

Reflective Informatics: Conceptual Dimensions for Designing Technologies of Reflection

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ABSTRACT

Despite demonstrated interest in designing for reflection, relatively little work provides a detailed explication of what exactly is meant by reflection or how to design around it. This paper fills that gap by reviewing and engaging with conceptual and theoretical models of reflection, organized by the disciplinary and epistemological perspectives each embodies. Synthesizing across this theoretical background, the paper identifies three dimensions of reflection: breakdown, inquiry, and transformation. Together, these dimensions serve as the foundation for *reflective informatics*, a conceptual approach that helps bring clarity and guidance to the discussion of designing for reflection. The paper distinguishes reflective informatics by demonstrating how it both differs from and complements existing related work. Finally, the paper provides a critically reflexive consideration of its own latent assumptions, especially about the value of reflection, and how they might impact work on designing for reflection.

Author Keywords

Reflection; reflective informatics; design; reflective HCI.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

“Without [reflection] no judgment of experience would be possible at all.” [25]

Researchers in HCI have demonstrated significant interest in designing technologies to support reflection [6,15,31,42]. While it provides an exciting and challenging application area, there persists a certain “fuzziness in which the term ‘reflection’ is used within the HCI community” [15:221]. Indeed, few of the papers describing systems purported to

support reflection provide more than a one- or two-sentence definition of the concept [6,15]. Work in this area may benefit from a more explicit discussion of what we mean when talking about reflection.

Part of the issue may arise from the diverse auspices under which prior work has been conducted. As mentioned above, substantial work has already been undertaken in designing technologies of reflection [6], so reflection *per se* is not necessarily novel. However, much of this work remains somewhat disjoint, spanning applications from health to education to personal informatics to design support tools [15]. Articulating a larger conceptual umbrella under which this work operates may facilitate engagement with foundational concepts and theories of reflection.

This paper, then, seeks to provide such a conceptual grounding, one that can be relevant to and shared by the disparate strands of work around designing for reflection. After reviewing previous approaches to reflection in HCI, it considers several theoretical approaches, organized under the various disciplinary and epistemological perspectives they embody, that might prove useful in conceptualizing what exactly we mean by reflection. Synthesizing across these theories, the paper proposes the term *reflective informatics* and offers three dimensions along which computational and information technologies may be designed to promote, foster, encourage, or support reflection. These dimensions are explicated both through grounding in the theoretical literature on reflection and through comparison with prior instances of designing for reflection. The paper concludes by taking a critical, reflexive turn, considering its own underlying commitments and latent assumptions about reflection as well as some of the tensions inherent in designing, and evaluating, technologies of reflection.

Crucially, it would be deleterious to use “reflective informatics” as a keyword or silo to set reflection-oriented papers apart from other, ostensibly non-reflection-oriented work. Rather, the term represents a sensibility toward the relationship between computational technology and reflective thought in such a way that highlights its permeation though and relevance in numerous different contexts. Indeed, reflection cannot and should not be isolated as its own subfield within HCI. Instead, this paper works toward providing underpinning concepts and unifying concerns that may be readily applied to a variety

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of domains, from health to education to personal informatics. Furthermore, it also aims to elucidate both how endeavors to support reflection in those disparate areas might share commonalities and how they might mutually benefit from each others' insights.

The paper thus makes two primary contributions. First, by reviewing work on reflection from a variety of disciplines, it provides needed [6,15] conceptual and theoretical grounding for reflection in HCI. Second, by synthesizing across that work, it suggests three specific dimensions for applying these concepts and theories in technology design.

RELATED WORK

This section both demonstrates reflection as a topic of interest in HCI and considers some of the ways in which prior work has engaged with the concept. Such work can be grouped into two broad, partially overlapping strands.

The first strand acknowledges the importance of reflection in the design process. For example, Schön's descriptions of reflective practice [43] and of design as a reflective conversation with materials [44] have been applied to improving the quality of interaction design [33]. Value sensitive design [18] emphasizes designers' capacity for reflection on the value commitments embedded in (a) design. Numerous approaches have been taken to facilitating reflection in the design process, including (perhaps somewhat reflexively) designing tools to help designers reflect [see 6 for a review].

A second strand of work, more directly relevant here, deals with reflection among users. This section reviews three approaches that explicitly discuss reflection among technology users. For each, we argue that the dimensions articulated below help fill a gap by providing the theoretical grounding and conceptual language necessary to engage with, and design for, reflection [6,15].

Personal Informatics

Reflection plays a central role in the conceptualization of personal informatics. Li et al. define personal informatics as systems that "help people collect personally relevant information for the purpose of *self-reflection* and gaining self-knowledge" [31:558, emphasis added]. In addition to giving reflection a central place in its definition, their model of personal informatics includes reflection as one of five stages. An individual who (1) has the *motivation* to examine her or his personal information, (2) has *collected* that information, and (3) has *integrated* it into a meaningful form(at) can then (4) *reflect* on her or his data. This reflection leads to subsequent (5) *action* wherein the individual changes her or his behavior (or perhaps not) based on reflections about her or his data and the resultant increase in self-knowledge.

Reflection, then, functions as the impetus in personal informatics that moves the individual from examinations of her or his data to action. Despite this central importance,

work on personal informatics provides relatively little detailed explication of what actually constitutes reflection. For Li et al., "looking at lists of collected personal information or exploring or interacting with information visualizations" [31:562] is constitutive of reflection. A colloquial definition such as this, rather than one based in previous theoretical work on reflection, is not itself a weakness. However, this definition provides relatively little guidance in terms of how we might go about designing for reflection. The dimensions of reflective informatics presented below provide needed conceptual and theoretical grounding, along with design strategies for each identified dimension of reflection. Thus, this paper supplies both a working definition of what constitutes reflection and guidance as to how we might design for it.

Reflective Design

Reflective Design [45] applies Agre's notion of critical technical practice [1] to HCI. In so doing it brings "unconscious aspects of experience to conscious attention, thereby making them available for conscious choice" [45:50]. This approach involves designers identifying "attitudes, practices, values, and identities" [45:50] on which existing, norm-reinforcing designs are often predicated and instead designing based on alternative assumptions. As one of the few lines of prior work to provide theoretical grounding, Sengers et al. define reflection by drawing on "a Western tradition of critical reflection [in] Marxism, feminism, racial and ethnic studies, media studies and psychoanalysis" [45:53]. For example, in considering the design of technology for a museum, Boehner et al. [9] identified one-way transfer of information, from curators to visitors, as the dominant paradigm in existing designs. Using reflective design led to developing alternative technologies that allowed "visitors to add their own voice to the curator's voice" [45:53]. The influence of critical theory, and a resonance with critical design [14] (described further below), can be seen here in how this design challenges and shifts the power relations between visitors and curators.

While they chiefly emphasize the importance of reflection among designers, Sengers et al. [45] also mention and discuss the importance of promoting reflection among users as part of reflective design. However, of the six principles of reflective design, only two explicitly focus on users: "designers should support users in reflecting on their lives" and "dialogic engagement between designers and users through technology" [45:55–56]. These principles acknowledge users primarily in terms of their relationships with designers. Moreover, they provide little in the way of practical guidance for designers. Thus, an approach that provides explicit dimensions of reflection and concomitant strategies for designing around those dimensions represents an important complement to this previous work.

Slow Technology

Much technology is designed in service of enabling

efficient work, wherein speed and productivity are lauded above almost all else. Hallnäs and Redström [20] explore an alternative. Drawing an analogy from the distinction between fast food and a gourmet meal, they suggest countering existing “fast” technology by designing “slow” technology. For example, consider “an electronic doorbell that plays short fragments of a very long melody” [20:202] with each ring. The doorbell cannot be fully understood after one use. Doing so takes time, both in terms of repeated use and in terms of pausing to consider the relationships among the melodic pieces. Another example, the ChatterBox, is described below. Such designs, they suggest, help make space for reflection.

Slow technology provides a certain design sensibility that uses slowness to make space for reflection, making it complementary to but distinct from the dimensions of reflection articulated here. Furthermore, Hallnäs and Redström [20] remain somewhat vague as to what constitutes reflection. This vagueness is not necessarily a limitation; they may have intentionally avoided constraining the possible design space of slow technology. However, this vagueness also opens an opportunity to articulate more fully what we mean by reflection, as is done in this paper.

THEORETICAL BACKGROUND

To provide more grounded explication of how we might approach reflection in interaction design, this section describes a variety of conceptual and theoretical approaches to reflection. An exhaustive review of such work far exceeds the scope and space constraints of this paper [see, e.g., 16,34]. Instead, this section revolves around various disciplinary-epistemological approaches to reflection. Researchers in a range of disciplines—from philosophy to psychology to education—have provided a variety of conceptual and theoretical tools for thinking about and analyzing reflection. Organizing this work in terms of discipline and epistemology helps us see not only commonalities but also differences among these various approaches.

Note that this paper does not argue that any single conceptualization of, epistemological approach to, or theoretical framework for reflection *should* be used as an underpinning to designing for reflection. Indeed, each of the following have strengths and limitations in terms of guiding design. Rather than championing one approach or another, this paper instead suggests that greater insight with respect to informing design can be gleaned by identifying differences between and, moreover, commonalities among these theoretical approaches.

Philosophical

One of the original considerations of reflection in Western philosophy comes from Kant [25]. He begins his philosophical investigations by arguing for the existence of two types of mental faculties. The first, Understanding,

involves comprehension of and reasoning about (or as Kant calls it “legislating”) the domain of the natural world. The primary role of understanding is the identification and application of natural laws that necessitate how the world works. The second mental faculty, Reason, has the moral world as its legislative domain. Reason involves the identification and application of moral laws based on what freedoms of action are and are not possible with respect to human desire. Later, Kant extended this framework to include a third faculty of Judgment that mediates between nature and morality, between the natural world and the world of human desire. It is our faculty of judgment, he argues, that enables notions of aesthetics and beauty, i.e., the application of human desire to the natural world.

“The power of judgment in general is the faculty for thinking of the particular as contained under the universal” [25:Intro. IV, 5:179]. Of this faculty of judgment, Kant describes two kinds. In instances where the universal (e.g., a law) is given, then the judgment that operates to subsume particular instances under that universal is referred to as determining or as “determinant judgment.” “If, however, only the particular is given, for which the universal is to be found, then the power of judgment is merely reflecting” [25:Intro. IV, 5:179] or “reflective judgment.” Universals arising thusly do not derive directly from nature, otherwise they would be considered given. Rather, the reflecting power of judgment itself generates and gives rise to such universals. Kant places great significance on this capacity, suggesting at one point that all empirical concepts derive from it and that “without [this reflecting power] no judgment of experience would be possible at all” [25:FI V 20:212].

Another example comes from Dewey’s [12] discussion of reflective thought, which places significant importance on reflection as a fundamentally important type of thinking. He defines reflective thought as “active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends” [12:6].

This type of thought occurs through five distinct steps. First, it begins with “the inherently doubtful—with the confusing, obscure, or conflictual situation” [12:121]. The second step, identifying and defining the nature of the perplexing situation, may coincide with the first step. The third step involves suggestion of possible explanations. In the fourth step, the implications or consequences of each potential explanation are generated and considered. The fifth and final step compares these implications with the troubling situation to verify which, if any, of the potential explanation can account for it.

Dewey describes this puzzle-testing process occurring in even the most quotidian of situations, from navigating a city in order to arrive at an appointment on time (“I was down on 16th St. [at 12:20 and] I had an engagement at 124th St., at one o’clock” [12:69] p. 69), to puzzling out why bubbles

form on the outsides of freshly washed glass tumblers placed upside-down (“Air from outside must have been expanded by the heat of the tumbler” [12:71]). Dewey devotes much focus to the training of (reflective) thought, especially the conduct and goals of education, which accounts for his influence in scholarship on the role of reflection in education [e.g., 17,36], to which we return below.

Cognitive

Another series of approaches to reflection comes from cognitive and developmental psychology. From this perspective, reflection is seen as a particular type of cognition, differentiated from others by its non-automatic character. Many dual-process models [24] describe two general modes of thought. The first, the automatic system, is responsible for quick, instinctive, or reactive decisions in our everyday activities. Indeed, drawing on prospect theory [23], Thaler and Sunstein [48] acknowledge that much of the thought conducted by this system is more likely to be seen as instinct than as “thinking.” In contrast, decisions made by the reflective system occur slowly, with much deliberation and conscious intentionality. Thaler and Sunstein, though, focus primarily on using “nudges” to influence decisions made by people’s automatic system, making their work not as directly relevant here.

In a similar example, Norman [38] differentiates between what he calls experiential cognition and reflective cognition. The former deals with “a state in which we perceive and react to the events around us efficiently and effortlessly” [38:16]. Reflective cognition, on the other hand, deals with intentional thought, decision making, and, crucially, “new ideas [and] novel responses” [ibid.]. While he acknowledges this bipartite treatment of cognition as an oversimplification, Norman goes on to suggest that much work in technology design focuses too greatly on experiential cognition. Incorporating a greater balance of support for reflective cognition, he suggests, can facilitate the design of technologies that better draw out humanity’s creative capacity.

Other cognitive approaches are more fine-grained. King and Kitchener [26] developed a stage-based model of what they call reflective judgment describing how people come to be (more) reflective (without explicit invocation of Kant’s [25] notion of reflective judgment described above). Rather than two modes, reflective and non-reflective, their model consists of seven stages. In the pre-reflective stages, “knowledge is assumed to exist absolutely and concretely” [26:48] in the world and thus needs to justification. More reflective stages are characterized by an acknowledgment of the contingency of knowledge. Knowledge is rarely seen as absolutely right or wrong but rather more or less reasonable, based on the arguments made and evidence available.

Reflective judgment, King and Kitchener [26] suggest, provides greatest value in situations of ill-structured

problems involving significant uncertainty. For such problems, solutions cannot be “described with a high degree of completeness,” nor can the problem be “resolved with a high degree of certainty” [26:11]. For example, the question of whether or not the ancient Egyptians had the mathematical knowledge, the necessary tools, and adequate power sources to build the pyramids can be seen as ill-structured. A non-reflective response would indicate that, because the pyramids are in Egypt, the Egyptians must have built the pyramids. A more reflective response might acknowledge, as one participant did, that “right and wrong are not comfortable categories [here...] it’s more or less likely or reasonable, more or less in keeping with what the facts seem to be” [26:72]. Thus, in this view, reflection enables reasonable, evidence-based decision making, even in the face of uncertainty.

Educational

The potential relationship between education and reflection can be seen in some of the work above. Dewey [12] specifically describes the importance of reflective thought in education. Norman [38] suggests that education functions best when combining a balance of experiential cognition and reflective cognition. Much of King and Kitchener’s [26] empirical work examines how reflective judgment develops as individuals move from primary and secondary education through university and into post graduate education. Indeed, several other scholars articulate deep connections between education and reflection [e.g., 17,27,36,37,43], two of which are described here.

For Moon, “reflection is intimately linked with the process of learning” [37:100]. She describes reflection as a mental process or, at times, a mental function, taking as inputs things that are already known to the individual and producing as output greater understanding. Thus, “reflection [is] a secondary action on already learnt material” [37:159], a reprocessing of knowledge or theories that may itself produce further knowledge or theories. In this way, reflection represents a form of deeper learning, involved not only in making meaning but in what Moon calls “working with meaning.” Thus, reflection is integral to what Kolb [27] calls “deep learning,” i.e., learning that transforms experience into knowledge.

Focusing more on the informal education of professionals and professionalization, Schön’s [43] investigation of reflection studies how professionals think. His interests lie in what he refers to as “the epistemology of practice” [43:vii], that is, the kinds of knowing that professionals evidence through the conduct of their practice. In many ways, this focus resembles tacit knowledge, when there are things we know but “we cannot say what it is that we know” [43:49]. This knowledge is not abstract but is knowledge in doing, or, as Schön puts it, “knowing-in-action.”

Schön describes a number of examples, ranging from professional baseball pitchers “finding the groove [...]

studying [their] winning habits and trying to repeat them every time [they] perform” [43:54], to an investment banker who acknowledges that operating numbers “allow him to calculate ‘only 20 to 30 percent of the risk in investment’” [43:63]. Situations of reflection are often precipitated by the unexpected, and such “reflection tends to focus interactively on the outcomes of action, the action itself, and the intuitive knowing implicit in the action” [43:56]. This conception creates an inextricable, dialogic link between reflection and action; reflection is not an abstract, heady activity but is intimately intertwined with the performance of action. This kind of reflection-in-action, Schön argues, moves beyond positivist-based technical rationality to grapple with “situations of uncertainty, instability, uniqueness, and value conflict” [43:49].

Critical

Work in a fourth epistemological paradigm does not always use the term “reflection” but nonetheless shares many goals and sensibilities with other work reviewed here. Critical design “asks carefully crafted questions and makes us think, [...] its purpose is to stimulate discussion and debate” [14:58]. Put another way, “critical design [means] things that make you think” [8:501].

The epistemological paradigm underlying critical design derives largely from critical theory. This perspective neither sees knowledge as externally existent and objectively knowable in the style of positivist epistemology, nor does it see knowledge as a fully intersubjective social construction in the style of interpretivist epistemology. Instead, critical approaches consider knowledge as contingent upon, and in many ways arising from, the particular historical circumstances and power structures in which that knowledge is created [39]. While a detailed explication of critical theory exceeds this paper's scope, the application of critical perspectives in design [cf. 3,4] bears relevance to reflection. Specifically, critical design represents a means of drawing attention to, and arguably encouraging reflection on, the power dynamics and historical contingencies on which knowledge is predicated.

The influence of critical approaches can be seen in recent developments in HCI [e.g., 3,4,20,22,45]. However, critical designers do not always use the term “reflection” to describe the experiences they hope to evoke. Indeed, a recent review of reflection in HCI found few, if any, critical design papers that self-identified as pertaining to reflection [6]. Nonetheless, we include critical approaches here for two reasons. First, they provide an important epistemological alternative to other approaches dominant in HCI [cf. 39]. Second, they demonstrate that interest in the phenomena of reflection exist in HCI beyond work that self-identifies as being about reflection.

Summary Notes

Before moving on to consider how these theoretical approaches can be leveraged to inform design, it is valuable

to note some comparisons and contrasts enabled by the epistemological grouping used here.

First, in both the philosophical and cognitive approaches, reflection is seen as a largely mental, almost exclusively individual activity. Dewey's [12] descriptions in his examples of reflective thought foreground vividly the individual, internal aspects. Likewise, Kant's [25] discussion of reflection arises during an explicit focus on mental faculties. This focus also appears salient in cognitive frameworks that emphasize the role reflection plays (or at times does not play) in individual decision making [48]. Similarly, King and Kitchener's [26] model describes individual cognitive development.

In contrast, educational approaches at least mention, if not emphasize, social (inter)action. For example, Schön's [43] case study of town planners shows that they do not work in isolation; rather, their reflection is embedded in a complex milieu of regulatory systems, advocacy groups, etc. Furthermore, these practitioners' reflection occurs not primarily through internal mental activities but “in action,” in the conduct of their work. For Freire [17], the sociopolitical contexts give reflection not only its shape but also its purpose. Similarly, “critical design takes as its medium social, psychological, cultural, technical and economic values, in an effort to push the limits of lived experience” [14:58].

Second, these approaches differ in the value judgments they make about reflection. Cognitive approaches clearly imply reflective thought as often preferable to or even superior to “automatic” [48] or “pre-reflective” [26] thinking. Simultaneously, though, they acknowledge both the value of the rapid decision making that comes with such automatic thought and the impossibility of constantly engaging in reflective thought [38,48]. Critical approaches also value reflection for its potential to challenge existing sociocultural norms.

In contrast, philosophical approaches do not make such expressly clear value judgments about the preferability of reflective thought. For Kant [25], reflective judgment represents one mode of being, one particular way in which an individual experiences and interacts with the world that accounts for the ability to navigate relationships between abstract generalizations and particular concrete instantiations. Despite the importance Kant places on reflective judgment, he does not suggest that individuals should (or perhaps even could) be “more” reflective.

SOME DIMENSIONS OF REFLECTIVE INFORMATICS

Rather than arguing for or against the use of any one of these theoretical approaches or conceptual models, this section moves from contrasts to consider commonalities. In some ways, this strategy resembles that of Fleck and Fitzpatrick [15], who review literature on reflection to enumerate five levels of increasing reflectivity. However, rather than suggest means of designing for more reflection,

this section synthesizes across the different perspectives reviewed above to distill several common elements. These commonalities serve as dimensions that can help guide the design of technologies for reflection.

These dimensions are not intended as prescriptive, i.e., they do not tell designers what to do. Nor do the dimensions constitute a phase- or stage-based model of reflection; the reflecting individual need not necessarily progress linearly from each dimension to the next. However, they are not totally independent of one another, either, as described further below. Finally, this section articulates *some* dimensions of reflective informatics. Future work, especially both design work and empirical studies of reflection, may identify valuable revisions, limitations, or alternatives to these dimensions. Rather, these dimensions provide a series of generative conceptual tools that can help inform or perhaps inspire design. In addition to grounding each dimension in the theoretical work reviewed above, this section also provides examples of previous work on designing for reflection. These examples both demonstrate how each dimension may play out in practice and provide design strategies for addressing each dimension. Ultimately, these dimensions help establish common ground, advancing the discussion both of what exactly we mean by reflection and of how to design for it.

Breakdown

Instances of reflection are often precipitated by various types of breakdowns. Dewey [12] emphasizes doubtful or puzzling situations. Schön considers situations of surprise, uncertainty, or conflict where “there is some puzzling, or troubling, or interesting phenomenon” [43:50]. Making an analogy to Kuhn’s notion of paradigm shifts [29], Mezirow [36] focuses on “disturbing anomalies” that do not fit with an individual’s current meaning perspectives.

Why are breakdowns important moments with respect to reflection? The importance of breakdowns in other intellectual traditions provides some suggestions. Ethnomethodology [19], for example, focuses on breakdown and repair as moments when the tacit, implicit social structuring of interaction must be explicated by its interactors. Similar resonance can be seen with the phenomenological distinction between ready-to-hand, wherein a tool is used so unconsciously as to feel like an extension of the self, and present-at-hand, wherein a tool is examined consciously for its own properties [21]. Such changes from ready-to-hand to present-at-hand are often precipitated by moments when the tool ceases to function normally. Such conscious and explicit consideration of that which was previously unconscious and implicit, similar to the reflective modes in dual process models of cognition [23,24,38,48], acts to provide opportunities for reflection.

Taking breakdowns into account when designing may mean at least two things. First, as noted elsewhere e.g., [13,46], providing support for breakdowns can help technological tools better align with human practices. In some instances,

such support may also help facilitate reflection. Second, perhaps somewhat more provocatively, drawing attention to or even inducing breakdowns may provide opportunities for moments of reflection. “Unless there is something doubtful, the situation is read off at a glance” [12:102]. Critical design takes a similar, if more measured, approach to breakdown by striving for a “slight strangeness [...] too weird and [designs] are instantly dismissed, not strange enough and they’re absorbed into everyday reality” [14:63]. Thus, drawing attention to or even creating moments of perplexity and doubt may prove a useful design strategy.

Examples

While breakdown plays a central role in several conceptual and theoretical approaches to HCI design [e.g., 13], designing explicitly for breakdown in support of reflection occurs less often. As one example, some of the work in personal informatics [31] is predicated on breakdowns, often via comparison either with a user’s own past data, such as task performance [e.g., 35], or data from other users, such as related search queries [e.g., 5]. Such breakdowns resonate primarily with the cognitive and educational perspectives reviewed above. Another example, ShoddyPop [32], randomly delays the delivery of email messages. Doing so arguably alleviates the onus to respond quickly, since the recipient will not receive the reply immediately, thus making time and space for reflection [cf. 20] on the content of the exchange. This example aligns more closely with philosophical and, to some extent, critical accounts of reflection.

All these examples work by violating expectations. That is, the designer identifies an expectation the user is likely to hold. The system then renders that expectation inaccurate, either by suggesting that the expectation does not hold or by intentionally violating the expectation. Doing so implicitly suggests that the expectation warrants closer examination.

Inquiry

Another important aspect in many frameworks of reflection is the process of conscious, intentional inquiry. Such processes figure prominently in both Kant’s [25] notion of reflective judgment and Dewey’s [12] description of reflective thought. The whole process he describes of examining why fog forms on freshly washed glass tumblers [12:71] exemplifies a process of inquiry, of generating, testing, revising, and further testing hypotheses. Indeed, Dewey at times refers to his conceptualization of reflection as a process of inquiry.

Inquiry plays a similarly important role in educational approaches to reflection. In Moon’s [37] description, reflection involves re-examination of things—concepts, ideas, theories, etc.—already learned, i.e., inquiry on existing knowledge. Inquiry also takes a central place for Freire [17], though for him inquiry focuses on the political, social, and cultural contexts of learning.

Among cognitive approaches, this idea of inquiry occurs

most saliently in King and Kitchener's [26] work. In particular, their emphasis on the nature of knowledge and the basis of justification for that knowledge essentially represents a particular type of inquiry. In contrast to Thaler and Sunstein's [48] reflective mode or Norman's [38] reflective cognition, inquiry for King and Kitchener examines not knowledge itself but the origins thereof, i.e., epistemological inquiry.

Critical approaches often spur inquiry into the values underlying design. Indeed, critical design often employs "value fictions" wherein dominant values are subverted, for example, challenging the masculine-dominant gender norms of a gym [4]. Such subversions can (though not always do) provoke inquiry into the normative values being challenged.

Thus, designing for reflection means creating opportunities for, as well as supporting, inquiry. Doing so could take many forms. Taking after Dewey [12], a design could enable and encourage a process of iterative hypothesis testing and refinement. Resembling Moon [37], a design might focus on the explication of what a user already knows to encourage reflective re-examination of that knowledge. Bardzell et al. [4] suggest that inquiry may result less from the design *per se* and more from dialog between participants and researchers. Drawing on King and Kitchener [26], a design could emphasize inquiry into the origins of knowledge and the evidence provided therefor. Keeping in mind Schön's notion of reflection-in-action [43], such inquiry need not be entirely abstract or cognitive but may occur tacitly in the process of interacting with the system.

Examples

Prior approaches to inquiry become most apparent in work that focuses on reviewing (and reflecting on) past experience(s). For example, Wandering Mind [40] attempts to promote reflection by encouraging exploration of old journal entries. The personal informatics systems mentioned above as triggering breakdown often subsequently allow or encourage users' inquiry into their data, demonstrating the interdependence among dimensions. Inquiry becomes especially notable in work involving group discussion. For example, Prilla et al. [41] describe a system that supports stroke ward staff in reflecting on conversations with family members of patients. The design focuses on users (re)examining notes about their experiences, as well as subsequent group discussion. Arias et al. describe a system for collaborative civic design that explicitly includes a reflection space for "present[ing] information related to the problem at hand for exploration and extension" [2:95]. Thus, the design designates a separate space specifically for inquiry. ConsiderIt [28] similarly distinguishes between statements either supporting or opposing state ballot measures and the arguments to support those statements. Doing so allows for further investigation or examination of the arguments and the statements they support.

From these, we can draw out three design strategies for supporting inquiry. First, a design may incorporate review of past experiences. Second, a design can designate a particular space for inquiry separate from the primary activities to which that inquiry pertains. Third, group discussions may prove an effective means of promoting reflective inquiry.

Transformation

Reflection ultimately involves change. It is not only about examining the current state of the world or one's self but also about envisioning alternatives.

For educational scholars [10,27,37], reflection transforms experience into learning. Especially for Moon, reflection is a process of refining previous learning, that is, transforming understanding. For Kant, reflective judgment is that which reorders our conceptual schema. Reflection occurs precisely when our existing conceptual schema do not apply (or do not apply well) and thus we need to reschematize nature in order to come to a (better) understanding of it.

Schön's reflective practitioners often transform their understanding of a situation. For example, an investment banker found himself leery of an opportunity with a large Latin American bank where "the bank's operating numbers seemed satisfactory" [43:63] but he still felt an unease. The investor realized that "he had been treated with a degree of deference out of all proportion with his actual position" [43:64]. This reflection altered his understanding of the situation, and he chose to forgo any new investments with that bank. "Some months later, the bank went through the biggest bankruptcy ever in Latin America" [43:64].

Cognitive approaches that contrast reflection with more automatic thought processes grant reflection the ability to change the rules by which the automatic systems act. For example, heuristic decisions often function based on loss aversion [23], a preference for avoiding losses over seeking gains. Reflective decision making, however, enables decision making that is not subject to such biases [24].

Critical approaches involve not only questioning fundamental assumptions but exploring alternatives. Value fictions [14] represent one type of transformation enabled by critical design. Transformational products "attempt to actively shape their users' attitudes" [30]. An emphasis on transformation is also evident in Freire's [17] arguments about social change based on critical reflection.

Examples

Of the dimensions described here, transformation likely poses the most difficult challenge to designers. Transformation involves change to the fundamental, basic conceptualization of a situation, such as in Kant's reschamitization [25] or critical design's value fictions [14]. A design, however, often embodies a particular (i.e., single) stance or conceptualization of a situation. Designing for transformation, then, requires that the design be at least

comprehensible (and perhaps usable and/or useful) when approached with different conceptualizations.

Consider Hallnäs and Redström's ChatterBox [20]. The system randomly concatenates snippets of text mined from office emails and displays them as isolated statements, e.g., "To participate in the burglar it will be necessary to register for the i3 Annual," or, somewhat more intriguingly, "Who else is to?" If approached as a tool to increase efficiency and productivity, i.e., as "fast" technology, the ChatterBox seems nearly incomprehensible. Instead, the system requires a transformation of the user's perspective to one that allows for slow technologies, that is, it requires "slowness in learning, understanding and presence [giving] people time to think and reflect" [20:203]. Importantly, such transformation could not occur without breakdowns triggered by the system's inscrutable sentences, again illustrating interconnections among the dimensions. In a related vein, Cheng et al. apply a similar stance on slowness and reflection in the design of GoSlow [11], mobile application that encourages moments of solitary contemplation. Their evaluation of the system, however, suggests that a gap may exist between simply pausing, i.e., going slow, and fundamental transformation.

Similarly, the lens of transformation provides for multiple interpretations of ChatterBox. On the one hand, one could see ChatterBox as designed for transformation in that it requires a transformation from the normative approach to technology in order to make sense of it. On the other, one could argue that ChatterBox does not support transformation in that it requires users take one particular approach rather than supporting the user as s/he moves through the experience of transformation.

DISCUSSION AND FUTURE

In the spirit of reflection, this section takes a reflexive turn on the paper itself. That is, it calls out some of the assumptions underlying the paper (i.e., it incites breakdown), examines the implications thereof (i.e., it conducts inquiries), and considers potential alternatives (i.e., it proposes transformation). Doing so does not cause the paper to undermine itself; rather it ensures that the ideas herein are presented with a degree of humility, acknowledges the paper's underlying value commitments, and suggests important areas for future investigation.

Reflection as Valuable – First and foremost, this paper is predicated on the assumption that reflection is valuable and that engaging in it is desirable. Given the extent of work on reflection in both interaction design [6,15,42] and other areas [16,34], this assumption seems hardly exceptional. However, considering its ramifications and alternative guiding assumptions may be illuminating. Situations may exist in which reflection is less valuable or perhaps even harmful. A doctor at the operating table, for example, might benefit from reflection-in-action [43] related to the procedures s/he is conducting, but s/he may become distracted from the task at hand by reflection on the

economic and sociopolitical inequalities perpetuated by her or his country's health care system. One could even imagine a sort of "paralysis by analysis" in which an individual or group becomes so consumed by reflecting—on their assumptions, value commitments, biases, etc.—that it becomes difficult if not impossible for them to come to a meaningful resolution. Granted, given the close linkages between reflection and action argued for by some [17,43], such situations may be unlikely. Other conceptualizations of reflection [e.g., 12] may certainly allow such paralysis by analysis as a possibility.

Power and Privilege – This paper also does not explicitly address questions about the potentially privileged position of reflection. Who is granted the opportunity to reflect, by whom, and under what conditions? The critical approaches reviewed here speak to some of these concerns [14,17,45]. For Freire [17], the capacity for reflection does not necessarily derive solely from positions of power. Rather, given an appropriate pedagogical approach, reflection, particularly critical reflection on the power dynamics between oppressors and the oppressed, can become a tool for and means of empowerment. While fully addressing these issues exceeds this paper's scope, such sociopolitical concerns should remain central to work on designing for reflection.

Evaluation – Finally, evaluation poses a highly complex challenge. How does one evaluate technologies of reflection? Trying to determine when an individual (or group) is being "more reflective" seems at best a misconstrual of the value of reflection and at worst a harmful and deleterious reduction of an incredibly intricate phenomenon [cf. 47]. Instead, this paper suggests three approaches that may prove more suitable.

First, rather than trying to determine *how much* reflection a person is demonstrating, we might instead ask *in what ways* an individual (or group) is reflecting (or not reflecting). Aspects of either King and Kitchener's [26] or Fleck and Fitzpatrick's [15] frameworks could be used to describe which types of reflective thought occur in what contexts. In both cases, though, it would be difficult to avoid the temptation of seeing a technology of reflection as more effective because users engaged in styles of reflection associated with higher stages in the model. Alternatively, one could hinge such an evaluation on the dimensions articulated here. Perhaps, for example, experiences with a technology provide strong evidence for acknowledging breakdowns but less evidence of inquiry. Moving thusly from quantification to qualification may help grapple with reflection's complexity. Furthermore, doing so may provide valuable revisions to or extensions of the dimensions articulated here.

Second, rather than attempting to assess reflection *per se*, one could instead ask what role reflection plays in the broader contexts in which it occurs. The question, then, may become what benefits reflection provides. Carrying

this approach too far, however, risks a displacement, wherein reflection is linked with some desired outcome (e.g., increased learning, improved performance), and assessment of that outcome is taken as evidence that reflection occurred [6]. Making a comparison between evaluating reflection and evaluating art, Hallnäs and Redström suggest that “one cannot explain what a symphony by Beethoven is [...] by empirical studies of a collection of concert visitors” [20:209]. Similarly, formal methods and traditional user studies of people interacting with technologies of reflection may provide poor accounts of that reflection. Instead, novel evaluation methods may need be necessary to grapple with the broader contextual ramifications of reflection.

Finally, HCI evaluation generally attempts to ascertain the impacts of design, often asking the question, “Did it work?” In the context of reflection, focusing on this question may limit the potential impact our studies of such technologies can have. Instead, we might consider using the design as a means of deepening our understanding of reflection itself. Rather than trying to design systems to make people more reflective, we can seek to understand how different interventions alter the nature of reflective thought. This approach suggests a move from seeing reflection as a problem area in need of a solution to seeing reflection as a complex situation in which we can pose various design interventions [cf. 7]. Thus, avoiding an insistence on demonstrating that our design “works” may open up opportunities to understand more fully both the nature of reflection and the potential impacts of our interventions.

CONCLUSION

Designing for reflection does not represent an entirely novel endeavor [6,15,31,42]. While important prior work has pioneered this area, it lacks a strong conceptual and theoretical grounding [6,15]. Designers of technologies for reflection need a common vocabulary for talking about (1) what reflection is (and, implicitly, what it is not) and (2) how we might go about designing for reflection.

This paper addresses that gap, reviewing a range of literature on reflection from a variety of disciplinary and epistemological perspectives. Focusing on commonalities among these theories, the paper proposes three dimensions of *reflective informatics*, which help articulate how design may support reflection. To help ground the discussion, each dimension is explicated with examples from existing systems and design interventions. These examples demonstrate that the dimensions map well onto and help us understand better existing design practice. Furthermore, comparisons with related approaches show how these dimensions fill a gap in our existing approaches. Thus, this paper provides an important contribution toward drawing work on designing for reflection under a shared conceptual umbrella, as well as giving that work a common conceptual language to discuss the unique challenges in designing for reflection.

Ultimately, this paper not only provides a scaffold for designing for reflection, it also seeks to provoke conversation about and deeper engagement with the conceptual definition and theoretical grounding of reflection in technology design. That is, the theoretical grounding of reflection should not be seen as a “solved” problem. Indeed, future work should explicitly engage with multiple definitions of, theories of, and frameworks for reflection in design. Only through such practical application can we hope to understand how best to design for reflection.

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