Advances in Engineering Education

SUMMER 2015

Research and Assessment of Learning Environments through Photoelicitation: Graduate Student Perceptions of Electronics Manufacturing in India

CATHERINE G.P. BERDANIER

AND

MONICA F. COX
School of Engineering Education
Purdue University
West Lafayette, IN

ABSTRACT

This research studies the positive and negative perceptions of graduate students from the United States studying issues of sustainable electronics and electronics manufacturing in India as part of a National Science Foundation Integrative Graduate Education and Research Traineeship (IGERT) curriculum. The purpose of this paper is to discuss the use of an online photoelicitation method, which intends to probe learning experiences from the graduate students' international experience through the use of participant-generated photographs taken during the trip. This research provides insight on the importance of international learning experiences in graduate-level engineering education and the value of non-traditional formats of graduate student learning. This research exemplifies the use of this novel method in research and educational assessment of non-traditional learning environments, as well as offers interested engineering educators guidelines to implementing this technique in their individual contexts.

Key Words: Photoelicitation Methods; Electronics Manufacturing; International Engineering Education

INTRODUCTION

For engineering educators, deep engineering knowledge and learning can often not be assessed through quizzes, exams, or problem sets. This paper may offer another tool in the innovative engineering educator's assessment "toolbox" for extracurricular, project-based learning, or international

experiences, to name a few. Photoelicitation is a research method that uses photographs in order to elicit deeper reflections or responses from research participants. Used in educational settings, photoelicitation can also be a novel resource for assessment of deep understanding and student values or perceptions. In this paper, we show the use of photoelicitation methods as insight into graduate student learning in an international context—a context that is complex, extracurricular, and cannot be assessed through tests. Rather, using multimedia tools, photographs taken during the experience, and online survey software, deep student reflections were elicited which yield interesting research findings and evidence of graduate student professional development and awareness.

The Integrative Graduate Education and Research Traineeship on Sustainable Electronics (IGERT-SE) is an NSF-funded collaboration between Purdue University and Tuskegee University. The program seeks to provide graduate students with broad interdisciplinary research and professional development skills to augment their depth of knowledge in sustainable electronics research. Sustainable electronics research seeks to develop of new electronics and manufacturing process in order to protect the environment, resources, and health as much as possible in an industry that is often known for hazardous materials and manufacturing processes. In addition to a weekly IGERT class and professional development meetings, this traineeship included an international component of learning, where the trainees and associated professors participated in a two-week trip to India to experience international culture and observe attitudes, and viewpoints of electronics manufacturers.

This study intends to address the following research questions:

- What are the positive and negative aspects of sustainable electronics as perceived by the IGERT-SE students from their experiences and photographs from the trip?
- How can photoelicitation be adapted to an online survey in order to elicit deep participant reflection on a non-traditional learning experience?

After answering these two research questions, guidance is given for other engineering educators who are interested in employing photoelicitation techniques in their research or teaching practices. Our study exemplifies the use of multimedia photoelicitation methods through online survey software as both a research tool and an educational assessment tool.

LITERATURE REVIEW

Global engineering competencies are becoming important in the education of undergraduate and graduate-level engineering students, since many engineering teams are comprised of interdisciplinary professionals from around the world in global companies, and since many engineered products are manufactured at global facilities. Many reports call for the inclusion of international

and global competencies for engineers, calling these competencies as necessary for professional engineers of the future (International Engineering Alliance 2013; Nerad and Blumenfield 2011; The Council of Graduate Schools 2012). Therefore, training in interdisciplinary settings are of interest to engineering education researchers. National Science Foundation-funded programs such as Integrative Graduate Education and Research Traineeship (IGERT) collaborations, along with other doctoral and post-doctoral engineering education researchers have sought to provide students with international engineering experiences, as well as document the advances in global competencies learned by students. Reports from IGERT international experiences have been documented in literature (Cutler and Borrego 2010; Gamse, Espinosa, and Roy 2013), and their gains are consistent with the recommendations from other reports, indicating that students make advances in research ethics (The Council of Graduate Schools 2012), understanding the importance of inter-cultural communication skills (Oladiran et al. 2011; Blumenfield and Nerad 2012; Nerad and Blumenfield 2011), and learning to work with people who define problems differently (Downey et al. 2006). The assessment of these global competencies is not clearly defined. General frameworks exist which try to map intercultural competencies, assess global programs, and include international instruction based on learning outcomes for students (Blumenfield and Nerad 2012; Nerad and Blumenfield 2011; Deardorff 2006; Lohmann, Rollins, and Joseph Hoey 2006; Rubin and Matthews 2013; Sadrozinski 2008), but few studies specifically research graduate level international education.

In order to assess the reflections of graduate engineering students in their international experiences in India through a different IGERT collaboration, the researchers in this study used photoelicitation methods, which employ photographs or pictures as prompts in interview protocol in order to better facilitate interview dialogue and reflection from participants. Photoelicitation as an interview technique has been used across disciplines for decades, spanning the disciplines of anthropology and sociology (Tunnell 2012; Schwartz 1989; Cappello 2005), psychology (Heisley and Levy 1991; Keats 2010), education (Schulze 2007; Wright and Larsen 2010; Carlsson 2001; Preskill 1995; Thompson and Gunter 2007), and other social sciences (Clark-Ibanez 2004) in order to better facilitate interview dialogue and reflection from participants through the use of photographs or pictures (Harper 2002). These images can be provided by the researcher or provided by the participant. Auto-driven (participant-generated) photoelicitation uses images drawn or photographed by the participant, from the participant's point of view, to elicit a more complete understanding of meaning, purpose, and reflection through the interview process (Heisley and Levy 1991). Auto-driven photoelicitation has achieved success as a method, especially when working with children (Epstein, Stevens, and Mckeever 2006; Cappello 2005), marginalized populations (Harley 2012), and in participant action research (Harley 2012; Jenkings, Woodward, and Winter 2008). Previous studies using photoelicitation techniques are distinctly defined as researcher-generated photoelicitation or participant-generated

photoelicitation. Literature on photoelicitation analyses and interview techniques verify this line and appropriate the use of each technique for different circumstances (Guillemin and Drew 2010). The number of studies using photoelicitation as an interview technique are numerous and can be found in many complete literature reviews available (Pain 2012; Harper 2002).

The use of photoelicitation as a method also has theoretical and philosophical connotations. For example, the benefits of photoelicitation from literature include the establishing of trust and rapport between participants and researchers, increasing interview dialogue and depth of reflection, and reducing the power gap between interviewer and participant, as the participant is perceived as the expert in conversation (Pain 2012). Most importantly, guidance of interview using participant-generated photographs allows the participant to place importance and reflect on issues that the researcher, as an outsider, might not initially perceive to be important. This idea, called photovoice, makes the assumption that participants "can best identify and represent their own realities" (Harley 2012, p. 322).

In the field of engineering education research, photoelicitation has been employed by researchers in order to understand cross-disciplinary identity development (Forin, Adams, and Hatten 2012; Hatten, Forin, and Adams 2013), to better elicit deep interview responses while studying gender in engineering (Morley et al. 2011), and to study the use of photoelicitation as a pedagogical method in addition to a research method (Jordan et al. 2009). Each of these studies were conducted through interview situations of different sorts, where participants were asked to either bring or email the researchers several pictures related to the scope of the study.

METHODS

Nine graduate students from Purdue University and Tuskegee University Materials Science and Engineering departments and related engineering disciplines, such as Mechanical Engineering, were involved in the traineeship and participated in the IGERT-SE India trip. The trip was composed of tours to several electronics manufacturers (both Indian companies and international companies) as well as several Non-Governmental Organizations in northern India. Seven students completed the photoelicitation survey. All of the participants in this study are current graduate students studying materials science and engineering. Since the survey was anonymous, gender data was not correlated with the responses of the students through the online survey. Although faculty attended the trip as well, this study focuses on student learning. Of the students that responded to the online survey, only one participant identified never having travelled internationally before this experience. This paper will discuss the results from the photoelicitation survey and the benefits of using photoelicitation in

an online format for data collection. The research protocol and consent forms for the photoelicitation survey were approved through the university's Institutional Review Board, and the participants were informed of the purpose of this photoelicitation study to understand their perceptions and international experience with sustainable electronics in India during Summer 2013. Students chose to participate in an online photoelicitation survey regarding their perceptions. Photographs submitted by the students were taken personally, not as part of the study. Cameras on personal cellular phones and personal digital cameras were used to capture the images. No limits were placed on the number of photographs that could be taken by students. However, certain sites banned photography, resulting in no photographic documentation from those experiences. No IRB approval or consent forms were given to the subjects of the photographs: For this reason, we have blurred out the identifying features of the subjects of the photographs presented in the results section. To our knowledge, the only manipulation of the photographs occurred when this blurring was done.

The following indicate the differences between the current study and previously documented photoelicitation techniques:

1. This study was conducted *after* the trip to India: The photographs generated by the students were already taken during the trip without the intent to capture or reflect on sustainable electronics in India.
2. The photographs that were elicited from the students in the first part of the study were not necessarily taken by each student. One participant, an avid photographer, took most of the photographs from the trip, and these photographs were available to the students to submit for photoelicitation. Students submitted photographs that reflect aspects of sustainable electronics in India accompanied by a description and an interpretation on the connotation of the picture. The written answers were coded by the researchers.
3. This research is trying to capture the perception of the outsider (here, graduate students from the United States that research aspects of sustainable electronics) in a foreign culture. Most photoelicitation studies are interested in studying the native perception within a culture of issues to reflect and solve social issues (Jenkings, Woodward, and Winter 2008; Thupayagale-Tshweneagae and Mokomane 2013; Van Auken, Frisvoll, and Stewart 2010; Slutskaya, Simpson, and Hughes 2012) or are interested in visitor perceptions for tourism purposes (Westwood 2006; Matteucci 2013).

The survey, conducted through online survey software, included a total of 29 questions, including brief demographic data and confirmation that the photographs provided were a product of the India trip in June 2013. The remainder of the survey systematically asked students to upload and describe photographs from their trip that represented the *most-positive,* the *second-most positive*, and the *third-most positive* aspects, and *most-negative, second-most negative, and third-most*

negative aspects of electronics manufacturing in India. Following each of the photographs uploads, students were asked to describe the photo they uploaded, and then answer the question "Why does this picture have a positive/negative connotation?" The written survey results describing the participant-generated pictures were open-coded in order to determine primary and (if applicable) secondary and tertiary themes.

POSITIVE PHOTOELICITATION RESULTS

The participant-generated photographs that represented positive aspects of electronics in India are presented in this section. Since each of the seven survey participants provided three "positive" pictures, a total of 21 "positive" pictures were collected. Of these, only two were duplicated, resulting in a total of 19 unique participant generated photographs. The primary, secondary, and tertiary codes from the written descriptions of the photographs were coded into six emergent themes: (1) Safety, Cleanliness, and Working Conditions; (2) Community Improvement; (3) Employee Education; (4) Sustainability; (5) Women's Equality; and (6) Student Experience. Figure 1 shows the frequencies of each of these themes in the student responses. These six predominant

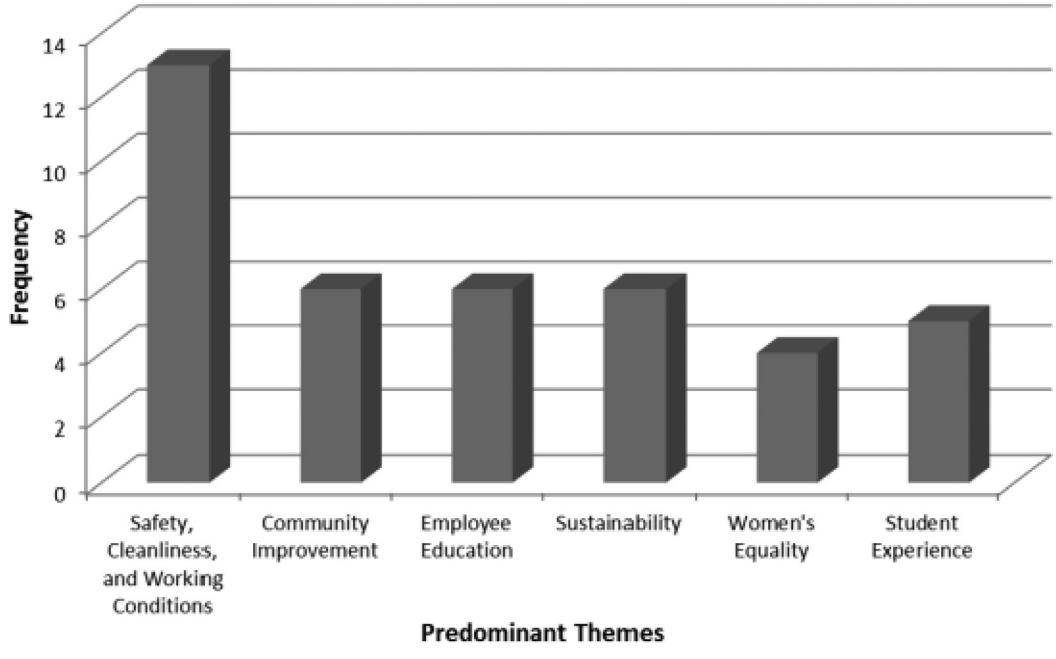

Figure 1. Distribution of themes from positive participant-generated photographs.

themes were reflected in the descriptions that students provided when they uploaded the photographs to the online survey.

The number of times that safety, cleanliness, and good working conditions were mentioned is much higher than the frequencies by the other themes. Students expressed appreciation for worker safeguards, safety education, and guest/visitor safety regulations, as well as the presence and use of appropriate personal protective equipment. For the "most positive" picture shown in Figure 2, the prompt was answered:

> "This picture has a positive connotation due to the cleanliness and safety implementations that are visible. The workers are all wearing proper personal protective equipment (lab coats, closed-toed shoes, etc.) and the path for visitor safety is clearly marked in yellow tape. There is little to no clutter or miscellaneous articles within the facility."

The student who submitted this described the photo: "This is an image on a factory floor. This specific facility deposits solder paste onto circuit boards using screen printing, attaches components and heats the system to create electrical and mechanical connections between the board and components."

Figure 2. Example of a "most positive" picture representing safety measures in electronics manufacturing facilities.

Specific notation of personal protective equipment and safety regulations may be due to other factory tours where such high standards were not upheld, resulting in a particularly "outstanding" connotation to the student in retrospect. Another student, in a "third-most positive" photograph, depicted a worker demonstrating a coating process, wearing "protective respiratory equipment, which was a rare find."

In the frequency analyses of the predominant themes identified in student descriptions, the themes of community improvement, employee education, and sustainability were nearly equally represented. The picture in Figure 3 was taken during a meeting with students and faculty from the United States and a Non-Governmental Organization (NGO) in India, where "they described their missions and goals as an organization, their past achievements, as well as the future priorities with respect to sustainable electronics."

The student description of the photograph showed how a simple picture of a meeting, for example, can represent such a broad and important theme in student learning and global engineering topics. However, as this student notes, the positive aspects of sustainability are tainted with the reality that regulations are more easily made than enforced:

"[T]here are efforts associated with improving the status quo of electronics waste and handling in India. One of the major concerns of [an NGO near New Delhi] is to reduce

Figure 3. Example of a "second-most positive" photograph representing non-governmental organizations' sustainability efforts in electronics manufacturing.

the amount of mercury exposure for Indian citizens. They work tirelessly to create new regulations against the use of mercury in manufacturing. The outlook, however, is not as positive as it could be, since enforcement in India is not as stringent as the actual regulation."

Many students' descriptions of sustainability-oriented photographs specifically acknowledged some facilities' efforts to manage waste and hazardous materials safely, with concern for the environment and the health of the surrounding community. This is demonstrated by the picture shown in Figure 4, which describes "a waste handling site for unlicensed recyclers or rag pickers in New Delhi. Throughout large Indian cities, one would find large waste sites directly off main roads."

Although an outside observer of this picture might think this dump site would have a negative connotation, the student submitting this photograph showed that the context and interpretation of her or his learning experience through photographs leads to a better understanding of Indian culture, community, as well as manufacturing:

"Though everything about this picture is not positive, the main premise of what's happening here is. We learned that the national average of recycling in India is over 60%, far exceeding

Figure 4. An example of a "third-most positive" photograph focused on sustainability, reuse of waste, and community.

the international average of about 35%. The reason why reuse and recycling are so heavily emphasized is partly because of the tradition of waste pickers. Many people make a living off of sorting through city waste and making use of materials and entire products."

The importance of community in many of the student responses through the use of many different types of photographs was noted, both in community improvement through sustainability, as in the example above, but also in community improvement through education. The issue of workforce education was specifically addressed by many students. Several students submitted photographs of worker education bulletin boards, where "the company is providing basic materials and properties information in order to educate their workers," since "[m]any of the workers in these factories do not have a background that provides them with the education to understand the fundamental science behind what they are doing [in their work]." In addition to technical worker education, many students noted examples of the combination of education and community improvement. Figure 5 shows one student's "most positive" picture.

The description given by the student submitting the paper: "In the photograph, you can see women from impoverished situations learning how to operate and maintain photovoltaic assemblies. The students represent many nations from across the globe, including India, Cambodia, [and] Panama."

Figure 5. A "most positive" picture representing sustainable practices, community improvement, and education.

The prompt asking the student to describe why the picture was rated as most positive yielded a response noting the themes of sustainability, community improvement, and education:

> "The photograph truly exhibits the best of instituting sustainable practices. The goal of the program depicted here [...] is for each student to return to her home village and install as well as maintain solar panels. For many of these villages, beforehand there existed no electricity. Installing solar panels will have a considerable effect on the local societal structure of each village. Also, it gives each village the opportunity to create a local economy, in which they can sell energy or services to neighboring villages. Overall, the program hits sustainability in all three of its pillars: environmental with a renewable energy source, societal with the addition of electricity to villages and economic since the village can sell its energy. On a personal note, this photograph captures the most incredible moment of my trip [...I spoke] with a woman from Panama. Using my broken Spanish, I ask her how she feels about working here [...]. She responded in Spanish, "We are not working. We are studying." A truly life-changing conversation!"

Interestingly, this student did not express in her or his description or interpretation the theme of women's equality, which was expressed by other students through other elicited responses and photographs, such as these responses to similar pictures of women working in electronics manufacturing: "The amount of working women we saw while touring electronic manufacturing facilities was shockingly low. This picture has a positive connotation because the ratio of working women at this facility was visibly greater than any other we visited." Another student noted that "[w]omen are traditionally housewives in India. Being willing to hire large numbers of women greatly increases their control over their own life." Since engineering tends to be male-dominated, the fact that these graduate students were perceptive of women's representation and equality issues shows a respect and appreciation for diversity in technical fields, as well as a value for discussion of justice and equality issues in an engineering context.

"Ranking" Positive Photographs

One might argue that asking participants to upload simply three positive pictures may have elicited similar emergent themes, however, the researchers found that where a participant "ranked" her or his photographs, with descriptions and justification of the ranking, researchers could identify the frequencies of the themes as a function of the "rank" of the photograph. Figure 6 shows the distribution of the themes for the most, second-most, and third-most positive photographs.

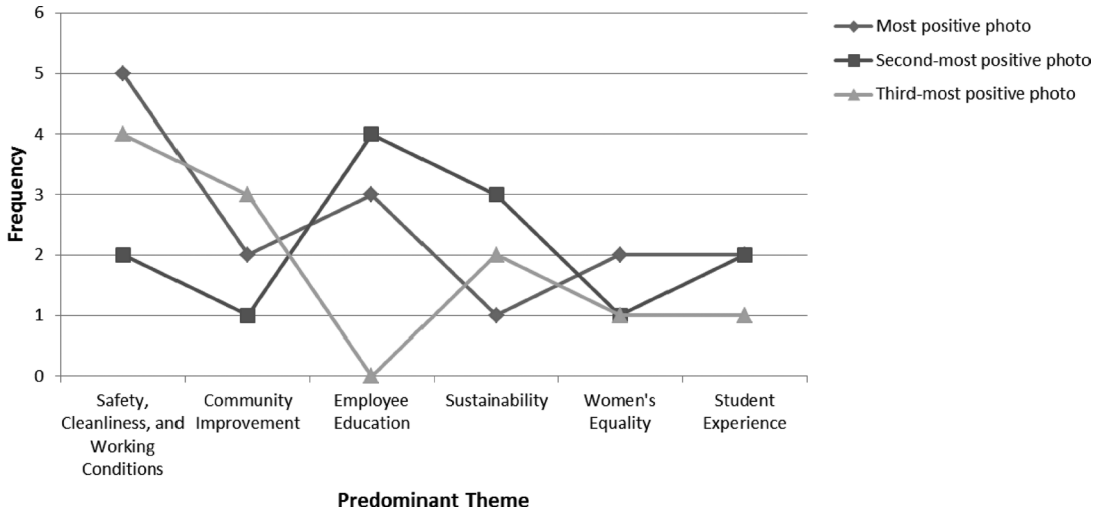

Figure 6. Distribution of theme frequencies for most, second-most, and third-most positive photographs generated by students.

For the most-positive photograph, it is seen that most emphasis is placed on the presence of safety measures for employees, cleanliness, and healthy working conditions, while sustainability and education were higher for the second-most positive photographs. Education was so highly noted by the participants in the "top" two ranks, that it was not mentioned at all in the third-ranked position, which means it was very important to the participants.

NEGATIVE PHOTOELICITATION RESULTS

The participant-generated photographs that represented negative aspects of electronics in India are presented in this section. Since each of the seven survey participants provided three "positive" pictures, a total of 21 "negative" pictures were collected. Of these, only two were duplicated, resulting in a total of 19 unique participant generated photographs. The primary, secondary, and tertiary codes from the written descriptions of the photographs were sorted into five themes: (1) Hazardous Working Conditions; (2) Lack of Personal Protective Equipment; (3) Negative Impact on Community Sanitation and Environment; (4) Materials Handling Procedures; and (5) Other. The "other" category tended to include student discussions of city traffic and mention of potential hiring of minors. Figure 7 shows the frequencies of each of these themes in the student responses.

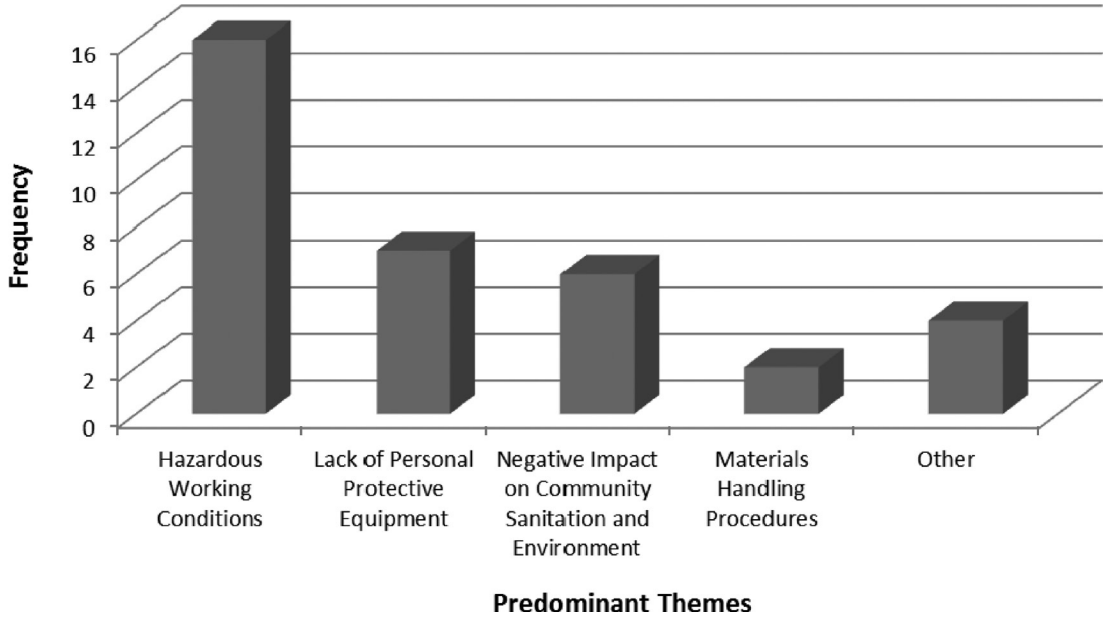

Figure 7. Distribution of themes from negative participant-generated photographs.

The topic of hazardous working conditions was the most frequently referred to in student descriptions of their uploaded photographs. This category included participant reference to lack of safety measures, machine safeguards, and otherwise dangerous working conditions, as depicted by Figure 8.

The description provided by the student: "Similar to other images provided there is a large safety issue present in this image. The drilling process is creating sparks and the operator has used paper towels to fill in an area that needed support. This is a fire hazard."

Other students identified the lack of machine safeguards on other machines in their uploaded photographs. For example, one picture of a machine operator was uploaded with the description, "This shows a worker operating a complex pneumatic machine with many pinch points and no guards…It would take very little effort to drastically lower the risk of this worker losing a finger." One student uploaded a picture of a safety sign as a negative picture. Although an outsider may consider signs posted about safety to be more positive than negative, the student reflected on the photo that "The fact that we saw more notices about protecting the product produced than safety warnings for the workers was very troublesome."

Similarly, the category showing student identification of the lack of personal protective equipment is another high-ranking category—so much so that the researchers decided to separate the category of protective equipment from general hazardous working conditions in this analysis. Figure 9

Figure 8. Example of a "third-most negative" photograph depicting an unsafe drilling process with resulting sparks.

Figure 9. Example of a "most negative" picture showing a lack of appropriate personal protective equipment.

shows one example of a student's submission of a "most negative picture" regarding the lack of personal protective equipment within an electronics manufacturing plant.

The description given by the student: "This is a very common situation in electronics manufacturing. The operator is running a coating machine with open vats of chemicals. He has an ill-fitting mask which is not rated to protect against organic solvents and no safety glasses and cloth gloves which will just hold spilled chemicals on his skin."

Many of the students that uploaded pictures of processes or workers mentioned these types of glaring safety errors on the part of the factory toward its workers. One student uploaded a picture which showed "two IGERT students putting on ear protection in an extremely loud manufacturing facility. We had to ask for the hearing protection which they had on site but no one used." Another student similarly noted that in a lead acid battery manufacturing facility the students toured, issues regarding improper regulation and handling of materials caused significant risk of worker and visitor hazards as well as harmful environmental impact.

> "Visitors were exposed to sulfuric acid fumes, lead oxide exposure and open heating elements. The working conditions were extremely unsafe and allowed for significant contamination of the environment… Improper regulation or lack of enforcement of regulation of the lead acid battery industry encouraged significant environmental damage."

The lead acid battery manufacturer came up several times in the responses of different students; however, no students had personal pictures from this factory because photography was prohibited. Instead, students uploaded similar pictures, but wrote caveats into their descriptions of the photographs, for example: "It should be noted that if I had a picture from the lead acid battery manufacturer that would be the most negative picture." Some students similarly used pictures they had in order to guide a response for photographs they *wished* they could have taken. For example, the same picture presented before in Figure 9:

> "[…] reminds me of facilities we saw which were much worse that we were not allowed to take pictures in. Imagine that machine only in a half burned down building covered in pigeon poop, pouring molten lead and shooting out blasts of open flames. It is painful to think about the lives of the workers in the worst facilities in India."

The improper use, handling, and storage of hazardous materials also were present themes in student photographs and responses. Figure 10 shows just one student example of a picture of open materials, with little or no safeguards present. The student describes the safeguards for this "solder

Figure 10. Example of a "third most negative" picture showing an open solder bath.

bath used to fuse components" as "almost laughable. There is nothing protecting workers from the high temperatures or the fumes."

Overall, student emphasis on the lack of safety measures and often-absent personal protective equipment for workers and visitors alike demonstrates student understanding of some of the ethical issues surrounding electronics manufacturing in countries with fewer regulations and lower enforcement of health and safety standards.

"Ranking" Negative Photographs

Just as conducted for the "positive" photographs in the previous section, Figure 11 shows a plot of the frequency of each of the categories for each student's "negative" pictures.

One interesting result of this data is that, although the frequencies for safety and personal protective equipment categories are the highest ranked overall, most students mentioned elements of their negative pictures having a negative effect on community sanitation and the environment in their descriptions and reflections. The second-most negative pictures, as chosen by the participants, overwhelmingly focused on dangerous working conditions and lack of protective equipment, whereas the third-most negative pictures acted as "catch-alls", where students felt the need to continue to show negative examples of safety violations, but were also compelled to

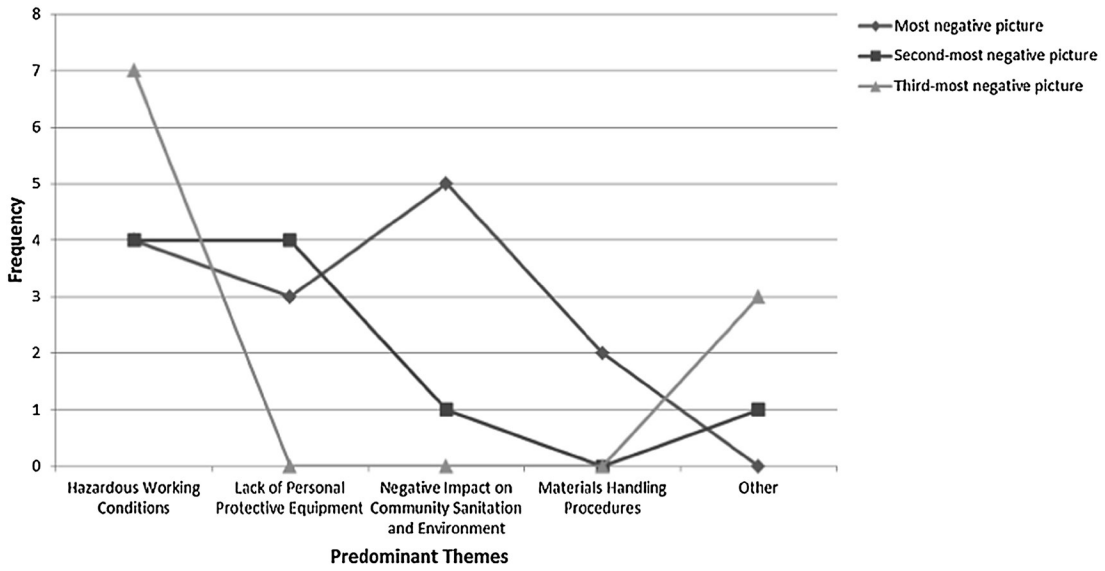

Figure 11. Distribution of theme frequencies for most, second-most, and third-most negative photographs generated by students.

explain some other components that fell into the "other" category. One student mentioned she or he had overheard rumors of minors working on an assembly line, and that was why a photograph of a crowded production floor was chosen as the third-most negative picture—not so negative to be a "most negative" picture, but important enough to the student learning experience that it justified a related picture.

DISCUSSION

What are the positive and negative aspects of electronics manufacturing as perceived by the IGERT-SE students from their experiences and photographs from the trip?

Specific answers to this question have been discussed at length in the results section based on the emergent themes and discussion from the students, frequency analysis of the themes, and the ranking of the photographs by the students. It is important to restate that the students were not aware that this photoelicitation study would be done when they travelled to India and participated in the international learning experience. The photographs taken during the trip by any of the participants could be used by any of the other participants during the survey in order to demonstrate concepts

the students thought were positive and negative. Although the pictures elicited may potentially have changed slightly if the students were instructed to take pictures representing particularly positive and negative aspects of the electronics manufacturing processes during their experience, based on the level of reflection provided by the participants for each of the photographs, especially the mention of experiences that were not captured by photographs, it is likely that the overall themes would have remained similar to the results captured here. It is also important to remember that the data reported here are graduate students' perspectives on issues in sustainable electronics manufacturing practices. Many of the prior understandings of these students have been informed through U.S. standards and practices in sustainable electronics research.

How can photoelicitation be adapted to an online survey in order to elicit deep participant reflection on a non-traditional learning experience?

In this study, an auto-driven (participant-generated) photoelicitation experience was employed by asking students to upload pictures *in retrospect* of participating in an international learning experience related to electronics research. This is a unique method that has not been applied before in photoelicitation research. By asking students to upload photographs taken on the trip to be assigned into the categories of most positive, second-most positive, third-most positive, most negative, second-most negative, and third-most negative, a wealth of information was gained through the descriptions and interpretations of the photographs. Sometimes, the interpretation was counter-intuitive to what an "outsider" might assume about the photograph, calling to mind the "positive" picture of the roadside waste that was submitted to indicate a higher national recycling rate due to waste pickers (Figure 4). Additionally, since approximately six months passed between the trip and the survey, the themes emerging from this study represented long-lasting lessons learned from the trip. In a few instances, one student uploaded one picture to reflect a positive image of electronics manufacturing, and a second student uploaded the same picture to reflect negative connotations instead. This, rather than being a contradiction of data, shows the necessity of a participant-generated photoelicitation experience, with as few "leads" or "prompts" as possible, in order that the participants can reflect on their own constructed learning experiences independently. Additionally, by asking students to provide photographs from their trip, the researchers learn what themes were most important to students, without generating researcher bias that may have come from researcher-generated photographs at the onset of the study.

Advantages and Limitations of Online Photoelicitation and the Study

The online format of the survey may have both positive and negative effects for participant-generated photoelicitation methods. Jordan et al (2009) identifies several advantages as "affordances"

of photoelicitation as a research methodology and a pedagogical technique, which include accommodation of diverse background, the use of technology, and elicitation of multiple perspectives, as well as the opportunity for student learning through deep reflection on experiences (Jordan et al. 2009). We find similar affordances and advantages. By using an online format for the photoelicitation survey, students could take the time to find the picture that best represented their experiences, rather than being rushed by researcher-led protocol, as well as using photographs from their own files. Based on the methods shown in this study, this novel online method for participant-driven photoelicitation should be considered for other researchers considering probing learning experiences of a reflective and mature audience. One potential drawback of employing an online survey in this manner is that reflections require mental energy and time, and it is more difficult to type a story than tell a story to a listener. However, the online descriptions excelled in quality: word choice and student meaning was generally direct, clear, and persuasive. The limitations of this specific study include the small number of students that were involved in this trip, as well as the participants' U.S.-centric views on electronics manufacturing and engineering processes which introduce bias in the interpretation of the situations and photographs.

Guidance for Engineering Educators Employing Photoelicitation Research or Evaluation Methods

Photoelicitation can be used as a method for research, a method for evaluation and assessment, or both. In this research, we have shown how photoelicitation (which, up until this point had only been used in face-to-face interviews) can also be used in an online survey format. Additionally, in this work, we extend the use of photoelicitation from a purely research method to an assessment method.

Ontological and Epistemological Considerations

Guidance for engineering educators interested in using this in their educational settings stems from ontological and epistemological points of view: This is a qualitative method, so rather than searching for a positivist overarching "answer" or "truth" about this kind of learning, we are looking to probe each individual's unique truth (i.e. what each student experienced.) Even though the students experienced the same meetings and tours on the trip, the knowledge gained by each graduate student on the international trip is fundamentally different, since knowledge is not universal, and depends on students' prior experiences with international issues, views on sustainability, ideas on gender issues, and the like. We also approach this as an evaluation method with these ontological ideas in mind: If each individual has her or his own truth, then a method to assess individual learning should not be binary, with a "right" or "wrong" answer, or even a variety of pre-determined choices. This is one reason why open-ended responses and student selection of their own photographs in the

positive or negative experiences were appropriate for this study. It is also the reason why sometimes the same picture was placed in the positive category by one student and the negative category by another student, which is enlightening for educators and researchers alike. Additionally, assessment in our case is not equivalent with "scoring" in terms of achieving a grade. Graduate students in this international experience were a unique population: The experience was extracurricular, so there were not grades associated with the responses. If there had been, likely, students would have anticipated this and changed their reflections to be aligned with what they thought the professor wanted to hear. This is ineffective and counterproductive because it would elicit inauthentic responses and would ruin the research integrity of the assessment.

Learning Environment Considerations

It is important to determine if the learning environment is appropriate for the use of qualitative photoelicitation techniques. It might be the case that the skill/learning is better assessed through a written reflection or traditional exam, rather than through this method. This method is great for non-traditional educational settings, small groups of students, experiential learning, and international learning. It will be of great interest to the authors to note how other engineering educators use and adapt this method.

Online Survey Software Considerations

Online methods offer the advantage of avoiding transcription and coding of spoken words. It is good practice to double-check that the online survey software used allows the survey-taker to upload pictures into the survey, as well as to provide written reflection and any other types of questions that will be incorporated. This study employed Qualtrics software, which worked well. Also, upfront planning about data representation and analysis aids in efficient planning and survey data collection processes.

Photographic Considerations

Determine if participant-generated photographs or instructor/researcher-provided photographs will be used. In this study, we used participant-generated photographs because we felt they were more authentic. The students had shared all their photographs with each other, so they had access to the same photographs from the trip. However, if the assessment is for students to go out with the assignment to take pictures of a certain phenomenon and then come back and describe it in an assessment, for example, the circumstances will be different. On this note, make sure that all students have access to a smartphone or camera: Even in this digital age, students may not have access to digital photography equipment, or may feel uncomfortable saying they cannot afford such technology if everyone else is using the newest available smartphone technology.

Data Usage and Sensitivity Considerations

If you are intending to publish your results, Institutional Review Board (IRB) approval is still necessary for both survey and photoelicitation methods. Data collected is personal and should be treated sensitively. Additionally, if you or your learners are taking pictures of people, the researcher has an obligation to either blur out identifying features and/or gain consent before taking the picture.

CONCLUSION

The research presented in this study showed the use of an online, participant-generated photoelicitation survey to study graduate student learning experiences in an international setting. Written responses were open-coded in order to categorize responses into emergent themes for both the positive and negative photographs. The photographs themselves are also artifacts for a wealth of future planned photoelicitation research on global engineering learning and international experiences. The results of this method for photoelicitation showed promising depth of interpretation by the researchers, and generated insightful findings for the field of electronics manufacturing and materials science/engineering. Future work using photoelicitation in engineering education could relate to other cultural studies in other countries, as students experience engineering norms and practices from a global community. Additionally, capturing engineering learning perspectives from students even in the United States could afford researchers a rich data set about the engineering values that students hold at various stages of their university career and career as a practicing engineer, showing development of a student into the engineering community.

ACKNOWLEDGEMENTS

This work was supported by NSF Grant #1144843. The authors would also like to thank the IGERT-SE participants and faculty involved in the India trip, and the reviewers of the paper.

REFERENCES

1. International Engineering Alliance. “Graduate Attributes and Professional Competencies.” (2013): 1–16.

2. Nerad, Maresi and Blumenfield, Tami. “Investigating the International Experiences in STEM Graduate Education and Beyond : Report from the February 2011 Workshop to Develop a Research Agenda.” (2011): 1–71.

3. The Council of Graduate Schools. "Modeling Effective Research Ethics Education in Graduate International Collaborations: A Learning Outcomes Approach," Washington D.C., National Science Foundation (2012): 1–23.

4. Cutler, Stephanie and Borrego, Maura. "Developing Global Competence in Graduate Engineering and Science Students through an IGERT International Internship Program." Paper Presented at the 40th ASEE/IEEE Frontiers in Education Conference, Arlington, Virginia, October 27–30, 2010.

5. Gamse, Beth C., Espinosa, Lorelle L., and Roy, Radha. "Essential Competencies for Interdisciplinary Graduate Training in IGERT." Washington D.C., ABT Associates, 2013.

6. Oladiran, M. Tunde, Uziak, Jacek, Eisenberg, Marco, and Scheffer, Cornie. "Global Engineering Teams – A Programme Promoting Teamwork in Engineering Design and Manufacturing." *European Journal of Engineering Education* 36.2 (2011): 173–186.

7. Blumenfield, Tami and Nerad, Maresi. "Assessing International (Post) Graduate Education: A Research Agenda." *Australian Universities' Review* 54.1 (2012): 72–82.

8. Downey, Gary L. et al. "The Globally Competent Engineer: Working Effectively with People who Define Problems Differently."*Journal of Engineering Education* 95.2 (2006): 107–122.

9. Deardorff, Darla K. "Theory Reflections: Intercultural Competence Framework/Model." (2006).

10. Lohmann, Jack R., Rollins, Howard A., and Hoey, J. Joseph. "Defining, Developing and Assessing Global Competence in Engineers." *European Journal of Engineering Education* 31.1 (2006): 119–131.

11. Rubin, Donald L. and Matthews, Paul H. "Learning Outcomes Assessment: Extrapolating from Study Abroad to International Service-Learning." *Journal of Higher Eduation Outreach and Engagement* 17.2 (2013): 67–86.

12. Sadrozinski, Renate. "Evaluative Framework for International Collaboration." (2008).

13. Forin, Tiago R., Adams, Robin, and Hatten, Kristin. "Crystallized Identity: A Look at Identity Development through Cross-Disciplinary Experiences in Engineering." Paper presented at the 119th ASEE Annual Conference & Exposition, San Antonio, Texas, June 11–14, 2012.

14. Hatten, Kristin, Forin, Tiago R., and Adams, Robin. "A Picture Elicits a Thousand Meanings: Photo Elicitation as a Method for Investigating Cross-Disciplinary Identity Development." Paper presented at the 120th ASEE Annual Conference & Exposition, Atlanta, Georgia, June 23–26, 2013.

15. Morley, Katherine M., Pawley, Alice L., Jordan, Shawn S., and Adams, Robin. "Gender and Engineering: Photo Elicitation as a Method of Inquiry." Paper presented at the 118th ASEE Annual Conference & Exposition, Vancouver, BC, Canada, June 26–29, 2011.

16. Jordan, Shawn S., Adams, Robin, Pawley, Alice L., and Radcliffe, David. "Work in Progress - The Affordances of Photo Elicitation as a Research and Pedagogical Method." Paper presented at the *39th* ASEE/IEEE Frontiers in Education Conference, San Antonio, Texas, October 18–21, 2009.

17. Tunnell, Kenneth D. "Reflections on Visual Field Research." *International Journal of Qualitative Methods* 11.4 (2012): 340–352.

18. Schwartz, Dona. "Visual Ethnography: Using Photography in Qualitative Research." *Qualitative Sociology* 12.2 (1989): 119–154.

19. Cappello, Marva. "Photo Interviews: Eliciting Data through Conversations with Children." *Field Methods* 17.2 (2005): 170–182.

20. Heisley, Deborah D. and Levy, Sidney J. "Autodriving: A Photoelicitation Technique." *Journal of Consumer Research* 18.2 (1991): 257–272.

21. Keats, Patrice A. "The Moment is Frozen in Time: Photojournalists' Metaphors in Describing Trauma Photography." *Journal of Constructivist Psychology* 23.3 (2010): 231–255.

22. Schulze, S. "The Usefulness of Reflexive Photography for Qualitative Research: A Case Study in Higher Education." *South African Journal of Higher Education* 21.5 (2007): 536–553.

23. Wright, Newell D. and Larsen, Val. "Every Brick Tells a Story: Study Abroad as an Extraordinary Experience." *Marketing Education Review* 22.2 (2012): 121–142.

24. Carlsson, Britta. "Depicting Experiences." *Scandanavian Journal of Educational Research* 45.2 (2001): 125–143.

25. Preskill, Hallie. "The Use of Photography in Evaluating School Culture." *International Journal of Qualtiative Studies in Education* 8.2 (1995): 183–193.

26. Thomson, Pat and Gunter, Helen. "The Methodology of Students-as-Researchers: Valuing and Using Experience and Expertise to Develop Methods." *Discourse: Studies in the Cultural Politics of Education* 28.3 (2007): 327–342.

27. Clark-Ibanez, Marisol. "Framing the Social World with Photo-Elicitation Interviews." *The American Behavioral Scientist* 47.12 (2004): 1507–1527.

28. Harper, Douglas. "Talking about Pictures: A Case for Photo Elicitation." *Visual Studies* 17.1 (2002): 13–26.

29. Epstein, Iris, Stevens, Bonnie, and McKeever, Patricia. "Photo Elicitation Interview (PEI): Using Photos to Elicit Children's Perspectives." *International Journal of Qualitative Methods* 5.3 (2006): 1–11.

30. Harley, Anne. "Picturing Reality: Power, Ethics, and Politics in Using Photovoice." *International Journal of Qualitative Methods* 11.4 (2012): 320–340.

31. Jenkings, K. Neil, Woodward, Rachel, and Winter, Trish. "The Emergent Production of Analysis in Photo Elicitation: Pictures of Military Identity." *Forum: Qualtitative Social Research* 9.3 (2008): 1-30.

32. Pain, Helen. "A Literature Review to Evaluate the Choice and Use of Visual Methods." *International Journal of Qualitative Methods* 11.4 (2013): 303–320.

33. Guillemin, Marilys and Drew, Sarah."Questions of Process in Participant-Generated Visual Methodologies." *Visual Studies* 25.2 (2010): 175–188.

34. Thupayagale-Tshweneagae, G. and Mokomane, Z. "Needs of South African Adolescents Orphaned by AIDS: Evidence from Photography and Photo-Elicitation." *International Nursing Review* 60.1 (2013): 88–95.

35. Van Auken, Paul M., Frisvoll, Svein J., and Stewart, Susan I. "Visualising Community: Using Participant-Driven Photo-Elicitation for Research and Application." *Local Environment* 15.4 (2010): 373–388.

36. Slutskaya, Natasha, Simpson, Alexander, and Hughes, Jason. "Lessons from Photoelicitation: Encouraging Working Men to Speak." *Qualitative Research in Organizations and Management: An International Journal* 7.1 (2012): 16–33.

37. Westwood, Sheena. "Shopping in Sanitised and Un-sanitised Spaces: Adding Value to Tourist Experiences." *Journal of Retail and Leisure Property* 5.4 (2006): 281–291.

38. Matteucci, Xavier. "Photo Elicitation: Exploring Tourist Experiences with Researcher-Found Images." *Tourism Management* 35.1 (2013): 190–197.

AUTHORS

Catherine G.P. Berdanier is a Ph.D. student in the School of Engineering Education at Purdue University. She earned her B.S. in Chemistry from The University of South Dakota and her M.S. in Aeronautical and Astronautical Engineering from Purdue University. Her current research interests include graduate-level engineering education, including inter- and multidisciplinary graduate education, innovative and novel graduate education experiences, global learning, preparation of graduate students for future careers, and engineering writing.

Monica F. Cox is an Associate Professor in the School of Engineering Education at Purdue University and is the Inaugural Director of the Engineering Leadership Minor. She obtained a B.S. in mathematics from Spelman College, a M.S. in industrial engineering from the University of Alabama, and a Ph.D. in Leadership and Policy Studies from Peabody College of Vanderbilt University. Teaching interests relate to the professional development of graduate engineering students and to leadership, policy, and change in science, technology, engineering, and mathematics education. Primary research projects explore the preparation of engineering doctoral students for careers in academia and industry and the development of engineering education assessment tools. She is a National Science Foundation Faculty Early Career (CAREER) award winner and is a recipient of a Presidential Early Career Award for Scientists and Engineers (PECASE).