Artifact Elicitation as a Method of Qualitative Inquiry in Engineering Education

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Abstract

Many qualitative research studies in engineering education use semi-structured interviews as an approach to inquiry. However, traditional semi-structured interviews do not always enable participants to answer questions in deep and meaningful ways. Recent research in engineering education has successfully drawn upon the inquiry method of photo elicitation, which uses photographs as interview prompts to elicit "thick description" from participants. Some studies have extended the methodology of photo elicitation to artifact elicitation, in which research participants are asked questions about artifacts (physical, virtual, etc.) that they have previously created and bring to the interview. Artifacts are similar to photos in that they embody the knowledge, skills, and attitudes held by the artifact creators. In this paper, we will provide examples of two current studies in engineering education that use artifact elicitation. Through these examples we demonstrate how artifact elicitation can elicit new meanings not possible through traditional interview techniques.

Introduction

Interpretivist qualitative research seeks to understand individuals' experiences and "consists of a set of interpretive, material practices that make the world visible" (p. 3).[1] In doing so it places primary importance on the meaning made by individuals as they interact with their worlds. In this constructivist perspective the participants' perceptions, values, beliefs and experiences are of primary importance.[1] Additionally, constructivism focuses on the individual meaning making process, and individuals are viewed as active agents gaining knowledge about social context through their experiences with the environment.[2,3] However, the thoughts that are of importance to meaning making may actually be unconscious, and thus inaccessible to both the interviewer and interviewee. While some authors describe ways to prompt increased disclosure and self-awareness during interviews,[4,5] specific techniques that remind interviewees of differing contexts can be especially useful at prompting new insights.

Several techniques that use artifacts during interviews have been described in the literature. Photo elicitation interviews are semi-structured interviews with a few predetermined general questions about the topic and the majority of questions based on the photographs that interviewees bring to the interview.[6-9] Photographs are used to elicit responses and negotiate different understandings related to the content of the photos, bridging and opening up various understandings of the topic under study[10,11] and "evoke information, feelings, and memories that are due to the photograph's particular form of representation"[6] and stimulate "latent memory, reducing areas of misunderstanding, eliciting longer and more comprehensive accounts of ideas... eliciting values and beliefs, and connecting to core definitions of the self to society, culture, and history".[12] Another method for stimulating latent memories is the critical incident technique, which "consists of a set of procedures for collecting direct observations of human behavior in such a way as to facilitate their potential usefulness in solving practical problems and developing broad psychological principles".[13] The critical incident technique is used to better understand a major incident or turning point and is created from direct observation of human

activity.[14] More recently critical incident techniques have expanded to real life incidents and incorporating behavioral and cognitive responses.[14]

Elicitation interviews use some type of artifact, usually visual, to help gain a direct understanding of the participant on an abstract topic. Artifacts used can include diagrams, relational maps, photographs, drawings and arts, writings, scrapbooks, maps, television programs, and video diaries.[15-19] Graphic elicitation is common to help visualize and simplify a complex and abstract idea.[20] Both graphic and media based elicitation interviews are often used for children and younger participants.[18] The photo elicitation method has been used successfully in engineering education,[12,21-23] science,[24] and math[25] as both a research and pedagogical method.

In this paper we describe two different ways in which we have expanded the use of artifacts during interviews to elicit understanding within engineering contexts. These descriptions come from two different studies currently being conducted by the authors. In one study, class assignments are used to help students describe how they have used critical thinking. In the other study, inventions are used to understand the knowledge, skills, and attitudes related to engineering that are embodied by Makers in the Maker community. Through these excerpts we aim to illustrate the potential for artifact elicitation to elicit new meanings in engineering education research.

Artifact elicitation for understanding critical thinking

Critical thinking is considered to be an important skill in engineering, and yet defining what critical thinking is and what skills it entails is difficult. A recent paper reviews definitions of critical thinking and how it is used in engineering.[26] What is striking about this review is the variety of definitions that exist, and the lack of understanding the ways in which critical thinking may be the same or different from these general definitions. For the most part, the term "critical thinking" is used in engineering without a clear understanding of what it means.

In our work we seek to understand how students use critical thinking, with the ultimate aim of developing a clear definition of what critical think means within engineering. For the data presented here, we interviewed five materials engineering students about how they used critical thinking and what it meant to them within the context of their engineering curriculum. Interviews were transcribed and analyzed using thematic analysis. Further discussion of the results of the analysis is given in a previous paper.[27] Here we focus on the use of assignments to elicit discussion of critical thinking during the interviews.

As an abstract concept, especially for students, describing critical thinking in the absence of any context is difficult. For example, the following is an exchange between the interviewer and a student when the student was asked to define critical thinking.

A Well, I would define critical thinking as the employment of reason in order to reach a conclusion especially in regards to problem solving.

Q Okay. Um, can you elaborate a bit more on that, like give me more explanation to it?

A Um, more explanation of?

Q Your, what you believe, maybe your reas—how you reason through something.

A Okay. Um, (pause) well, I mean, you have to, well, I mean, I consider the multiple aspects that, um, are, it's hard to phrase, let's see…

This student is having difficulty conceptualizing what critical thinking is. Without a context on which to base a definition, the definition remains abstract, limited to poorly (for the student) defined concepts such as "reason".

Table 1: Use of assignments during interviews on critical thinking.

Participant	**Type of example/ assignment chosen**	**Benefits**	**Challenges**	**Example Quote**
Rachel (MSE)	Computer programming class assignment – blocks (individual)	1) Framed problem solving/ CT around the problem	1) Could not broaden example to further her discussion 2) Stuck in jargon of the assignment 3) Assignment may not have been very representative	"Critical thinking to me is just like problem solving so what I did was I came up with like the basis of the code like the framework and what I like left for last was figuring out how to actually make it do this. So for me it was a lot of trial and error. I just had to figure out the best way to make it do what it needed to do."
Charles (MSE)	Finding corrosion at home (individual)	1) Closely connected the assignment with the 'logical' process of CT 2) Example connects to the definition of CT the student provided 3) Student referenced this example throughout and lead to further examples during discussion	1) Didn't have the actual assignment but stories 2) Only reflected work in school (mentions a separate example to cover other aspects)	"Uh It seemed like it fit the description of like making observations and like collecting data and then drawing conclusions and like even developing next steps, um like the whole logical process seemed like it was there in the assignment."

As part of the interview process, students were asked to bring an assignment that they felt had required them to use critical thinking. The purpose of using an assignment during an interview was to provide a context for the discussion. Students could point to specific tasks they underwent when completing the assignment and describe how those tasks were related to critical thinking.

The same student described above mentioned later in the interview an assignment outside of engineering involving translation of a passage from Japanese to English.

A Okay, well, in terms of translation, um, I first go and check the Japanese to English resources that I have like dictionaries or that kind of thing, um, to see how those specific words have been translated before and see if I can use that, either use that word or use a synonym that, um, more appropriately fits into the context.

In this case the student is able to describe his process of critical thinking when translating as analyzing the passage for its meaning in order to identify the appropriate English word, rather than just substituting an English word for the Japanese word based solely on a dictionary definition.

Table 1 illustrates the use of engineering assignments during the interviews. Among the benefits we found for using assignments as part of the interviews were:

1) Able to look at physical assignment.
2) Framed problem solving/ critical thinking around the problem.
3) Example connects to the definition of critical thinking the student provided.
4) Student referenced this example throughout and it leads to further examples during discussion.
5) Allowed break down of parts or broadening ideas of critical thinking that may not have come up otherwise.

However, there were also a number of challenges. Overall, students found it difficult to move beyond specific aspects of the assignment to discuss critical thinking more broadly. For example, students used the technical jargon associated with the assignment, could not identify additional examples to broaden the discussion, did not always discuss critical thinking aspects of the assignment, and often needed prompting to connect the assignment to broader concepts.

Artifact elicitation for understanding the Maker community

A Maker is an emerging colloquial term we use to describe a group of do-it-yourself-minded individuals participating in informal communities (doing-it-with-others) that support and celebrate building and prototyping technical proof-of-concept exploration and ad-hoc product development. A Maker is a modern-day tinkerer and hands-on doer and fashioner of stuff. As Makers embolden the *Engineer of 2020* characteristics of *practical ingenuity*, *creativity*, and propensity toward *lifelong learning*,[28] we pose the following questions: Can a Maker be considered an engineer and vice versa? Should Makers be the engineers of the future? We aim to explore the possible overlap between what we can discover about Makers and what literature describes about engineering students and practicing engineers. This study is advancing the currently limited knowledge of the Maker community by developing theory characterizing Makers and their pathways through the lens of formal engineering education. The aim is to establish evidence as to how Makers embody specific attributes of the *Engineer of 2020* and discover additional attributes of Makers that could define the engineer of the future.

Forty two adult Makers were recruited from flagship Maker Faires in the San Francisco Bay Area and New York City. Semi-structured artifact elicitation interview were conducted in person or Skype to examine the knowledge and skills a Maker develops as a result of making creations, and the attitudes they have about making, engineering, and their careers. Interviews were conducted in the presence of a physical artifact/creation that the Maker had created, providing a similar foundation to photo elicitation since the artifacts embody the knowledge, skills, and attitudes that Makers hold. Participants were first asked to describe their artifact, followed by additional questions (see Table) to elicit "thick description".[29] The semi-structured interview protocol evolved based on emergent themes discovered during early stages of analysis.

Table 2: Artifact elicitation interview questions

Question	**Purpose**
1. Can you tell me a little bit about what you brought to Maker Faire? 2. Why did you come to the Maker Faire? 3. What knowledge and skills did you have to learn to make this invention? 4. What is your process for designing your invention?	Knowledge, skills
5. Where do you do your Making? 6. Who do you do your Making with?	Attitudes, skills, knowledge
7. Where did you learn these things?	Lifelong learning
8. How did you come up with the idea for this invention?	Attitudes
9. What's the next thing you're going to make, and why?	Lifelong learning
10. What will you have to learn to make this new invention?	Knowledge, skills

Artifact elicitation interview transcripts (along with critical incident interview transcripts from another part of the study) were analyzed in parallel both inductively and deductively to generate a theory. One part of the research team used open coding[30] and theoretical memoing[31] to conduct the constructivist grounded theory analysis.[32] Sorting and theoretical coding[31] were used to connect the resultant themes into a theory. Simultaneously, other members of the research team deductively analyzed the data using thematic analysis[33] based on a coding scheme derived from the relevant conceptual frameworks. The deductive analysis was then used in a confirmatory and triangulatory capacity for the inductive analysis and uncover theoretical "holes" that informed the next round of theoretical sampling for new participants. The research process is shown in Figure **1**.

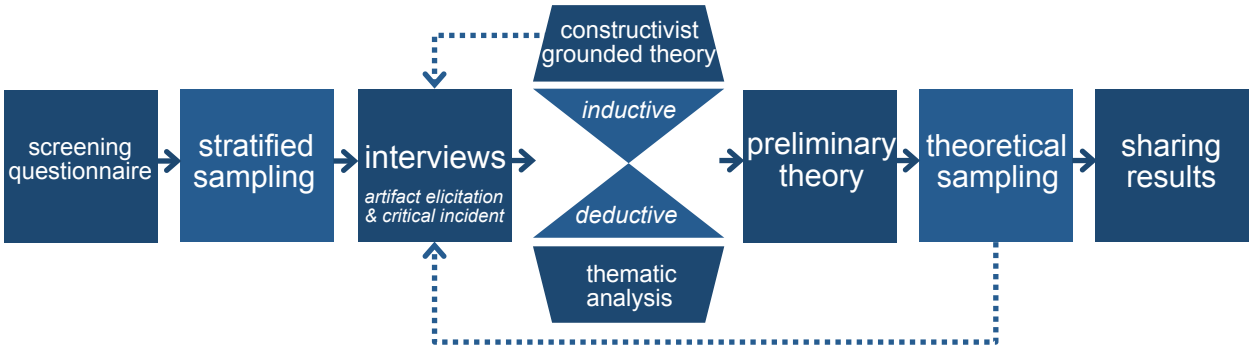

Figure 1: Research process (adapted from Martin et al.).[25]

Artifact elicitation has a number of advantages as a data collection method. The artifact interviews conducted for this study were all completed in a public festival environment where

participants were accustomed to sharing their inventions with reporters. This provided an ideal environment for data collection, because interviewees were excited to share their projects. Conducting artifact elicitation interviews in public provided participants with a sense of control, because we were entering their community rather than us inviting them to our confernece room. Most importantly, it provided a framing for interviewees to describe their artifacts, and provided the interviewer with visual cues to support detailed follow-up questions to peel away layers of understanding. An example of how the presence of an artifact supported the interview process is shown below.

Q Can you tell me a little bit about what you brought to the Maker Faire?

A I brought a lot of boxes that make noise basically.

Um this is the only circuit bent one that I brought; most of the rest are circuit built which means that the circuitry is built. It's a little bit different than circuit building bending where you take an existing circuit and go sideways with it and have it do what it wasn't originally intended to do.

With this I'm taking some ICs and soldering them together. Oddly I'm still having them do what they were originally intended to do because most of them are logic circuit so they weren't meant to make sound. But if you think of a logic circuit it's a one and a zero, it's an off or an on. And also if you think about a square wave, you know one of the basic building blocks of electronic sound it's up and down, off or on.

So from that very simple base most of this has been built. Right here, this is one that's very popular. As you might have guessed it's an eight step sequencer. You turn it on; I'm going to turn it down a little bit here.

We use them as instruments in improvisational noise band performances which are a lot of fun.

So I, I build all these instruments and I get enough crazy people together to play with me on a stage with them.

Q What is your process for designing your invention?

A Actually I have a really nice big studio in Portchester. If you want to visit let me know.

Q Yeah cool. You have, so you start with the, the vision of what you want it to be and you have the stuff there or you have to go out and purchase the, the.

A It's a combination. I have a whole bunch of these old sort of things hanging around in my studio.

And often I'll start to get interested in a circuit because of a particular challenge or a particular sound it can make and then you know the circuit will lend itself to a particular form, like this you know it's a sequencer so something long and narrow that has enough space for all the knobs and then I'll look around in my boxes and I'll find something or I won't. You know I'll build the circuit and I don't have the box yet, then it may be another couple years before I find the right box. You know.

Artifact elicitation also facilitates building initial in-person relationships with participants prior to later follow-up interviews . For example, our in-person artifact elicitation interviews were followed by critical incident interviews over Skype. However, not all interviewees choose to participate in a follow-up interview, necessitating careful inquiry during the artifact elicitation interview.

A primary disadvantage of artifact elicitation is that it requires more skill as an interview due to the semi-structured nature of the interview and the dynamic data collection environment. For example, some participants will point to their artifacts and say less because the interviewer can see the artifact, making later analysis of transcripts more difficult. Other participants tend to "sell" their artifacts in a superficial sales pitch rather than reflecting deeply. Interviews also tend to only be as comprehensive as the artifact, providing a limited snapshot of the participant. These scenarios challenge interviewers to ask strong probe questions to peel back the layers of understanding and get to thick, rich description by participants.

Artifact elicitation can also be logistically challenging, since it typically requires the interviewer to go to the location of the artifact to conduct the interview. In public events, participants can be easily distracted, and the interviewer is not in control of the interview situation. Interviewees interacting with their artifacts can attract crowds, who may interfere with the interview. It is also difficult to filter potential participants, find where they are physically located, and find a time when they are not busy and willing to talk.

Conclusions

Our research excerpts illustrate the ways in which artifacts contribute to the meaning making process during interviews, although in different ways. When studying complex concepts, such as critical thinking, participants may have difficulty articulating their overall understanding of the concept. When asked to define critical thinking, students in our study could not formulate a clear definition. Use of an assignment as a prompt allowed them to point to specific skills or strategies they used as critical thinking, leading to a broader discussion. This broader discussion would not have been possible without the specific examples from the artifact. In the case of Makers, their embodiment as Makers is inextricably interwoven with the artifacts they create. As a set of individuals whose identity as Makers relies on creation of artifacts, it would not be possible to

explore their experiences without reference to those artifacts. Thus, understanding who these people are as Makers relies on the use of the artifact to explore their experiences and beliefs.

We propose that expanding the use of artifact-elicitation interviews in engineering education research has the potential to open new meanings that are not accessible with standard interview techniques. Possible areas include complex concepts such as reflective practice, engineering identity, and adaptive expertise. We also suggest that artifact-elicitation interviews could be used to identify knowledge transfer. For example, asking students to bring artifacts from two different classes could provide a concrete means for them to discuss how knowledge from an early class (e.g. thermodynamics) transfers to more advanced classes (e.g. reactor design). As engineering is inherently a hands-on activity, the use of artifact elicitation has the potential to uncover currently hidden aspects of how engineering is conducted and learned.

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