



Engineering Education meets Human-Computer Interaction (HCI): Exploring how the work on "probes" can guide the design of reflection activities

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Abstract

Reflecting on educational experiences is widely understood as an essential component of learning and development of expertise for both educators and students. However, incorporating reflection in a way that engages engineering students can be challenging, and educators seek ways to design or introduce effective and efficient reflective practices that best address this issue.

In this paper, we describe three example case studies that use the concept of probes and we analyze their potential for stimulating reflection to help identify new ways of supporting reflection in engineering education. Our goal is to introduce engineering educators to the concept of probes as a method to support students’ reflection and also to inspire and facilitate collaboration between engineering educators and HCI practitioners.

Introduction

Numerous studies have identified reflection as an essential element in learning, development of expertise, and supporting motivation.^[1,2,3,4] As Rodgers put it “reflection is identified as a standard toward which all teachers and students must strive” and “the cry for accomplishment in systematic, reflective thinking is clear”.^[5] While reflection is generally understood as an important part of learning, it is emerging as a critical area of scholarship in engineering education.^[1] Operationalizing the concept of reflection in classrooms in order to help engineering students engage in reflection has been a challenge and educators are seeking ways to best address this issue.^[6,7,8]

Similar to educators in engineering education, designers in the field of Human-Computer Interaction (HCI) are also interested in eliciting difficult-to-acquire information such as users’ values or assumptions. One approach for HCI designers to achieve this goal is by employing the concept of probes. Probes are small collections of artifacts accompanied by *open-ended questions* and *evocative tasks* to which participants respond *over time*.

In this paper, we describe three example case studies that use the concept of probes and we analyze their potential for stimulating reflection to help identify new ways of supporting reflection in engineering education. Our goal is to introduce engineering educators to the concept of probes as a method to support students’ reflection and also to inspire and facilitate collaboration between engineering educators and HCI practitioners.

While this paper is likely to be relevant to anyone interested in techniques for supporting reflection in engineering education, it may be particularly interesting to readers who have been actively working to support reflection and are in a position to appreciate creative and non-traditional supports.

Background

In reviewing reflection literature, there are variations in how reflection is conceptualized and defined in different contexts. As Moon notes “if there is to be an improvement in reflective processes, it will be most effective if the idea is clearly related to the general understanding of the word.”^[9] In this paper, we briefly present definitions from three influential writers in the area

of reflection and learning, and provide our commentary.

John Dewey is seen as the founding father and one of the primary figures associated with reflective thinking and education. Dewey states that reflection is “turning a topic in various aspects and in various lights so that nothing significant about it shall be overlooked” (p. 52, 2013)^[10]. From Dewey’s perspective, reflection enables learning by helping individuals connect various elements of their experiences through reconstructing and reorganizing those experiences.^[10] Building on Dewey’s work, David Kolb, another renowned educational theorist, notes, “Learning is the process whereby knowledge is created through the transformation of experience,” which happens through reflection. (p. 38, 1983)^[11] For Dewey and Kolb, reflection is a critical element of deep learning and education that supports knowledge generation.

Jennifer Moon is another expert in reflective techniques and she defines reflection as “a form of mental processing with a purpose and or anticipated outcome that is applied to relatively complicated or unstructured ideas for which there is not an obvious solution.” (p. 98, 2004)^[9]

The definitions listed above are similar in that they suggest reflection happens when people consciously and intentionally process information for a useful purpose. They also talk about bringing together past experiences while thinking about future possibilities. From our perspective, these definitions complement each other. While we acknowledge that there are several other definitions and that there is no simple and agreed upon definition for reflection, in this work, we build on the definitions of Moon^[9], Dewey^[10,12], and Kolb^[11] and describe the term reflection as intentionally looking back at experiences in order to make meanings that help with future actions. These definitions provide a backdrop for understanding work in engineering education that is explicitly about reflection, and also work in human-computer interaction that is implicitly about reflection.

Reflection in Engineering Education

Reflection and the promotion of reflective activities are essential in engineering students’ overall learning and their future role as professionals.^[10,11,13-16] According to CPREE (Consortium to Promote Reflection in Engineering Education), there is an expanding need for “diverse, adaptive, broad-thinking, and nimble engineering experts who can respond to the ever-increasing challenges that society faces.”^[17] Jolly and Radcliffe note that in order for engineering students to broaden their views of the world and situate themselves within the social and cultural environment, they need to continuously reflect on their engineering experiences to make sense of them, to be aware of and understand their own basic assumptions, and to construct future actions based on these insights.^[18]

Currently, reflection is employed in the engineering curriculum in various ways. Reflection essays, reflective journals, portfolios, end-of-course evaluations and feedbacks, surveys, reflective discussions, and peer evaluations are amongst the more standard reflective activities. However, studies show that incorporating reflective activities into a classroom can be very difficult and students are often not inclined to engage in reflective activities or to develop reflective thoughts.^[18-21] For example in a study conducted at a medical school in the UK where reflective learning is now a requirement for licensing of doctors, out of 232 students, only 20 took the introductory Reflective Learning lectures. One of the students said: “... *people don’t like to talk about what they’re doing as a general rule, and certainly it’s a fairly taboo subject over lunch or in the evenings.*” Some of the other students did not think the reflective learning would

help them with the curriculum and thought it would take too much of their time because reflective learning demands “reproduction of facts rather than conceptual learning.”^[22]

A few studies show that students in engineering education are particularly resistant to participating in reflective activities because engineering students are “generally fact focused”^[23] and many engineering students consider reflection to be a non-engineering or a soft skill.^[6,18,24]

In a two-year study of 350 engineering students in Australia, Jolly and Radcliffe report that students were generally resistant to reflection writing and required a lot of follow up and encouragement to get the reflection task done. Jolly and Radcliff added that the students participated more actively only when the grade percentage of the reflection journal assignment was increased. They suggest that students’ attitudes are evidence for the need for engineering educators “to model reflective practices and place regular emphasis on its value as a professional learning tool.”^[18]

In another study, Turns et al. enumerate several issues that create problems for both students and educators when implementing reflective activities. These issues include students’ difficulties in selecting topics, structuring the essays, understanding the role of the activity, as well as the overhead associated with the submission, grading, distribution of help, and management of the activity in the classroom.^[21] Walther and colleagues connect these difficulties to a lack of defined, systematic strategies to stimulate purposeful student reflection and to overcome the inherent difficulties of the engineering cohort to engage in reflective thoughts.^[25]

These studies highlight the importance of designing reflective activities in a way that would place fewer burdens on educators, while helping engineering students take the time to understand the lessons that are afforded by engineering courses through reflective activities.

To address these issues, a few researchers in engineering education have successfully designed or developed new methods and tools to support student reflection. For example, Chen et al. combined the use of weblogs and wikis with the creation of portfolios (Folio Thinking) to support learning and reflection in an introductory freshman seminar on design engineering at Stanford University. Chen et al. indicate that a challenge in project-based design courses is that students “see what they have produced but they do not see what they have learned.” They report that the combination of Folio Thinking with wiki and blog environments increased the awareness of what the students had learned, and enhanced the students’ experience while helping them articulate the connection with learning the design processes taught in the class.^[14]

In another study, Turns et al. designed and developed an electronic environment called “Reflective Learner” to support and facilitate the learning essay writing for both students and educators. The Reflective Learner tool facilitated the submission and organization of the assignments for students, while provided an environment for educators to define, review and grade the essays. The careful design of the “Reflective Learner” tool streamlined the entire process for posting the assignments through grading them for both students and educators and, more importantly, students reported that the tool helped them be a more reflective learner.^[21]

In each of these examples, the researchers took time to design and develop appropriate methods and tools to facilitate the reflective activities in classrooms. These examples illustrate that when reflective activities are *designed* with care, they can positively impact engineering students’

desire to participate in reflective activities and to help them see the value of reflection in their learning experience.

Supporting reflection is difficult and these studies show that conducting reflective activities is challenging. As we mentioned earlier, HCI designers and researchers employ cultural probes as a method to elicit difficult-to-acquire information such as users' values or assumptions. In the next sections, we introduce the concept of cultural probes and unpack and compare examples of the use of the cultural probes in HCI.

Cultural Probes

Cultural Probes are small collections of artifacts accompanied by *open-ended questions* and *evocative tasks* to which participants respond *over time*. Cultural probes help designers elicit inspirational responses from participants in order to understand the participants' culture, thoughts, and values. These inspirational responses are not meant to be "comprehensive information about the participants but fragmentary clues about their lives and thoughts."^[26]

Bill Gaver and his colleagues originally developed the concept of cultural probes through a European Union Sponsored project called the Presence Project.^[27] In the Presence Project, the designers' goal was to investigate the ways technology can be used to increase the presence of older people in their local communities.

In the Presence Project, each cultural probe was a package including postcards, maps, a disposable camera, a photo album, and a media diary booklet (See Image 1). Some example tasks and questions included in the packages were *take a picture of something desirable, give us a piece of advice that is important to you, and use 6 to 10 pictures to tell us a story*.

The intention of Gaver et al.'s use of cultural probes was to support creativity and imagination, while amplifying the participants' existing pleasures. Cultural probes also explored how technology could support the participants' values.



Image 1- Left: a disposable camera with requests for specific pictures. Right: postal cards.

Key characteristics of Cultural Probes:

Cultural probes have been widely adopted and adapted by several industrial and academic research and design groups. Many researchers took the original cultural probes as an inspiration and introduced modifications of the concept such as Empathy Probes^[28], Mobile Probes^[29], Technology Probes^[30], or Broken Probes^[31]. However, several of these practices are

fundamentally different than the original cultural probes. While Gaver thinks of this wide proliferation as “heartening”, he also thinks it is “troubling” because the modifications tend to disregard some essential attributes of the cultural probes.^[26]

Below, are the key characteristics of the cultural probes that Gaver et al. suggest researchers and designers to consider:

“Probology” is not a scientific approach. Gaver et al. introduced the term probology for their approach of using probes to “encourage subjective engagement, empathetic interpretation, and a pervasive sense of *uncertainty* as positive values for design.”^[26] However, the term probology is not widely used by other researchers and we see that the term probes is being used for both the approach and the package.

In the Presence Project book, Gaver and Hooker indicate that cultural probes are partly inspired by contemporary art, which is fundamentally different than scientific approaches. Probes are not analytical tools and Probe Returns are not supposed to be analyzed or even summarized.^[26] Gaver notes that summarizing probe returns produce an average picture that may not reflect any individual well and also filters out the unusual items that can be most inspiring.^[27,32,33]

Cultural Probes are playful and imaginative. Gaver et al. embrace the playful element of human life and the fact that people are not rational at all times, for example when they daydream or ponder. Gaver et al. emphasize that design should support ways that people explore, wonder, worship, waste time, or do activities that are meaningful and valuable to them. In the cultural probes, the focus is more on designing for pleasure than designing for utility.^[26,27,32,33] Cultural probes are influenced by situationism theory in which they consider pleasure and intrigue as means of discovery.^[28]

Cultural Probes are ambiguous and subjective. Gaver and Hooker value subjectivity because it leaves room for exploration, encourages imagination, and allows people to project their hopes and desires onto the products of their designs (Page 11)^[27]. From Gaver and Hooker’s perspective, asking unambiguous questions would result in what we already know, whereas posing open-ended or absurd tasks, return surprising results.^[27]

Gaver et al. distinguish between ambiguous design and poor design. For instance, they think of low-resolution displays, inaccurate maps, or sensors as ambiguous designs. They believe that ambiguity encourages participants to use their own interpretations and to question the truth of a situation.^[34] This technique stems from Surrealism in which “tactics of ambiguity, absurdity, or opacity are used to strip away habitual interpretations and open new possibilities.”^[35]

Cultural Probes require careful documentation. In The Presence Project’s book, Gaver and Hooker provide numerous photos of the probes packages, the study sites, the participants, their designs, and more. They also discuss their methods in detail, including how the probes were presented to the participants and how much explanation was given to them while still keeping it “ambiguous”, and how the team of designers moved from the probes results to the final designs. While Gaver and Hooker admit that probes would not make design easy and probes returns might not provide clear guidance to the design process, they emphasize that “without them we would not have produced the designs we have.”^[26]

Now that we have introduced the concept of cultural probes and the key characteristics of it both as a method and as a package, in the next sections, we will present two examples of the use of probes in HCI and explore how educators seeking inspiration on supporting reflection in a classroom can understand these examples. Given the diversity of probe-inspired studies in various contexts, we first present an example from the creators of cultural probes and then describe a probe-inspired study.

Example One: “Projected Realities”

Projected Realities is part of the Presence Project that we discussed in the previous section. In this project, Bill Gaver and his colleagues’ goal was to find new ways that technology could “enter and affect everyday culture”^[35] and increase the presence of the elderly residents of a large housing development within their local communities in the city of Bijlmer in the Netherlands. The designers’ aspiration was to offer opportunities through design of new forms of *engagement* rather than *solving the residents’ problems*. The designers were also interested in opening a dialogue with the residents about design possibilities “to provoke their reactions instead of a scientific method to study their needs.”^[35]

- *The cultural probes package*: Packages included maps, postcards, and photo albums with a few other items along with questions and tasks to which the elderly would respond and mail back to the designers. (See Image 1) The designers were interested in inspirations such as clues about the participants’ *attitudes*, their *aesthetics*, and their *desires*. They gave the packages to ten participants.
- *Example of questions and tasks*: The designers included a map of the city along with stickers of ears, eyes, limbs, and other human organs printed on them. They asked the participants: “if Bijlmer (city’s name) was a body...” The participants were to place these stickers on the map. (See Image 2) There were also postcards in the packages with questions such as “tell us a piece of advice.” Designers also sent disposable cameras with tasks like “take a photo of something ugly” or to create a photo album of six to ten photos to tell a story.
- *Presenting the cultural probes*: The designers personally gave the packages to the participants and provided minimal information to conform to the intentional ambiguity.
- *Receiving the “probes returns”*: The participants mailed about half of their tasks to the designers in the following weeks. Some tasks were completed whereas other tasks only included a note explaining why they were not completed, as was encouraged by the designers. The designers used the probes returns as a resource to clarify their understanding of the city to guide their design as opposed to doing a formal analysis of the returns.
- *Design Methods or “Explorations and Sketches”*: Design was done in two phases. First, the designers generated as many design ideas as possible and discussed them with their colleagues as well as the participants.

In the second phase, they had ongoing brainstorming sessions to discuss and record all of their design ideas without criticizing them. They would allow for impractical ideas since they could be helpful in the discovery of new spaces for design. The designers also put together a “catalog of parts” to enable people to see the different elements that might appear in the final

designs. These discussions and reactions helped the designers to narrow down their ideas and to focus on the final design proposal.

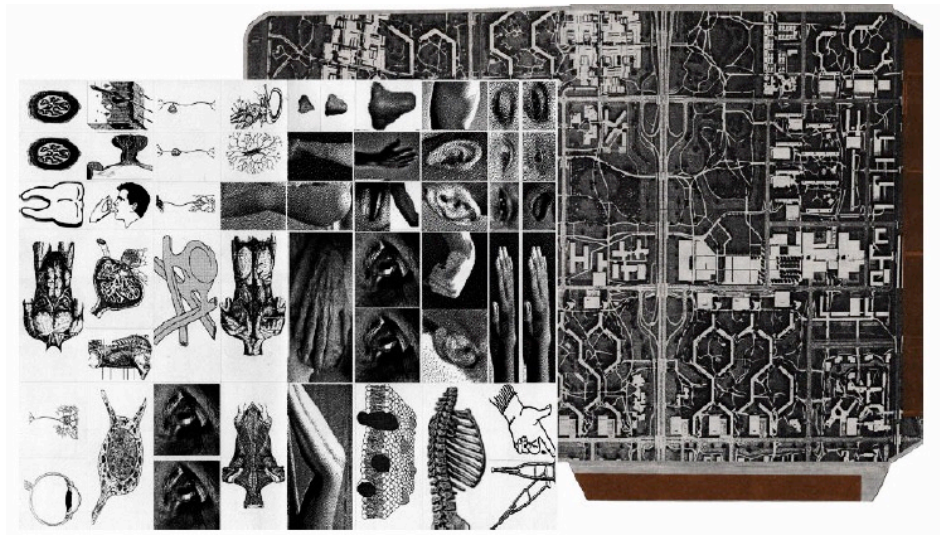


Image 2– A map and stickers of human body organs.

- *The final designs:* The designers developed three artifacts: (1) Image boards that were installed along the freeways and rail tracks that would show images produced by the participants. This was mostly to help improving the poor reputation of the city as an unsafe place into a culturally diverse place with proud residents (See Image 3). (2) Psychographic pagers: participants could carry these pagers to signal where they felt afraid, safe, bored, or intrigued. This design idea also helped with safety issues but at the same time provided a way to discover the city’s unknown attractions. The outputs appeared in various ways such as showing those spots on public displays or maps. (3) Linking security cameras together to address “people’s alienation from the physical fabric of the buildings.”



Image 3- Image boards installed on different parts of the city.

Unpacking the first example with regards to supporting reflection

In this example, which is part of the original cultural probes, the overarching goal appears to be producing a specific kind of design, and the designers’ goal is to *understand the participants’ reactions* to some given tasks and prompts. Gaver and Hooker did not articulate a specific

intention of helping the participants themselves reflect and walk away with a deeper understanding of the phenomena. However, it is important to highlight that the authors indicate that even though they did not leave any physical traces of the project behind, their team of designers left behind “ideas and experiences that were beneficial to the groups [of participants]” and that the participants had some really good insights. (p. 208, 2001) ^[27]

The example shows that the cultural probes helped reveal some hard to acquire information for the designers such as participants’ pride in their city which was unearthed through the photos they took, or their interest in collaborating with others. In addition, cultural probes empowered the elderly to make changes in their community, for instance, by being active members of their community. These outcomes are well aligned with the definitions of reflection that we discussed earlier in this paper. In other words, the elderly brought together their past experiences and thought about future possibilities.

We’d like to finish this section by reiterating that it was not the designs and the final products that may have benefited the elderly people, but it was the fact that the designers gave them a voice and a chance to think about and reflect on their lives and their surroundings.

The next example illustrates how other researchers get inspirations from cultural probes and how they tailor cultural probes to support their studies.

Example Two: “Broken Probes: toward the design of worn media” ^[31]

Broken Probes is an example of a probes-inspired study that uses probes along with other methods such as interviews, storytelling, and participatory design. In their paper, Ikemiya and Rosner offer the design and deployment of Broken Probes as a methodology to illustrate how by integrating with ubiquitous computing technologies, broken objects and acts of breakage may be given a new life.

The researchers started by conducting informal interviews where they presented six artifacts such as a white flat piece of paper, a white crumpled piece of paper, and an iPhone to the interviewees and asked them open-ended questions such as, “*If this object was a person, what kind of person would it be? Would it be male or female? How old would it be?*” Some interviewees perceived the flat paper as a symbol of calmness where the crumpled paper resembled wrinkles in human’s skin and hardships in life.

The interview results highlighted the notion of “wear” and “breakage” in use of everyday objects and raised questions such as “would interviewees respond differently if they were presented with shattered iPhone screens?”

To further study their findings, the researchers bought some inexpensive ceramic objects such as a bowl, a cup, and a plate and coated them with silicon in one side (Image 4a). Then, they gave these ceramic objects to the participants along with a hammer, and asked them to hit those objects on the non-coated side as many times as they wanted (Image 4b). The silicone coating would help the objects to retain its original shape but crack where hit by a hammer.

After hitting the objects with hammer, the participants painted the cracked objects with a blue acrylic paint and wiped off the excess paint. This highlighted the cracks and drew viewers’ attention to the form and location of the cracks on the objects (Image 4c). Then, the participants took pictures of the cracked objects and were asked to tell a story based on the form of cracks

(Image 4d). In creating their stories, participants were supposed to link the cracked objects' photos to any other images or texts or illustrations they liked. An iPhone application was used to facilitate linking these images. Participants took three days to two weeks to work on their stories.

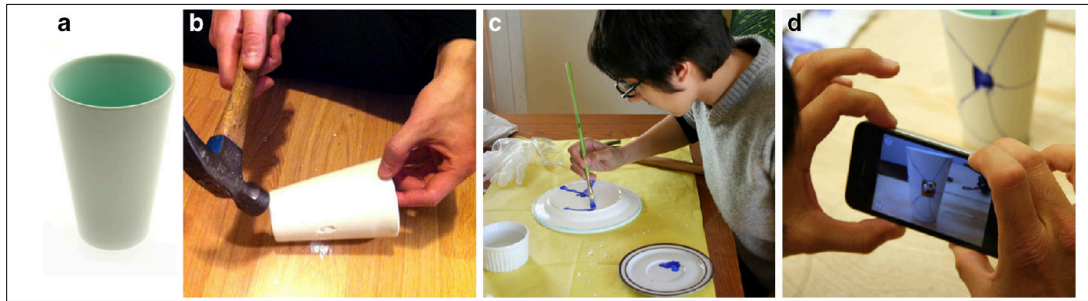


Image 4 - Left to right: (a) a liquid rubber-coated ceramic cup; (b) the break; (c) the paint; (d) the story

Before going through the process of creating the stories, the participants had mentioned that the broken objects *have little or no value and they should be discarded*. However, when they came back to share their images and stories, they had changed their minds about those objects and some of them saw the objects as an art piece and a “representative of a transformative act”.

At each step, the participants were going through varying stages of transformation. One participant shared some images from the happy and sad points of his life and saw the broken cup as a symbol of his alcohol consumption habit. He used the broken cup to reflect on his emotional patterns around his drinking habit, which highlighted some forgotten moments in his life. Another participant saw the cracks on her ceramic plate as representation of geographical points on a map leading to a final destination. The broken plate helped her reflect on her move from another state and intrigued her to think more about her decision on moving out again in pursuit of higher education.

Overall, the broken probes and correlated stories allowed participants to undergo transformative reflection, which may not have been possible otherwise, by helping them to recall feelings of grief and moments of change.

Unpacking the second example with regards to supporting reflection

In this example, the researchers talk about the act of breaking and then of making sense of the broken objects. This example blurs the boundaries between focusing on the *participants'* engagements in reflection and the notion of the probe surfacing information for the *designers*. Unlike the cultural probes example, the researchers in Broken Probes talk explicitly about participants' reflection as well as finding ways that technology could support reflection. However, similar to the cultural probes example, the emergence of reflection was unintended and not anticipated by the researchers.

In addition, unlike the first example, there was no particular agenda in Broken Probes when participants were asked to link the images of the broken objects to the other images or texts they wanted to bring to the final interview. The participants in the Broken Probes were asked to create a story using their images as opposed to answering a set of questions similar to the participants in the first example. That means if the Broken Probes participants wanted to understand a specific part of their life, they were free to create a story around that. The act of breaking objects and creating stories helped the participants reflect, and some of them reported that they found the

whole process and the final discussions to be “transformative”.

Transitioning to the third example

In the last sections, we presented two examples of the probes in HCI and discussed how they could be perceived in supporting reflection. We selected the third example from an engineering classroom because it gives us an opportunity to illustrate how some engineering educators currently support reflection by seeking inspiration from other fields. As this example shows, engineering education has begun to use probes-like reflective activities successfully, although they do not situate it in the probes literature.

Example 3: A picture elicits a thousand meanings: Photo elicitation as a method for investigating cross-disciplinary identity development. ^[36]

In this study, Hatten, Forin, and Adams draw from various literatures and their own experiment to discuss the potential use of photo elicitation as a “pedagogical tool to promote active group learning” in a classroom setting. The study seeks to “characterize cross disciplinary learning trajectories through a lens of knowing (thinking and acting) and being (identity)”.

Photo elicitation is a method that was originally proposed in 1957 by photographer and researcher John Collier ^[37] to help participants’ reflections and responses, and has been widely used by researchers since then. In this study, photo elicitation was used as a method for “collecting, analyzing, and synthesizing participants’ *tacit* understandings of the complex phenomena of becoming a cross-disciplinary engineer.” Similar to the second example, this study involves multiple methods such as conducting two rounds of critical incident interviews and two rounds of online surveys, in addition to two rounds of photo elicitation interviews, over a period of three years. The researchers have published multiple papers to discuss their longitudinal study, but we present the photo elicitation method as illustrated in this paper.

In their study of thirty undergraduates, graduates, engineers with varying experience levels, and faculty members, the researchers asked the participants to take or provide up to six photos that they own or collect from another source that represents something important about them as (a) a person, (b) a professional, (c) their (primary) discipline, and (d) their cross-disciplinary work.

The participants emailed their photos to the researchers in advance so the researchers could use those during the interviews or focus groups in order to promote and navigate through the conversations. The researchers emphasize that it is important to focus the interview questions on explaining what the photo represents and means to the participants, rather than just asking to describe the photos. Some of the questions researchers asked were about source of the photos, how the participants searched or selected those, what does the photo represent about the participants, their disciplines and their profession, and some follow up probes to elicit the meaning and histories of specific ideas and why they were important. Finally, the participants were asked to reflect on “what cross-disciplinary practice means for them” and how and why these views may have changed over time. Some of the themes from this reflection activity indicated that:

- Photo elicitation helped the participants talk about and explain facets of their *identities*, *goals*, and *values*. For example, one participant selected image 5 (below) for the personal category. She used this image as a metaphoric way to explain how she starts her day optimistically (the

white face) and then the decline in her mood (the darker colored face) due to her job demands. The researchers note that the picture gave this participant a “vocabulary to explain her frustrations with having to divide between her personal goals and the demands of her work environment.”

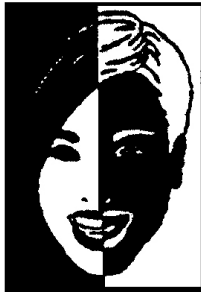


Image 5: A photo selected by a participant

- Photos allowed the participants to articulate the connections between how they think, how they act, and how they are. For example, one of the participants brought a brightly colored puzzle as a representation of her personal life. She explained

“I was trying to find a picture that looks more like a problem solver or a puzzle solver, or, you know, trying to fill the gap, umm, and, you know, trying to feel how important it is to fill those gaps, being the right person/the right location kind of thing. I was just, you know, hitting multiple thoughts while searching for this picture, and umm, I actually found this because [...] it has all the different colors not just the puzzle pieces.”

- Photos decreased power distance between participants and researchers, and increased agency. Unlike traditional interviews, this photo elicitation method in which the participants are allowed to bring in their own photos, gave them the freedom to talk about what they liked. This method gave the participants an agency in the interview process and the photos served as the “communication bridges” between the participants and the researchers. For example one of the participants said:

“I think that was a little harder because for me like I guess I think of what I do every day as interdisciplinary because [...] I work in a lab in the pharmacy school, but my discipline is biomedical engineering. So it’s kind of hard for me to like separate them at times because I’m always in pharmacy but my discipline’s biomedical engineering.”

In her case, the photo selection process helped her see and discuss the importance of cross-disciplinary nature of her professional life while it provided a way to let the researchers know how restrictive the four photo selection categories were.

Researchers noted that photo elicitation method allowed the participants to reflect on their past, present, and potentially future experiences and the meanings associated with these experiences, while also “demanded the researchers to engage in self-reflexivity.”

Unpacking the third example with regards to supporting reflection

This study takes place in engineering education, but it is important to discuss how this example is a representation of the use of probes and how it is related to the HCI perspective. This example talks explicitly about how photo elicitation and conversations about the photos helped the participants reflect on their past and present with respect to their future. The researchers

explicitly talk about how the photos helped the participants understand their identities and values as well as the connections between their identity and the field of engineering.

Even though the use of photos in this example is similar in nature to the first two examples, this study does not situate itself in the notion of probes but it anchors itself in prior body of literature in photo elicitation. However, considering the first example presented in this paper, these photos are also probes because they help reveal hard-to-acquire information about the participants such as their identities and values. In addition, photos are not inherently easy to see as having a single meaning, which makes them ambiguous objects. This ambiguity makes it easier for people to impose all kinds of meanings to photos, which is what Gaver et al. would like to achieve by using photos in a cultural probe package.

Another key take away from this example is the potential of photos and the photo elicitation method in bridging the communication gap between the students and the educators. Photos can empower the students to bring up topics that might not be possible otherwise, such as an assignment being challenging or exams questions being difficult to answer, without arousing conflicts, disgrace, or embarrassments on either side.

Conclusion and future directions

In this paper, we have (a) talked about the value of reflection, (b) talked about the challenges associated with reflection, (c) introduced the concept of cultural probes, (d) showed three examples from the literature, and (e) connected these examples to reflection.

Across the three examples, the emphasis on who was the focus of attention is different, but it seems quite reasonable that both researchers and practitioners benefited in all three cases. In education, the dominant discourse about reflection focus is on the benefits to students, and in HCI, the primary goal is to help designers come to have a better understanding. However, from our perspective and as these examples illustrate, reflection in education is not just about students, and in HCI is not just about designers. We saw that educators themselves benefited from conducting reflective activities and participants in HCI examples benefited from participating in the process.

In the engineering education example, the educators, who are also the researchers involved in this project, benefitted from the students' reflections because it "demanded them to engage in self-reflexivity" which they had not anticipated. The researchers deepened their understanding of their students by using the reflection experience to inform their future actions as educators and in the study. This dual role of reflecting while acting is what Schön refers to as reflection-in-action. Schön states, "[The practitioner] carries out an experiment which serves to generate both a new understanding of the phenomenon and a change in the situation" (P. 68, 1983).^[13] Furthermore, in both first and second examples, the participants benefited from reflecting on their lives and surroundings even though participants' reflection was not explicitly intended by the researchers of the projects.

The examples also unfold the role of designers as educators who have the potential to impact people's lives as well as the role of educators as designers trying to understand the potential of students. In the same token, participants in HCI examples can be seen as students having a chance to be walked through a learning opportunity, and students in the engineering example are

like people reflecting on their learning. This connection suggests that probe-related activities have a great potential to benefit all parties.

In all three examples, researchers used photos to help surface hard to reach ideas and then collected those ideas. However, there are important differences across the examples in how they used the photos. In the first example, participants had to take photos according to the instructions provided by the designers. In the second example, participants were allowed to tell stories about any topic that they would see relevant to their selection of images and the broken objects' photos. In the last example, photos were used as an alternative way to try to transform the participants' thoughts and understanding of engineering into words. The participants could choose generic or personal photos, but the interaction was tied to the notion of engineering. This observation opens up another window into the role that photos play in promoting reflection because it implies that *the act of* searching for photos and taking photos also played a role in all three cases. This suggests that studying the possible similarities and differences in the ways people search for photos and how it impacts reflection may be beneficial.

In addition, we would like to add that in all three examples presented in this paper, participants were volunteers and in the third example they also received compensations of \$50 every six months. However, students do not normally volunteer to participate in reflective activities because reflection is incorporated into their assignments. Further studies can reveal the possible impact of voluntary participation in reflection activities comparing to making them required assignments.

By drawing attention to synergies between the HCI concept of probes and the engineering education interest in reflection, we hope to inspire more opportunities for practitioners in HCI and engineering education to collaborate on designing probes-inspired reflective activities and to learn through and from the experiences. In such collaborations, practitioners in engineering education get new ideas and strategies for supporting student reflection while practitioners in HCI, who are new to reflection^[39], get a chance to learn from the sustained body of work on reflection in education.

Additionally, HCI practitioners can bring a wealth of ideas connected to the Research through Design (RtD) approach (of which the cultural probes work is situated in). Research through Design, which was first introduced by Christopher Frayling in 1993, is more focused on designers and researchers who would like to put their new design ideas into practice. RtD emphasizes on the importance of “what is being achieved and communicated through the activities of art, craft or design”.^[38] Through this approach, HCI and engineering education practitioners have the opportunity to design reflection activities for engineering students and study the effectiveness and efficiency of these reflective practices.

More generally, we note that our emphasis on HCI and engineering education collaboration on reflection draws attention to the opportunity for similar collaborations with other disciplines. Through such collaborations, the important goal of supporting engineering student reflection may be reached more quickly.

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