to what topics fit and which do not, within a course or program that is not primarily overlapping with HCI. As a result, despite a high degree of agreement on topics of relevance, as put forward by the various workshop participants, it remains uncertain as to how this subject will compete with established HCI programs. Whether this implies that usability concerns for handheld computing (and its future incarnations) will remain dominant over the design of calm and “invisible” technology, in particular, in the teaching of future generations of students, remains to be seen.

3.7 Creating Magic– reflections on ubiquitous computing

Ellen Yi-Luen Do (University of Colorado – Boulder, US)

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Do you ever wonder what would the future be like? What kind of technologies would people use in their everyday lives? What kind of the reality of ubiquitous computing would be achieved in the 21st century? Instead of singing the cute song “Que Sera, Sera. Whatever will be, will be. The future’s not ours to see”, we are fortunate to have Alan Kay’s suggestion that “The best way to predict the future is to invent it.” It’s so nice to be able to invent the future we will live in! Then, what kind of future shall we be inventing? How do we prepare our young generations to engage in meaningful and useful ubiquitous computing?

Weiser’s vision for ubiquitous computing is about calm technology, in which the technology disappears into the world we live in and become peripheral, and put us at home. This week’s Dagstuhl Seminar 19232 – Ubiquitous Computing Education: Why, What, and How created a unique opportunity for a community of scholars and professionals gather together to brainstorm and exchange ideas about ubicomp education and the type of curriculum that would be needed for inventors and designers of future interactive systems.

With various breakout sessions in thematic topics, we asked questions about what is Ubiquitous Computing, and whether it's useful or even necessary to still use the term, or should the term of Human-Computer Interaction (HCI) be the defining domain? How, then, do we differentiate these with the fields of information and the study, creation and analysis of media? Shall we instead use the term interactive systems? There is no one easy answer. We will just have to evolve the field. Of course each name comes with its own promises and baggage, as well as the persuasive powers to attract different kind of audiences. I am delighted with the active discussions and the questioning about ubicomp education, and pleased with the enthusiasm. Meanwhile, let's not forget the suggestion from the futurist, inventor, and science fiction writer Arthur Clark that "Any sufficiently advanced technology is indistinguishable from magic." In our design of the curriculum we certainly would like to empower students with technical competency, but also the creative spark and the power of play in creating magic!

3.8 Reflections on the need to discuss ubiquitous computing education

Audrey Girouard (Carleton University – Ottawa, CA)

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The ubiquitous computing seminar offered attendees an opportunity to apply their research expertise to improve the delivery of the topic to undergraduate and graduate students. This was a fairly unique opportunity: education is usually discussed internally within institutions, but rarely globally, other than in specialized conferences. Yet, education is at the core centre of our mission as researchers and faculty members. Teaching students the right topic using appropriate and engaging active learning methods can be challenging. This seminar stem from the organizers' interest to learn from their colleagues' various perspectives and experiences, to create a large community of teachers that can learn from one another. The seminar grew to become a place to discuss the vision of teaching ubiquitous computing, establishing the general topics to teach a well-rounded class, as well as proposing how to put that in action.

The seminar reflected on vision of teaching in the 5 to 20-year horizon, as well as design new curriculum based on how the field and teaching methodologies are evolving. A core challenge that emerged rapidly and recurring throughout is the difficulty of defining what is ubiquitous computing, what exactly it englobes, what are the salient examples that define it. Very few of the 28 participants teach a class explicitly named ubiquitous computing, though many have related topics, or include it as a topic instead of a focus. Another interesting observation was the necessity to distinguish general teaching and learning-related discussions to those that are ubiquitous computing specific. Ubicomp focused challenges included the necessary to differentiation between ubicomp and other related topics (e.g. general HCI), physical resources (lab space, hardware budget, etc.), and interdisciplinarity in the topic. Engaging though general topics included teaching workload, student recruitment and student engagement in classrooms.

Overall, this was a fruitful and engaging seminar with discussion and materials. It will lead me to update my teaching materials shortly and improve the delivery of ubiquitous computing to my students.

3.9 Reflections from Eva Hornecker on ubicomp education

Eva Hornecker (Bauhaus-Universität Weimar, DE)

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There was a lot of comments on what's the difference between HCI and Ubicomp. For me, the UbiComp we are discussing here (which is the more HCI'ish section of UbiComp) is a subset of HCI, a specialization, with some overlap to the more technical areas. It is specialized in terms of the types of technologies involved, as these have some form of sensing technology (often also acting back on the world), and interact with or relate with the outside world and objects (unlike general apps, which might just live on a phone – and even if used in a mobile situation, might not interact with the outside world). So this requires an understanding of the technology and its embedding in the world, and what follows from this. Many of the challenges with teaching we discuss appear to be of a more general nature for HCI and applied topics, still it is good to have an opportunity to discuss these. Devising a curriculum for UbiComp was interesting, in particular thinking about what a full degree could or should involve. The collection of teaching materials that was prepared on Thursday will be incredibly useful, and even though I'm already teaching Ubicomp, there are a lot of new ideas, in particular for interactive elements and activities for some of the Ubicomp core topics.

One of the reasons I like teaching UbiComp is that it lends itself to a holistic, systemic approach, which discusses applications as well as societal and ethical concerns (that partially may be specific to UbiComp, but should be considered in a technical degree education anyway). In UbiComp teaching, we need to discuss technology, hardware/sensors, system architectures, discuss applications, etc., and here discussions of impact (ethics, ecology, privacy) can be integrated easily ad hoc. This holistic approach also makes the class accessible and interesting both for more technical students and for students with a more human science or design interest.

3.10 Integrating Ubicomp in undergraduate education

Miriam Konkel (Clemson University, US)

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In the context of a workshop discussing Ubicomp in Education, we discovered that participants have different conceptions of the nature of Ubicomp. From the early 1990s context, there are well-known descriptions by Weiser. However, as some pragmatic understandings of ubiquitous computing are now deeply woven throughout our daily lives, it raises the question of broader present-day definitions and academic implications. We also realized the prospective value in characterizing the boundaries between Human Computer Interaction and Ubicomp. For example, is Ubicomp a part of Human Computer Interaction, or are they two separate disciplines with considerable overlap? We are aware that our student population is diverse. We see the need for transdisciplinary programs as well as technology-centered programs. Our group focused on program development for undergraduate students who are pursuing an interdisciplinary Ubicomp minor. Our focus group itself was interdisciplinary with domain experts ranging from computer science/engineering, design, and psychology. For

an interdisciplinary program, we anticipate a similar spectrum of students. Students might receive training in an Ubicomp overview course that covers the past, present, and future of Ubicomp. In this course students would also be introduced to ethics and the need to consider inclusiveness for the development and design of prototypes. These topics will be woven throughout other courses. We anticipate that students will be able to choose from a subset of courses ranging from programming, computer engineering, psychology, research methods, statistics, and object design.

3.11 Ubicomp as a vehicle for teaching students to generate new knowledge

Andrew Kun (University of New Hampshire – Durham, US)

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Having designed and taught two different ubicomp courses, I'm very interested in looking ahead to the next decade or more, and asking: what is the future of ubicomp education? This is the reason I was excited to co-organize Dagstuhl workshop 19232 "Ubiquitous Computing Education: Why, What, and How."

I believe that one central issue for ubicomp education is to help train students to successfully generate new knowledge. Ubicomp is a field that is advancing quickly, and many of the specific tools of generating new knowledge become obsolete quickly [1]. For example, the programming tools, and the tools for creating hardware change rapidly. Students need to keep up with this change in order to be successful in their future workplaces. However, the need to keep students up-to-date on the specific tools of the trade should not prevent us, educators, from also training them in the general tools of generating new knowledge. The general tools are described by Karl Popper's model of conjecture and refutation, in which scientific theories are built through proposing hypotheses which are subsequently empirically tested and either supported or refuted. Steven Pinker describes these general tools in terms of Bayesian reasoning: certain hypotheses are given a baseline probability based on prior knowledge, and this probability is adjusted based on empirical tests. Importantly, these skills are not only useful in scientific research in academia. As the recent work of Eric Ries demonstrates, these general tools are also critically important for productive research and development in industry.

Fortunately. Ubicomp education presents educators with an excellent opportunity to train students in both the specific, and the general tools of generating new knowledge. This is because very often ubicomp education focuses on creating artifacts. This process requires specific tools – students need to know how to program the latest gadgets, and how to use the latest hardware prototyping tools. However, students also need to create experiments in which they test their creations and assess their viability in different situations. Educators should seize these opportunities and help students gain an appreciation for, as well as training in, generating research problems, hypotheses, and approaches for testing hypotheses.

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3.12 Is Ubicomp here?

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Mark Weiser, the father of ubiquitous computing, predicted in 1999 a future where everything will be able to sense human input and augment its appearance with digital information: essentially computation will be fully embedded into all aspects of the real world and the transition between the physical and the virtual would become seamless for the user. Today is becoming this future, with the spread of interconnected devices not only in our pockets (smartphones, smartwatches, etc.) but also in our environment (smart buildings, connected bus stops). Interestingly enough, the fact that ubiquitous computing has become so “real” has also made the notion of ubiquitous computer itself less “clear”, in terms of which notions it encompasses and how they should be transferred.

During this seminar, several participants agreed that ubiquitous computing is a rich interdisciplinary domain, hard to define, and whose boundaries are hard to identify. It has been clear, however, that designing ubicomp systems requires a variety of skills usually instructed in various disciplines. After discussing what the typical student in ubicomp will be in 5, 10 and 20 years, this seminar tried to define typical programs and courses for teaching ubicomp for both technical or interdisciplinary groups of students.

3.13 From Weiser to Now: The Search for Ubicomp

Nicolai Marquardt (University College London, GB)

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Many inspiring conversations during the seminar brought up critical aspects to consider when putting together a possible ubicomp curriculum. First, it is difficult to clearly outline the scope and boundaries of what ubicomp includes. Individual definitions of what ubicomp is was quite diverse across all participants. Overlap and distinction to other technical HCI courses/modules is important to best position the strengths of a ubicomp focused course. Second, we might need to better understand the future career paths of the students, as their jobs in industry will likely not be framed around ubicomp and the particular ubicomp use cases, but cover broader areas across CS, automation and autonomous and networked systems (which is different to many other CS specialisations, such as AI/Machine Learning or Financial Computing, where career trajectories are more obvious). Third, it was discussed that we need a better differentiation between the fundamental principles vs. the applied ubicomp teaching. For example, what techniques and approaches can we teach our students that are still relevant in 10 or 20 years. Technologies, programming languages and tools we use today are outdated very quickly, and so the question is what are the skills and techniques that last. Related to this, it was mentioned to possibly consider creating collections of design patterns focusing on the ubicomp context. Last, we probably need to revisit Weiser’s vision

of ubiquitous computing (with all its qualities of calm computing, peripheral interaction, foreground/background interaction, situated in people’s environments, and so on) and ask how much of that vision and definition of what ubicomp is still applies, should be changed, refined or broadened.

3.14 What is Ubicomp?: A Student’s Perspective

Amanda McLeod (Carleton University – Ottawa, CA)

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We started off the 19232 seminar with the “Why?” of ubiquitous computation. I immediately began seeing similarities with the current Information Technology (IT) and Human Computer Interaction (HCI) terminology and curriculum that have, and are currently being taught to me in the Interactive Multimedia and Design program at Carleton University. On the second day of the seminar, we explored the “What?”, as in what would be taught in a new Ubiquitous computational education curriculum? Teams explored different themes and created course outlines in which we would need to cover multiple topics in order to confidently say a student has been educated in Ubicomp, however, all this exercise did for me was strongly establishing the parallel between current educational topics that have previously been seen in my past and present courses, for example, ethics, hardware, software, prototyping, statistics, and many more.

Following multiple discussions with the seminar participants, it appeared as though the established definition of ubicomp continued to blur. Multiple perspectives shaped the name to be about a higher complexity item. As discussions went on, the narrative of ubicomp education rapidly formed a Venn diagram with the HCI world. Both poles of the diagram overlapped greatly in terms of curriculum presentation and thoughts on what the curriculum should become. These repeating curriculum terms posed the questions of “What is ubicomp? What is it not?”, “what is HCI? What is it not?”. Do both of these terms occupy two completely separate worlds or do they morph into one under the same umbrella?

Additionally, while developing curriculums and methods of delivery, a great portion of the participants shared ways in which they capture their audience’s attention. This made me realize that for the past 3 years of my undergrad, I’ve been the subject of teachers tactics that attempted to get me more involved in class learning and discussions. During this same conversation, the subject of teaching evaluations were brought to the attention of the participants and their major impact on teachers opportunity for promotion as well as salary. This made me reflect on the existing teaching evaluations and how they are presented to the students and how some questions are quite frankly irrelevant to how well the professor taught the class. “Did the teacher speak loudly and clearly?”, “Did they end class promptly and on time?”. These existing teaching evaluation questions prompted me to question why we don’t cater these questions to specific classes in the same way we cater class content to particular classes. For example, if we question a student on if they believe they were sufficiently taught about specific learning outcomes from the course outlines, we would be able to sufficiently evaluate a teacher.

3.15 Reflections from Donald McMillan on ubicomp education

Donald McMillan (Stockholm University, SE)

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One discussion on the future of Ubicomp education that resonated was on the future students, their needs, and their abilities. As any technology spreads throughout society, it is appropriated, used, disassembled, and taught by and to a much wider audience than the technical experts, which sparked its creation. As Ubicomp makes its way through transport, architecture, and into K-12 education as part of the infrastructural facilities we can expect it to follow this trajectory (seen, for example, in web technology) of being taught as something to use, then as something to understand, and finally as something to manipulate and create (with or through). This pushes the underlying goal of teaching ubiquitous computing from the practical, technical aspects to more theoretical, abstract, and universally applicable principles – ones that encompass design, ethics, societal impact, as well as technology. This comes hand in hand with the technology we are talking about following the students into this future classroom (in whatever form it will take), and through their lives. This will necessarily change the ability and understanding of the students. In a manner akin to smartphones providing communication and search functionality being taken advantage of in current educational contexts, in the future the trace data from a host of ubicomp systems, possible social and cognitive enhancements, and access to the outputs of these in an interconnected and social manner provide a fascinating glimpse of a possible future of education not only of Ubiquitous Computing, but through and of Ubiquitous Computing.

3.16 Reflections from Tim Merritt on ubicomp education

Timothy Merritt (Aalborg University, DK)

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Ubiquitous Computing is a topic that is defined in various ways from researchers, artists, and practitioners from diverse perspectives. It became apparent to me that many agree that Weiser’s 1991 paper, “The Computer for the 21st Century”, is a good starting point and a way to open the discussion, yet from there, current examples and aims of related research differ dramatically. From a technical perspective, challenges arise when we try to define what is within scope and out of scope for Ubicomp. Is the disappearing computer the main intersection about which most agree?

Weiser discusses location and scale as crucial to the future of ubiquitous computing and paints a picture of a world free from common struggles. Actuated desks mean we no longer misplace papers in the office, deeply connected texts such as physical maps and electronic information, etc. While this vision is optimistic, there are, of course, implementation issues and ethical issues of connecting and actuating the physical world. Further, how should we teach for those who might research or work in related practice? Trends in hardware becoming cheaper, smaller, and easier to program has made “making” more accessible to many more people. Similarly, software is easier to create active environments utilizing toolkits and high-level languages.

Almost 30 years after Weiser’s seminal paper, there are some good examples of connected devices and seamless interactions, yet so many experiences with technology are problematic. Voice assistants are often awkward and require abrupt command and terse speech. This makes the technology conspicuous, yet in a very negative way. Aside from these clumsy speech interactions that disrupt social situations, they currently provide very limited opportunities for end-user programming and customization. The calm and smooth world is still elusive. Another technology that we find in everyday life, the smartphone has become pervasive and helpful in so many ways, but when we consider ways in which it fits into our social experience, it too is clumsy and problematic—this multi-purpose device has become almost a wearable companion device, ready at every moment to be helpful in so many ways, wayfinding, controlling home lighting, buying things, banking, socializing, almost everything is controlled through the small screen. Is the mobile phone the cursor for interacting in the world? Will we break free from the small screen and find more embedded displays woven into the physical world? Is the text and information provided on the small screen akin to Weiser’s example of the wrapper on a piece of candy? Ubiquitous computing might contribute to many of the concrete challenges faced in world—some of the envisioned smart environments and calm computing experiences have come to fruition and so many remain unsolved. When teaching ubiquitous computing, I hope we can inspire future generations to be creative, innovative, and at the same time, ethically responsible as we involve users to engage with these challenges and design the future together.

3.17 Ubiquitous computing: Accepting a fuzzy field

Caitlin Mills (University of New Hampshire – Durham, GB)

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One of the key issues that came up this week was the definition, validity, and purpose of ubicomp as a field. I was left wondering, however, if the definition aspect is necessarily the most important question to tackle at this point. From a philosophical perspective on scientific fields, it is expected that fields will have ‘fuzzy’ edges, and the very fact that we are organized around a central theme here argues for ubicomp as a valid scientific field (Casavall & Fang, 2015). This perspective further holds that the social aspect of the field is of utmost importance; current (self-organized) members of the field shape what questions should be pursued, what are the appropriate methods, what are the ethical standards, and perhaps most importantly, who will join the field in the future? These questions seem particularly important in the context of education since self-identified ubicomp members will undoubtedly impact the future of the field through the classroom.

Through breakout groups, we have identified the core areas that should be part of ubicomp curriculums, and basic interdisciplinary skills that students would be expected to have. We also discussed potential pathways for how such curriculums/courses may be adaptable based on prior knowledge and expertise. Finally, a substantial time was devoted to addressing topics related to ethics (appropriate methods), diversity, and inclusivity within a ubicomp education—important issues for the future of ubicomp membership.

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3.18 Reflections from Simon Perrault on ubicomp education

Simon Perrault (Singapore University of Technology and Design, SG)

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During the seminar, we found out that we could not exactly agree on the definition of what ubiquitous computing is. As pointed out by a participant, it was sometimes easier for us to identify something that is not UbiComp or not part of UbiComp. Another emerging thought was that UbiComp and Computing would simply become near-synonyms in the near-future. After discussing modules/programs design, all the participants seemed to reach a consensus on the following notions being part of a successful UbiComp training: hardware and software prototyping, networking, HCI. We also identified related topics that would be relevant to be part of a UbiComp teaching, such as machine learning, data science. UbiComp teaching, by nature, ends up being rather multidisciplinary, and with some changes of focus, could be a suitable topic to teach in many different majors (CS, Engineering, Design, Architecture, Social Sciences and even Business or Law).

3.19 Leveraging the multidisciplinary aspects of UbiComp

Thomas Pietrzak (INRIA Lille, FR)

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One of the many challenges in teaching, studying and conducting research in UbiComp is the multidisciplinary approach it requires. Similarly to HCI, it requires a broad range of skills that makes it challenging, but also exciting. Most of the participants have a computer science or engineering background. However we also have to teach topics related to design, psychology, mathematics, physics, and so forth. Putting together a curriculum or even a course is a challenge. Firstly because of the long list of topics that have to be covered. But also due to the diversity of students previous knowledge and experience. We designed a curriculum and course that can be adapted to students background (tech or not), and level (undergraduate, graduate). We believe these efforts will contribute to the promotion of UbiComp, and raise awareness about it among students, and the society in general.

3.20 Reflections from Michal Rinott on ubicomp education

Michal Rinott (SHENKAR – Engineering. Design. Art – Ramat-Gan, IL)

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The workshop is a good opportunity to understand the perspectives of different participants on UbiComp, be it a more system-centered outlook or rather human-centered one; an extreme (“in UbiComp all interfaces disappear”) or a broader perspective on ubicomp interactions. It seems that the lack of a specific and definitive definition is a necessity for maintaining the breadth and wealth of the topic, especially in the context of the workshop. However when planning specific learning experiences there emerges a need for more specificity. Another interesting issue concerns the best conditions for teaching and learning UbiComp. Specifically, how do we create a physical space that is optimized for learning and research? How does

this relate to the ability to scale teaching and learning beyond the people that can work together in a hands-on session? The hybrid learning model of non-synchronous learning of certain materials, coupled with co-located opportunities for group work and interdisciplinary collaboration seems promising. The space in this case should contain tools and methods for supporting this type of meeting. It should answer both specific ubi-comp needs (sketching, prototyping, implementing) and more general tools for collaboration (dynamic structures for group learning, presentation, exhibition). An opportunity arises for the space to implement a ubicomp protocol and, through data and interfaces, provide insights about collaboration within it, and tools to improve learning and functioning within it. The topic of hybrid learning spaces and data is being explored recently by colleagues of mine, for example in this workshop, see open CFP!

3.21 Reflections from Anne Roudaut on ubicomp education

Anne Roudaut (University of Bristol, GB)

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The goal of the seminar was to rethink the form of current ubicomp teaching and the role of universities in education in 5/10/20 years. A very insightful idea was to change the current traditional form of courses to a more modular one where students can “pick and choose” modules depending on their existing skills and based on what they want to major in (and consequently shape their future career). This could be done through some kind of visual infographics representing pathways that students took. In parallel pathways that industries need could be assessed every few years to better understand what are the skills needed and help the students choose their pathways. Doing so would require tackling some new challenges such as timetabling but also the need to access skills of students entering the program (and how to avoid students taking the “easier” modules). Such model would also be competing with online courses that are rather following this modular approach (e.g. Khan academy) without necessarily producing accredited diploma.

3.22 Strong Disciplinary Skills are Key – Ubicomp Teaching is then the Multidisciplinary and Practical Application of these Skills in Context of a Realistic Problem

Albrecht Schmidt (LMU München, DE)

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The vision of ubiquitous computing has inspired a generation of computer scientists to make computing part of everyday life. At the time Mark Weiser [1] wrote about the computer for the 21st century desktop was dominant and the vision of networked computers everywhere was still far out. As technologies have progressed, we have seen that networked mobile computing has become ubiquitous and is an essential part in everyday life. Sensing and actuation in the infrastructure as well as in devices is common and people constantly used networked services that. However when we think of a parking garage that has sensing to

keep track of which parking spaces are occupied and make this online accessible, when the navigation service adapts to sensor information from cars, and when the tools are recording their use automatically in a database we do not talk about ubiquitous computing. Once the technology is woven into the fabric of everyday life, we consider it normal and rely on it. We are currently at a point where hardware cost is becoming a minor factor in comparison to the cost as of software development, system deployment and maintenance. A wireless computer (e.g. ESP8266) is available in 2019 for less than 2€. The limiting factor is our ability to create meaningful systems and applications that have utility and the challenges are all along the life cycle [3]. One further key aspect is how to design the interaction with ubiquitous systems [2] where there is little systematic understanding. Can we improve our ability to creating ubicomp systems through teaching? What will people need to know in order to envision, design, prototype, create, deploy, and study ubiquitous computing systems and applications? At this point I think the field of ubiquitous computing is so wide that it is hard to imagine to set-up a course on ubicomp. I think the best approach is to teach solid foundations in one subject (like computer science) and only add a high-level course on the concept and visions of ubiquitous computing (e.g. a seminar). Additionally having students doing practical projects in ubicomp will help to apply knowledge and deepen it in the field. The serious learning of how to create ubicomp applications will be hands-on in multidisciplinary teams based on strong disciplinary skills.

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3.23 Reflections from Oliver Schneider on ubicomp education

Oliver Schneider (University of Waterloo, CA)

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We continue to struggle with a definition of what Ubicomp education should contain. I have tried to answer three questions to help with that.

What is Ubicomp? → Physical interactive systems, but that doesn't help us define its scope. Physical interactive systems require sensing and a response, either to the user or other stakeholders. It overlaps with Human-Computer Interaction (people and interactive systems). Because these systems are physical, the field involves hardware; because these systems are computational, they involve software; because it involves interacting with people, human-facing fields are involved.

How can we teach it? → Education is difficult because it is interdisciplinary and involves physical systems. Since Ubicomp involves hardware, software, and people, it necessitates different disciplines working together. Educators need to position students' needs within each of these subtopics, and bring them together in a high-level framework. Although education continues to scale through online methods, we still need physical infrastructure for prototyping. Educators will need to decide what students can learn online and what they need to learn in-person. Ubicomp requires physical systems and expertise in multiple disciplines.

What might help us define UbiComp education? → Don't ask what UbiComp is, but rather what it is not. UbiComp is not app design; it is not VR headsets; it is not pure automation; it is not a more precise machine learning classifier. I think that looking at the complementary set will be more fruitful for positioning and defining the field.

3.24 Reflections from Orit Shaer on ubiComp education

Orit Shaer (Wellesley College, US)

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The notion of ubiComp has inspired my research and teaching throughout my career – offering the promise of augmenting our everyday environment through the integration of interconnected computational devices. At the core of ubiComp is the idea that technology becomes invisible and accessible anytime and anywhere. Yet, invisible technology, has visible impacts on individuals, communities, and society. While ubiComp presents opportunities for improving our work and wellbeing, it has potential for misuse, in particular, compromising people's privacy and security.

How do we engage students in considering both the promise and challenges of ubiComp? How do we prepare them to become ethical citizens and leaders in an era of ubiquitous computing and rapidly increasing automation? What are the core conceptual and technical skills required for training students to become ethical ubiComp innovators and developers? What methods are effective for teaching complex and interdisciplinary topics to different audiences? The goal of this seminar was to address these questions through systematic investigation of the Why, What, and How of ubiComp education.

The seminar provided valuable and rare opportunity for interaction and exchange of ideas about teaching with colleagues who are experts in the field. While we often meet to discuss our research, it is rare for us to engage in deep and prolonged discussions about teaching, yet we are all educators in addition to researchers. Through small group discussions and hands-on activities, we questioned the definition of ubiComp, examined the purpose and challenges of ubiComp educations, debated the essential content of ubiComp courses for different audiences, exchanged and develop new methods for effective (and engaging) teaching.

Following the seminar, I feel inspired and motivated to reflect on my own teaching, rethink the concepts and ways that I teach, and engage with my students in new ways. The outcomes of the seminar, which include a living curriculum document, reading list, shared educational activities, will be extremely helpful in this process. I also believe that the connections and network of committed ubiComp educators that we formed here has a critical role in shaping how we train the next generation of ubiComp innovators and leaders.

3.25 Scoping Ubicomp for interdisciplinary students

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Designing an UbiComp curriculum brings up a number of connected topics, not only connected with the educational side of things, but also the scope and definition of what Ubiquitous Computing is. One thing that the majority seem to agree on is that UbiComp requires cross-disciplinary knowledge for both teachers and practitioners. This realisation connects to the already mentioned scope, especially when looking at different student profiles in UbiComp courses or programs, meaning how technical the curriculum has to be to provide the students with enough understanding or skills related with the computing part of UbiComp, and how much of the design or concept related to Social Science should be taught not to alienate technically oriented students? The possible way of addressing this challenge would be to gauge students' skills and interests at the beginning of the course or program and adjust the depth to which the topics will be taught. The assessment of students and adjustment of the curriculum might increase workload for the faculty, but is crucial for avoiding teaching unnecessary or out of scope topics.

3.26 Reflections from Aurélien Tabard on ubicomp education

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From developing as an academic research area over more than two decades, UbiComp vision has made its way into the fabric of our everyday lives. Embedded and inexpensive devices are now spread and networked throughout our environment, from wearables to smart buildings, libraries, hospitals, or urban infrastructures. One could argue that in a way, similar to AI, UbiComp is defined by a vision rather than a set of principles, and as principles and technologies mature and become broadly adopted, they are not considered as UbiComp anymore.

Designing and developing UbiComp systems requires to bring in a variety of skills that have been traditionally mastered by various disciplines. The precise blend of skills involved is what makes UbiComp unique. And the challenge lies as much in the mastery as in the way they are articulated. Broadly speaking, this means introducing sensing and embedded systems specialists to HCI and design, and designers to electronics but also networking and computing systems.

In terms of design approach and practice, I find teaching UbiComp because 1. It pushes to go beyond the notion of supporting a user accomplishing a task, to consider blending more deeply into existing human activities. 2. It pushes to think of systems at another scale than users or collaborative groups, e.g. designing for bodies, places or cities.

Because of the various skills involved. Educators can hardly expect a mastery or even an awareness of the basic . UbiComp education should be tuned to the skills of students.

A great outcome of the seminar would be a consolidated list of small-units that could be assembled in a variety of ways, as well as write-ups and reflections on existing curricula and teaching practices:

A Pervasive course outline with resources from the ITU of Copenhagen:
<https://blog.itu.dk/SPCT-F2012/>
<http://www.bardram.net/wp-content/papercite-data/pdf/bardram-ieaward2012.pdf>
 Two sources of inspiration from nearby domains: <https://wot.pubpub.org/>
 Interaction Design: <https://medium.com/ixda/education-summit/home>
 Visualization: <http://vgl.cs.usfca.edu/pdvw/2017/><http://vgl.cs.usfca.edu/pdvw/2016/>

3.27 Reflections from Brygg Ullmer on ubicomp education

Brygg Ullmer (Clemson University, US)

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While perhaps unsurprising, but simultaneously interesting and at times illuminating, has been discussion concern the “ubiquitous computing” term, implications of its use in the context of our respect academic institutional environments, etc. For example, several noted that in the 3-minute presentations on day 1, relatively few (perhaps 5 or fewer) of the 28 participants explicitly framed their work in terms of ubiquitous computing. Several times in day 2, participants described naming implications including (e.g.) gender engagement. As one specific example, among several sister institutions, it was noted “interactive product design” attracted a more balanced gender dynamic than “interactive product development.”

For some participants, one gathered that the particular scoping and components of terms like “ubiquitous computing” are quite consequential. For many others, it seemed a wide variety of descriptive terms – often engaging particularities of individual institutions, and their orientations toward engineering, art, design, liberal arts, etc. – might often inflect both local resonance and use. A sister bridging term that several referenced is “interactive systems;” or perhaps as an extension, ISDE (interactive systems design and engineering & evaluation, per multiple communities “overloading” individual letters of acronyms). One related exercise might be an (e.g.) 5xN mapping for some of the overarching themes discussed in some breakouts on day two – e.g. people, technology, objects, methods, business – and strong, weak, or non-engagement with UbiComp (early 90s), UbiComp (present-future), Pervasive, ISDE, CHI, TEI, and others.

3.28 Reflections from Vicky Zeamer on ubicomp education

Vicky Zeamer (Hubspot – Cambridge, US)

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Why is the training and education of students in UbiComp important for industry, not just academia? Much time at this seminar was spent debating what was even considered ubiquitous computing. Without a clear spotlight on the definition and why it’s important, industry does not have a clear incentive to put resources into UbiComp education. This seminar has illustrated not only the cross-interests we have as researchers and designers related to humans and technologies, but also the lack of consensus of what it really means in practice to live and work within a world with computers being “ubiquitous.”

As confused as we are by the implications for education related to UbiComp, imagine how our students and junior colleagues must feel about their own preparation and paths? I have always felt, as a student going through a pre-designed curriculum, that these programs were out of touch with the realities of real world contexts and problems. This disconnect between education and industry careers is often by design— academia is for exploring unknown frontiers and being free of the friction that real world implementations often impose. However, as professionals (either academics or practitioners) within the realm of human-technology interaction, we have a moral responsibility to prepare a majority of students to tackle the world's issues, primarily via industry.

At the end, I believe that we need to, as a group of experts, is to establish the fact that we are preparing students to be ethical leaders, builders, and users of ubiquitous computing outside of academic research environments. While this may seem like a straightforward sentiment, what I am stressing is that we must understand that a majority of students will not end up in positions like their own professors. With that in mind, how do we teach students who will shape our future world and make it a better place via UbiComp?

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