How Should We Teach Theory In An HCI Education?

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Recently, researchers have advocated for increasing the prevalence of theory building and theory-driven design in HCI research. In particular this is often combined with a desire to return to the cognitive science approaches of "second-paradigm" HCI and away from the design-focused and ethnographic methods that have informed much of contemporary HCI research. These "third-paradigm" methods rely on fundamentally different theoretical underpinnings. Given the wide variety of theories that are relevant to HCI, and the different roles that theory plays in these two HCI research paradigms, it's unclear what skills and content knowledge should be taught in HCI classes to equip new researchers to use and develop theories effectively, and what teaching strategies might support their learning. In this position paper we sketch out how theory is applied (or not) in HCI and adjacent disciplines, discuss the pedagogical challenges this creates for instructors and students, and introduce potential teaching interventions to improve how students are introduced to theory. We hope our paper will spark discussion about the place of theory in an HCI curriculum.

CCS Concepts: • **Human-centered computing** → **HCI theory, concepts and models**; • **Social and professional topics** → **Computing education**.

Additional Key Words and Phrases: theory, hci education, pedagogy

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1 INTRODUCTION

Theories are accounts of how we think things work. Because of the expansive scope of contemporary HCI research, a wide variety of theoretical approaches have been applied to better understand how humans use technology and to change technology to make it work better for humans. Cognitive and perceptual theories describe the limits of the human mind and sensory system, and can be used to predict performance on low-level tasks [9]. Activity theory provides a framework for explaining how artifacts such as computers can mediate human actions, and be employed in a variety of different ways depending on users' work contexts [25]. Feminist theory, and a variety of other social theories, allow us to better understand how relations between different social groups will affect how technology is used [2]. Rogers describes many of these theories in detail, outlining how an entire "theory industry" has emerged in HCI [31].

Despite this cacophony of available theories, however, it has recently been argued that theory is underutilized in contemporary HCI research. Oulasvirta and Hornbaek provide a formal account of how theories can be used to guide design by generating counterfactual speculations about how design decisions will affect interaction [27]. In a survey of 25 CHI best papers, they found that a relatively small number used explicitly used theory to drive design in this way. Theory can also be used more loosely, to inspire a general direction for research or to interpret

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results after the fact, but Oulasvirta and Hornbaek argue that this fails to make use of many of its potential benefits, and is less likely to result in falsification or refinement of theories [27].

We are particularly interested in this avenue for theory use in HCI, and in what knowledge is required to equip the next generation of practitioners and researchers to engage in this form of theory-driven design. However, we also acknowledge that given the many forms theory can take in HCI, this will not capture all the ways that theory can be useful, and that a breadth of pedagogical approaches will be required.

In this position paper we wish to spark discussion about how an HCI curriculum can meet the two challenges we have introduced above: that a huge number of relevant theories exists, with little agreement on or research into which ones should be taught in HCI courses, or how to accomplish this [11], and that successfully applying theories in the course of design is difficult. Can we change how we teach HCI to try and better equip new researchers and practitioners to use theories effectively in their work?

In the following sections, we will provide a brief overview of what theories are; the benefits and limitations of employing theory in HCI research; how HCI borrows theories from other disciplines; and what HCI can learn from the behavioral sciences' current "theory crisis". Along the way, we will discuss the pedagogical challenges associated with each topic. We will conclude with a discussion of general considerations for teaching theory in an HCI context, and some preliminary ideas for teaching interventions that might resolve the challenges that we have outlined.

2 WHAT EVEN *IS* A THEORY?

Theories are collections of statements (in natural language, mathematical notation, or some other form) that state causal relations between entities to describe, predict or explain some phenomena [19, 22]. Borsboom [5] gives the example of civil engineering, where Newtonian physics can be used to predict whether a structure will stand or collapse based on mathematical representations of the geometry and material properties of its structural elements. However, this definition can apply in a wide range of domains. For example, feminist scholar Judith Butler's verbal assertion that "gender is the mechanism by which notions of masculine and feminine are produced and naturalized" is also a theoretical statement that outlines a causal relation [7].

Despite this apparently straightforward definition, in practice recognizing theories can be difficult for both students and researchers. Theories are often conflated with frameworks, models, and hypotheses, but are not the same as any of these (refer to Guest and Martin for an overview [19]).

Borsboom uses the metaphor of "theoretical amnesia" to describe fields that rely on statistical methods and frequent data collection rather than having clear ideas about the underlying causal structure of their research domain [5]. In these cases, there are few theories that can provide precise explanations or predictions, and researchers in these areas are less familiar with what theories are and what makes a good theory, resulting in a vicious cycle that inhibits theory-building. Iterative design methods seem to serve a similar place in HCI to statistical methods in other disciplines; They allow individual HCI researchers and practitioners to make concrete advances without needing to directly apply theory, instead relying on a design-build-test cycle[1]. This means that many researchers are unfamiliar with the theories that are relevant to their research domain, and may have a hard time applying them, teaching students about them, and communicating their value.

Pedagogical challenge #1: Lacking familiarity with theories and having a fuzzy mental model of what theory is can make it difficult to introduce and explain theory to students. What training and resources are required to ensure that HCI instructors are equipped to meet this challenge?

[1]This is not to say that one cannot apply theory while doing iterative design, or form valuable insights and theories by reflecting on an iterative design process. (Similarly, statistical methods play an important role in confirming and contesting theories). However, we would argue that it is *possible* to employ iterative design in this way, and as others have [27], that it does often shake out this way in practice.

3 DO WE EVEN NEED THEORY?

Given that it is possible to do HCI research without directly applying theories, it is a valid question whether we need theory at all to advance our field's research agenda. If we do not, it might make sense to prioritize other topics over theory when training new HCI researchers and practitioners. To understand this question, it is helpful to briefly sketch the history of the "second paradigm" and "third paradigm" approaches [20].

Ethnomethodology [16, 34], developed by Garfinkel and introduced to HCI research by Suchman, provides the implicit philosophical underpinning for much of contemporary user-centered design and iterative design practice in third-paradigm HCI [2]. Ethnomethodology rejects the uncritical use of universal theories in developing descriptions of human behavior, instead arguing that ethnographic participation, close observation, and stakeholders' verbal accounts of what they are doing and why should serve as the basis of research. Grounded Theory Method, which is also widely applied in third-paradigm HCI, similarly encourages bottom-up formation of local theories that emerge from empirical observations [24]. Concepts from this paradigm, like "empathy" and "participatory design", encourage researchers to rely on participants' experience and domain knowledge instead of general theories about social systems or human capabilities.

This approach signaled a break from the "second paradigm" of HCI, which had high hopes for the ability of theories from cognitive science to improve the design of user interface technology [20]. In his book The Sciences of the Artificial, Herb Simon specifically lays out the goal of enumerating and understanding a small number of principles of human behavior that will predict how people will act in a variety of situations and interact with a variety of human-designed artifacts [33]. This vision was taken up by Card, Moran and Newell, who created a "Model Human Processor" that used theories about the structure of the human perceptual, cognitive and motor systems to predict user performance on low-level user tasks [9].

The turn away from these approaches is widely thought to have occurred because cognitive and behavorial theories were not providing enough tangible benefits, and approaches such as ethnography and iterative design allowed the field to build a knowledge base and improve upon designs more quickly [27, 31]. There are a few reasons for this. HCI encompasses such a wide range of contexts that it was hard to build theories that are relevant to all HCI researchers. In addition, theories and the models derived from them have practical limitations. For example, Card, Moran and Newell's influential keyboard-level model can only predict task time for expert users and fails to accurately model novice users, and in general cognitive modeling can't predict how users will perform complex tasks (e.g., training a coworker how to use a computer) that are dependent on cultural and social factors [8, 31]. Writing in the 1990s, Landauer argued that these types of theoretical approaches were fundamentally poorly matched to the requirements of technology development, and that "useful theory is impossible, because the behavior of human–computer systems is chaotic or worse, highly complex, dependent on many unpredictable variables, or just too hard to understand" [23].

These limitations spurred the development of the design methodologies that are in common use today, as well as the uptake of new theories such as activity theory and design theory. Research through Design (RtD) emerged as an way of incorporating the skills and work practices of designers into the HCI research process, with Zimmerman and Forlizzi arguing that RtD represented "a way for many new things to enter into HCI that can spawn new theory"[38]. They also note that designers often build off of behavioral theories, though perhaps not in the deterministic way that second-paradigm HCI intended [38]. The exact nature of the theories produced through RtD are contentious among design researchers, with Gaver arguing that theories produced in this way are likely to be "provisional, contingent, and aspirational" [17]. Höök and Löwgren describe how design research

[2]Ethnomethodology is not the only framework for doing ethnography in HCI, and other ethnographic methods such as the extended case method explicitly aim to extend existing social theories [6]. However, ethnomethodology has historically been an influential force, for a variety of historical reasons [4]. For a much more detailed exposition of how ethnomethodological assumptions shape third-paradigm HCI research, refer to [13]

can give rise to "strong concepts", an intermediate form of knowledge in between instance-level knowledge and generalized theories, and argue that HCI should rely more on knowledge from general design theory [21].

Given that design research produces a variety of types of intermediate and theoretical knowledge (and many design researchers argue that some essential parts of what is learned from design research remain implicit in the artifacts themselves [17]), it can be challenging for researchers from outside this subfield to incorporate the theoretical insights that it generates. Most HCI researchers who engage in iterative design are not formally trained in RtD (just as most HCI researchers who engage in needfinding are not trained as ethnomethodologists). As such, they may ignore the body of findings provided by design research in their own design process.

In sum, the frameworks popular in third-paradigm HCI (ethnomethodologically-informed inquiry, grounded theory method, iterative design) give users a toolbox that allows them to make progress while working in a empirical, bottom-up fashion rather than relying on existing domain-specific theories. Though it is certainly possible to incorporate existing theory into research done within this paradigm (as showcased by RtD and other design research methods) the fact that this toolbox is ready-to-hand, and that the relevant theories may be inaccessible, difficult to apply, or not that useful, might lead researchers to proceed without doing so.

However, there are a wide range of benefits to doing theory-driven design that are not typically obtained through theory-neutral approaches. Using and developing theory helps to understand *why* designs work in addition to *whether* they work. With a strong and well-validated theory researchers can better predict how and when results will generalize, reducing research waste from repeating data collection across different contexts (whether HCI has access to many strong and well-validated theories like this is debatable). Finally, designing experiments and interpreting results with respect to an established theory makes it more likely that the explanatory concepts used in various studies will match up with each other, helping to build a cumulative knowledge base for the field.

Pedagogical challenge #2: Since in some cases, theory-neutral approaches may allow researchers and practitioners to make progress on a given problem more quickly, how can HCI instructors teach students to recognize the situations where it might be useful to employ a theory-driven approach vs. a theory-neutral approach?

4 IMPORTED VS. HOMEGROWN THEORIES

Because of HCI's interdisciplinary nature, it has developed a culture of scavenging the most useful concepts and theories from adjacent disciplines. This often requires adaptation work on the part of HCI researchers, and several writers have reflected on the ways in which theories that are useful for designing technological artifacts differ from theories that were developed to explain or predict human behavior [3, 27]. Many of the most influential theoretical approaches in HCI (cognitive models, affordances, activity theory) entered the field through this route. However, the HCI research community contains many scientists who can build and develop theory in their own right. Other influential theories (one good example being Pirolli and Card's information foraging theory [30]) have emerged this way.

Both of these approaches pose challenges for building and teaching theory in HCI. We risk engaging in "cargo cult science" [15] when we expect to be able to adapt theory from other research domains with little thought or effort (e.g. finding a high-level description of an idea in a popular psychology book, putting a feature loosely inspired by it into a user interface and hoping for the best), rather than carefully considering the work that needs to be done to check the extent to which the theory actually applies. Rogers notes that some of the least successful theories in HCI have been those that were presented as ready for use by practitioners "out of the box" [31]. Adapting a theory to a new domain is a delicate process, and it is important to impress this fact upon students.

Pedagogical challenge #3: How can HCI instructors teach students the skills and content knowledge required to adapt theories from other disciplines in reliable ways?

The main difficulty of building useful "home-grown" theories is that as an interdisciplinary field, individual HCI researchers may not be aware of theoretical concepts and empirical findings from the behavioral and social sciences (or other relevant areas) that might be important for building strong theories about how humans interact with technology. Attempts to build new theories or extend existing ones might replicate past efforts in other disciplines, and result in wasted effort if HCI researchers recapitulate theoretical approaches that have already shown to be limited or flawed.

Pedagogical challenge #4: How can HCI instructors teach students to build their own theories that are specific to the domain of human-computer interaction? What skills and content knowledge from within and outside HCI are necessary to maximize their chance of success?

In addition, this lack of familiarity also poses a problem for instructors who are trying to teach "imported" theories. Often, the points of reference for "imported" theories are theory papers that introduce and explain them to an HCI research audience (one recent example is "Critical Race Theory for HCI" [26]). However, these theories may evolve as they are refined and tested by researchers from their discipline of origin, meaning that instruction that relies on the seminal HCI paper introducing a topic may eventually become outdated.

Pedagogical challenge #5: If HCI instructors are not experts in the domains where theories originate, how can they make sure that they are teaching them correctly and that the material is not invalidated or made less relevant by new research in that field?

5 THEORY CRISES IN ADJACENT DISCIPLINES

There is another reason to be wary of teaching imported theory in HCI courses: the replication crisis [29] has shaken some of the fields that parallel HCI (for example cognitive science and psychology) and caused them to re-consider how they develop and use theory, leading some to declare that these fields are also undergoing a "theory crisis" [14].

While a number of interventions (pre-registration [12], post-publication peer review [32]) have been proposed to increase replicability of research results, other scientists have argued that unless the quality of theories in the behavioral sciences is improved, problems will continue to arise. Though there is agreement that the status quo is bad (as evidenced by many theoretically-grounded psychological effects, such as ego depletion effects, failing to replicate [14]), different researchers have different opinions on what needs to change. Reviewing these is useful for understanding how we should go about building and teaching theories in HCI, especially for researchers interested in applying or extending predictive theories of human behavior.

Eronen and Bringmann argue that the "theory crisis" results from the fact that psychology is simply a particularly difficult area in which to build scientific theories. One reason is because theories are typically under-constrained by the available data - many available theories (which may rely on contradictory assumptions about human cognitive system) can explain the same psychological phenomena [14]. This is similar to the situation in HCI, where a wide variety of theoretical lenses can be applied to understand a given technology and how humans interact with it. Luckily, the breadth of different phenomena of interest to HCI, as well as the strong design and computational skills present in the HCI research community, allow us to build new systems and user interfaces that support experiments that can distinguish between competing theories. However, this is a skill that requires explicit instruction and practice.

Pedagogical challenge #6: How can HCI instructors teach students to find research designs (i.e., task and user interface combinations) that allow for informative comparisons between the predictions made by different theories?

Another line of research argues that the correct strategy for improving the quality of theory in the behavioral sciences is to formalize theories using mathematical and computational models, rather than relying on verbal theorizing [19, 35]. Verbal theories can be interpreted in many different ways because of the ambiguity of

natural language, while correctly specified formal theories are often less ambiguous and can be less prone to misinterpretation. However, verbal theories can often be converted into formal ones, a process that makes explicit researchers' assumptions about how a theory might apply to their problem domain [36]. Formalizing theory can provide a variety of additional benefits, such as exposing flaws or contradictions within a theory [19].

Pedagogical challenge #7: How can HCI instructors teach students the distinction between precise theories and underspecified ones, and how to convert an ambiguous theory to a well-specified theory appropriate for generating testable hypotheses about their problem domain?

6 GENERAL CONSIDERATIONS FOR TEACHING THEORY IN HCI

Previous sections of this paper have laid out how theory is applied in HCI and adjacent disciplines and how this introduces certain unresolved pedagogical challenges. In addition to these challenges, there are some additional general considerations for incorporating theory into an HCI curriculum.

When considering how we might restructure courses to teach theory more effectively, we must also take into account how theory will be balanced with other important course content (e.g. iterative design methods, specific technologies and tools, important empirical results from HCI research, etc.). It is also worth considering how the appropriate balance might shift in depending on the amount of HCI education students are likely to receive. How should teaching theory be approached differently if students are likely to take a single ten-week undergraduate course compared to an entire Master's or PhD program with a large amount of mandatory HCI coursework?

Though we have raised several challenges that focus on the difficulty of preparing students to engage in theory-building as part of HCI research, most students who take HCI classes will not go on to become HCI researchers themselves. They may work as UX practitioners, work as technologists who occasionally use HCI methods to improve the products they build, or simply use the knowledge they have gained to better understand their experiences with technology in their everyday lives. It is important to consider what benefits these different groups of students will derive from learning about the theories that are relevant to HCI.

Finally, a core challenge for incorporating theory into an HCI curriculum is deciding which theories should be taught, and in how much detail. Should this be driven by the expertise of the particular instructor, who might be better equipped to teach theories related to their own HCI research or practice? Or are there a core set of theories that every HCI student should learn, because they are particularly useful or influential in the history of the field?

7 POTENTIAL TEACHING INTERVENTIONS

Based on the considerations introduced thus far, we propose three potential teaching interventions aimed at increasing student's knowledge of the different theories that can drive design in an HCI context, as well as their skill and comfort level in applying these theories. These interventions are tentative suggestions (ironically we do not explicitly ground them in pedagogical theory) and not intended to be in any way exhaustive. They are also mainly focused on how to help students learn and apply predictive theories from other disciplines to artifact design, which is a current interest of the authors. We hope to solicit feedback on these proposals as well as additional ideas from workshop participants (especially on teaching interventions that might apply to a broader range of theories and uses of theory).

- **Design projects driven by predictive theories**: One avenue we are interested in pursuing is restructuring a graduate level HCI research course to emphasize theory-building and the use of predictive and speculative theories for theory-driven design. We would require that students explicitly engage in counterfactual reasoning in written project proposals, by describing how some theory predicts performance differences between different planned user interface variants. Students would then design experiments to test how well their reasoning predicted the behavior of the system they build. This would require front-loading

theoretical content by adjusting the order of readings in the course, to ensure that students are introduced to a range of relevant theories before they begin their projects.

- **Theory-driven self-experiment assignments**: Applying knowledge from vision science and psychophysics could be an excellent way to demonstrate the value of theory to students. There are well-defined, highly predictive theories about how the visual system works that are frequently applied in visualization research [37]. Students could get data on how well those theories can transfer to simple visualization designs by engaging in self-experiments.
- **Embedding teachers and students from adjacent disciplines in HCI courses**: One way to support teaching theory in HCI might be to involve instructors or students from domains where HCI frequently "borrows" theories (e.g., cognitive science[10], vision science [28], or sociology [1]). Having a teaching assistant or co-instructor from one of these areas could help ensure that relevant course material is up to date and taught effectively (similar to Harvard's experiments with hiring philosophy TAs to teach embedded ethics modules in computer science classes [18]). For a project-based graduate course, having a student on each project team who teaches their teammates about relevant theories from their discipline while learning HCI skills in return could be an interesting experiment. However, the specific interdisciplinary collaborations would have to be chosen carefully to ensure that students would actually benefit from this exercise.

8 CONCLUSION

We hope that this paper will be useful to HCI community in understanding how the complex history and contested nature of theory in HCI poses multiple unresolved challenges for the incorporation of theory into the broader HCI curriculum. We welcome discussion from workshop participants on whether they agree with our assessment of these challenges, and on potential answers to the questions we introduce. In particular, we hope that the workshop participants can discuss which criteria should guide curriculum developers in prioritizing which theoretical content to teach, and which directions might be useful for developing teaching interventions that can help overcome the challenges we introduce (inspired by the list above, as well as their own positive or negative learning experiences as students and instructors of HCI).

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