AC 2008-2535: TEACHERS' NOTICING ENGINEERING IN EVERYDAY OBJECTS AND PROCESSES

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Teachers' noticing engineering in everyday objects and processes

Abstract

Engineers have been so successful at seamlessly integrating their achievements into the fabric of our daily lives that we often overlook how they influence our lives. Pearson and Young [1] discuss this paradox to emphasize the importance of increasing technological literacy of everyone. Prior studies of people's (children and adults) perceptions of engineering describe peoples' ability to notice the visible aspect of engineering created by civil (buildings, bridges), mechanical (cars, machines) and electrical engineering (electrical energy that runs our machines). An examination of their descriptions of engineering, however, often contains misconceptions. If teachers are part of the solution to develop students' awareness of engineering, then we need to better understand their abilities to identify engineering within the world and to talk about it with their students. Our study evaluates teachers' abilities to notice what is engineering in common products that we interact with each day (e.g., milk carton, apple peeler, water filter) and to identify the work of engineers in the field (e.g., environmental). Further we asked teachers to share how they would explain to their students how pictures pre-selected by engineering education researchers relate to engineering. In this paper, we share our coding scheme for teachers' responses, and we compare their development from pre- to post- participation in our summer professional development activities. This method builds on prior studies that use photos as stimulus responses. Unlike other studies, we are systematically exploring specific image types that elicit response to a wide range of engineering products and processes that influence our lives. In addition, we are looking to see how well these methods work to differentiate various disciplines of engineering.

Keywords

K12 engineering education
Teacher professional development
Research methods

Introduction

The products of engineering have become common objects in today's world [1]. Despite this, the general population's understanding of engineering is extremely limited with 95% of a sample of adults in the United States believing that engineers solve problems, and develop transportation, including automobiles and airplanes, highways, bridges, and tunnels [2]. This limited understanding is also prevalent in schools with students in grades 3 to 12 having preconceived ideas about engineers as men that use tools to build buildings and fix car engines or are involved in designing things such as buildings and machines [3]. This limited view of engineering has a potentially problematic impact on meeting the future demand for engineers [4]. An even more important and more wide-spread impact is the need for people to be able to interact with the ever increasing amount of technology that engineering produces [1]. Misconceptions about engineering have lead elementary students to dislike engineering and hence not willing to learn about it [5, 6].

One way to address misconceptions held by students is through teacher education because of the strong impact of teacher knowledge on student knowledge [7, 8]. Teachers need adequate knowledge of engineering to be able to have informative discussions with their students and to integrate engineering activities into the classroom [9].

As part of the academies, a survey was administered to understand what the participants saw in their everyday worlds in relation to engineering. The survey consisted of photographs of scenes and included the participants writing responses to questions. The survey was given at the beginning (pre) and at the end (post) to evaluate any changes that took place as a result of the engineering experiences during the week. This allowed exploration of the aspects the participants noticed, how well they could explain those aspects, and how their ability to explain the role of engineering develops during the academies.

Eventually INSPIRE aims to measure this ability around a constant set of stimuli to evaluate some dimensions of what people notice in the world and their ability to describe and explain their perspective to others. Part of this outcome is to help define potential assessments for teacher learning.

Background

Engineering in the everyday

Studies have shown that Americans are not very technologically literate [10]. Technological literacy is the ability to "use, manage, evaluate, and understand technology from a broad perspective" (p2) [11]. Seventy eight percent of 18-29 year olds, however, have the very narrow view of technology as computers, and almost half of the college graduates surveyed think of design more as "blueprints and drawings" rather than "a creative process of solving problems" (p82) [10]. Despite the prevalence of so called "technology" courses in schools, it seems that students do not necessarily develop knowledge to identify and use technology in their everyday lives, or "evaluate the appropriateness and effectiveness of various technologies" (p2) [11]. There is certainly far less prevalence of engineering in schools even though engineering and technology are closely linked [12] and engineering is also not recognized for what it is despite much effort [13]. Some effort has been made to provide teachers with courses in engineering and technology that can be integrated into the classroom [9, 11, 14] but there is still a strong need for education standards across the board [12].

Once technology and engineering education have been implemented at the school level, however, it is important to know if it has been effective. Assessment of technological literacy has been done for students and teachers [15] and the influence of pedagogical practice has been investigated [16]. It was found to be important to assess content knowledge as well as the other cognitive dimensions of capabilities, critical thinking and decision making [15]. One approach to assessing these areas is to determine how well people can explain engineering to others as this shows conceptual understanding of the knowledge and the ability to use that knowledge [17]. Stimuli such as photographs can provide a prompt for such discussion. Explanations of how a situation or object relates to engineering, however, can incorporate many different things since the nature of engineering is so broad.

Photo-elicitation

Photo-elicitation stems from using photographs as stimulus for more information within an interview or survey [18]. The photographs are often generated by the researcher and can provide memory stimulus about a situation or event, or can provide opportunity for elaboration of personal perspectives [19]. Photo-elicitation has been used in cultural and social investigations [20-24], in social work [25], and in education [26-28], with a focus on describing what is occurring in the photographs including human interactions and physical descriptions of the scene. More than one photograph is often used with potentially conflicting or opposite scenes [21 29] to challenge and accentuate what the participants notice in the photographs.

The use of photo-elicitation has shown the different aspects that people can notice in a situation. For example, patients in a hospital have taken photographs of ‘spaces’ and ‘objects’ [30]. Also what people saw in a situation depended on how they felt and what they were thinking at the time [30]. Familiarity with the situation is also important. People often identify the aspects of a scene that they are very familiar with [31], or on the other hand, aspects that are completely new or different from anything they have seen before can capture their attention. Quite often when viewing photographs, people will notice objects first [31]. Smith and Woodward’s [32] study highlighted other aspects seen in photographs. The spatial relationship between people, actions of people, and attributes of people are often described. Interpretation is common, whether what the people are doing, why they are doing it, or symbolic representation of objects. Another level is abstracting to objects or people outside of the photograph, or supposed relationships between objects and people within and outside of the photograph. People also put their own feelings or beliefs into aspects of the photograph and report how the photograph made them feel.

Photo-eliciting activities are reminiscent of other representational studies with peoples’ interpretation of complex systems. Several design-based instructional methods ask learners to reverse engineer a device and describe how it works. For example, in a design-based instructional approach to science, learners are asked to design an aquatic ecosystem. The instructional goal is to help them notice the structural features of the system (fish, water, weeds) and the functional level of each of these components (food, carrier of oxygen, shelter) and the behaviors of the components (generate dissolved oxygen, consume carbon dioxide). Ultimately the students can generate a representation that illustrates the interdependence of critical objects. Students ability to notice the level of detail and specificity of invisible features (dissolved O_2, bacteria) come from their design of the system (e.g. an ecosphere) and science various didactic or experimental methods. Therefore, we are basing our analysis on a framework used to analyze expert and novices’ interpretation of complex systems using a Structure, Function and Behavior (SFB) framework [33].

One of our conjectures is that a photograph of an object could provide a representation of engineering with similar levels of description about how the image relates to engineering. Some of the features will be superficial features that are directly perceived. Other features will come from the participants experience and background with engineering that will facilitate their making a connection between the image and engineering.

Analysis methods using open coding and grounded theory

Open coding is used to explore the data for concepts then categorize those concepts based on patterns, similarities and differences [34]. Axial coding is the process of relating categories to their subcategories, and coding occurs around the axis of a category, linking categories at the level of properties and dimensions. The purpose is to reassemble the data that was broken down in the open coding part of the process. How the categories relate to each other becomes evident during open coding and are specified during axial coding. The categories are then integrated and refined by selective coding to form a larger theoretical scheme [34].

Open coding is often used in studies to find the scope of what the data could reveal. It is not based on a pre-existing framework such as in content analysis [35], but is the basis for grounded theory [34]. There is not necessarily one true method of conducting grounded theory, rather the method should allow the information within the data to be realized [36].

Open coding has been used in studies to discover definitions, dimensions and outcomes of behavioral phenomena and to determine overarching themes and grounded theory [37]. The initial result was a list of categories that was modified through selective coding to find five categories, twelve macro-themes, and twenty-nine themes as subcategories.

Grounded theory has also been used for understanding knowledge and how people know. Palmer and Marra's [38] study of epistemological beliefs about science and the humanities discovered "epistemological orientations" (p318) in a hierarchy of levels of thought. These levels represented different aspects and ways of thinking about science and the humanities. These levels were not exclusive and "some students exhibited aspects of more than one orientation in the sciences or the humanities" (p318) showing that thinking can be multi-faceted.

Methods

The Institute for P-12 Engineering Research and Learning (INSPIRE) is a Purdue University-based initiative and one of its goals is to research how to effectively educate teachers in engineering so as to create a more engineering literate society. INSPIRE ran two academies for a week each in summer 2007. Teachers of 3rd and 4th grades (N=60) from local schools attended the local academy and from around the country for a national academy.

We developed a Photo Prompting survey an administered it through a on online webform. Participants were shown an image and asked to answer three sections of questions related to, categorizing the types of engineering in the image, noticing engineering, and explaining a specific type of engineer perspective (indicated under the picture in Table 1). The specific questions were:

Categorize:
Question 1: What types(s) of engineering is (are) most closely related to this image? Click all that apply (selected from a list)

Noticing:
Question 2: Describe the object(s) or event that is the focus of this photo.
Question 3: Explain to your students how this photo relates to engineering and/or engineering practice.

Explain other Perspective:
Question 4: How does a(n) <insert engineering discipline> engineer relate to this image?
Question 5: What questions do you have about this image that would help you better answer this question?

Table 1 Images of situations shown to the participants

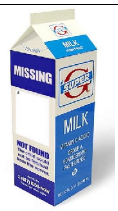	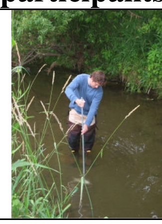
Image 1 – processing engineering	Image 2 - environmental
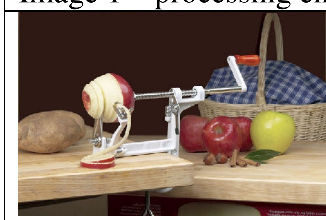	
Image 3 – mechanical engineer	Image 4 - environmental
	
Image 5 - materials	Image 6 - environmental

The question of relevance to this study was Question 3 as it would elicit the most in depth answer containing the participants' perceptions of engineering in the world.

The week long academies consisted of teachers learning to use the Museum of Science's Engineering is Elementary units. Specifically, on lesson was on water quality and purification and the other was on machines (windmill). The lessons concentrate on developing the teachers' awareness of the design process which was explicitly defined in 5 phases – ask, imagine, plan, create, test, improve. Also, the teachers and the workshop facilitators shared ideas on how to teach these concepts within the context of a sequence of design activities. They also meet with a number of engineers and engineering faculty to learn more about what engineers do. Teachers also developed their own lessons plans and implemented the plans on the last day with children at a local summer camp.

Analysis

The participants' survey answers were downloaded into a spreadsheet for each photograph and each question. Each answer for Question 3 was analyzed by open coding for distinct phrases and then those phrases were compared between participants for similarities via axial coding (described earlier). Categories were determined based on the nature of what the participant was describing. Since it was desired to compare answers between photographs of similar items, the kinds of words the participants were using was of more interest than the actual words themselves. For example, where participants talked about the milk carton being made of cardboard, it was more useful to have the subcategory 'materials' rather than 'cardboard'. This is because the description of the material an object is made of is a train of thought identifiable for any object. Also, the description represents a physical property that can be associated with the Structure portion of a SBF framework

Once all of the categories were found for the data, they were arranged into groups with a certain theme, or axis related to SBF [33]. In the case of the photographs of objects, the three themes were: the physical description of the object or its *structure*; the use of the object or its *function*; and anything to do with making the object or its *design (*which we are associated in the *behavior* of the system because design requires an analysis of interdependence. For the photographs of people, the themes were the *location* of the person, the *name or label* for the person, describing an action the person was doing, things the person might have to consider, and the goal of the person. Within these categories subcategories gave more details. The complete list of categories is in Table 2 for objects and Table 3 for People.

Some examples of how the data was coded are in Table 4. The first thing that was identified for each response was whether the participant was talking about an object or a person. Then, if the person was talking about an object, it was determined if they were talking about the structure, function or design, or if it was a person, then the location, naming, action, consideration or goal. Lastly the appropriate sub-categories were chosen. If two parts of the response warranted the same code, then two of those codes were given.

Table 2 - Categories and subcategories for Objects in photograph responses

Object				Codes
structure	adjective		1a	Structure 1
	color		1a	
	size		1a	
	materials		1b	Structure 2
	parts	general	1b	
		contents	1b	
		packaging	1b	
function	how it is used		2a	Function 1
	what it does/goal of object		2a	
	client/who uses it		2b	Function 2
design	manufacturing		3a	Design 1
	need the object fulfills		3b	Design 2
	who made it	engineer general	3c	Design 3
		engineer specific	3c	
		other	3c	
	design	general	3d	Design 4
		ask	3d	
		imagine	3d	
		plan	3d	
		create	3d	
		test	3d	
		improve	3d	
	considerations	biological	3e	Design 5
		chemical	3e	
		economic	3e	
		environmental	3e	
		mechanical/physical	3e	
		natural forces	3e	
		other people in general/societal	3e	
		safety	3e	
	goal of person making it	client driven	3f	Design 6
		improve/invent	3f	
		physical attributes	3f	
		other	3f	
		solve problem/meet need	3f	

Table 3 - Categories and subcategories for people in photograph responses

People				
location	air		1	Location
	land		1	
	water		1	
	specific		1	
naming	engineer general		2	Name
	engineer specific		2	
	other		2	
action	general action		3	Action
	investigate/study		3	
	observe		3	
	test		3	
	using something		3	
considerations	biological		4	Consideration
	chemical		4	
	economic		4	
	environmental		4	
	mechanical/physical		4	
	natural forces		4	
	other people in general/societal		4	
	safety		4	
goal	solve problem		5a	Goal 1
	understand/test		5a	
	client driven		5b	Goal 2
	design		5b	
	improve		5b	
	invent		5b	

Table 4 - Several coding examples

Participant response	Descriptive Phrases	Codes
<u>(Image 1)</u> This ***milk*** carton can relate to engineering because it was ***designed*** to make the storage and use of milk ***more efficient***. The carton was made for easy ***storage*** and ***pouring***.	**<u>Object</u>** structure – adjective design – design – general design – goal – improve function – what it does function – what it does	 Structure 1 Design 4 Design 6 Function 1 Function 1
<u>(Image 2)</u> An ***environmental engineer*** must ***know*** the formation of the ***land*** and quality of the ***water*** to make sure it is ***safe***.	**<u>Person</u>** naming – engineer specific goal – understand location – land location – water considerations – safety	 Name Goal 1 Location Location Consideration
<u>(Image 3)</u> This photo is related to engineering because ***engineers*** must ***create*** or ***improve*** items to ***meet the needs*** of everyday ***society***. This peeler is a simple ***machine*** that was once hand held, however now it has ***become more complex***.	**<u>Object</u>** design – who made it – engineer general design – design – create design – design – improve design – goal – client driven design – considerations – society design – considerations – mechanical design – design – improve	 Design 3 Design 4 Design 4 Design 6 Design 5 Design 5 Design 4
(Image 4) Woman ***checking*** possible ***water*** quality of area or how ***chemicals*** are ***affecting*** the ***plant life*** around.	 Person action – test location – water considerations – chemical goal – understand considerations – biological	 Action Location Consideration Goal 1 Consideration

The categories represent the concepts that the participants notice in the photographs. There are, however, different levels to that noticing. Thus a hierarchy was incorporated into the list. This hierarchy was based on the researchers' experience with thought process about engineering. The lower categories represent more obvious, every day thinking about an object or person and relate little to engineering whereas the latter categories represent higher engineering thinking. The reason for the hierarchy was to see if the participants developed more of an ability to notice engineering concepts in everyday situations. To do this, it was of interest to investigate what levels each participant could be categorized into.

One limitation with using this photograph and question technique is that sometimes the participants did not refer to the photograph and sometimes they did not answer the question. These types of answers were incorporated as best as possible, and did not form a separate branch of investigation for this study, but would be an interesting path to follow in the future. It could also lead to ways of refining the method to improve similar studies in the future.

Results

We anticipated that teachers will be more likely to notice more structural and functional dimensions of the features and less on the design. We did not have any preconceived notions of difference between teachers in the first academy (local teachers) and the second academy (national teachers). The design of the academies was intended to be the same experiences for the teachers, but since they really were two different events we chose to analyze them separately. Once all of the responses were coded, the results were tallied. The graphs in Figure 1 show the number of responses in each category as a percentage of the total number of responses overall for either objects or people. This way, the spread of the responses can be seen. Graphs can also be compared pre to post.

The categories are order from structure, function and behavior that the image stimulated a response from participants. The images are paired as one object with a person performing and activity. In most cases the teachers consistently focused on the object in one and the person in the other. Several teachers focused on objects the people were using.

Local

For the pre objects, the highest categories were first level function, second level structure, fourth and fifth level design. In the post they were fourth level design (Design 4), first level function, third level design and some fifth and sixth level design. This shows some move towards categories higher in the hierarchy. Most notably the Design level for was the most significant increase and is directly related to the design process taught at the academy.

For the photographs about people, the highest pre categories were consideration, action, and location. In the post they were action, consideration, naming. This actually shows some decrease in the hierarchy.

National

National teachers' entered the academy noticing more features of design and goal orientation of engineers in the field compared to the local academies. Their response to these stimuli did not change as a result of the academy.

For the pre responses for the objects, the highest categories were fifth and sixth level design, first level function and fourth and third level design. For the post they were sixth and fourth level design, first level function and third and fifth level design. This does not show a lot of movement. This indicated that many of the teachers may have come to the experience with some knowledge of the design process. We are looking into other measures we used at the academies to support this conjecture.

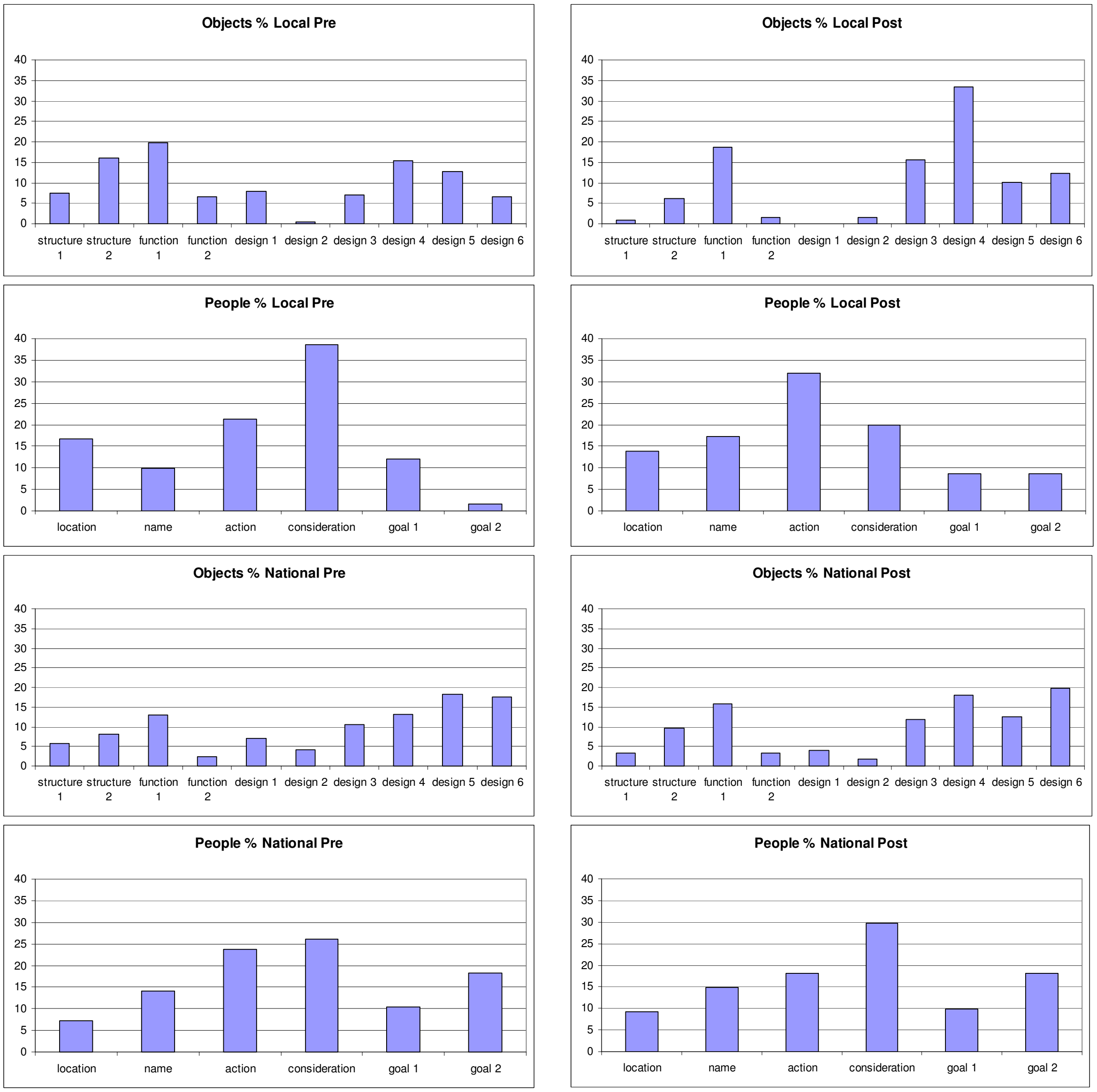

Figure 1 - Responses for each category expressed as a percentage of all responses

Discussion

Prior studies of people's perception of engineers and what engineers do indicate the general publics only notice superficial features of engineering (visible instances). They tend to notice only the obvious artifacts of engineers impact on our lives, such as building, roads, cars, electricity (civil, electrical and mechanical) and are unaware of the engineers that contribute to medicine, food service, agriculture and the environment, to name a few. Also, people tend to focus on the actual construction of the objects as the engineers job, rather then the person who designed it into a plan that was then executed by someone else. We had anticipated that teachers might share these same kinds of conceptions. We want a simple instrument that could go beyond superficial features of an object and have people spontaneously articulate more abstract ideas about how devices come to be, describe its function and how the function is achieved. We anticipated that this function and behavior would be just as invisible to teacher as the types of engineers that impact our daily lives.

Our preliminary analysis of the results indicates that teachers are able to articulate important ideas about function and design of various objects. Even before the workshops teachers can notice various aspects of the design process that went into conceiving of an object and the features of the design process (ask, imagine, plan, create and test). The post results of the local academy reveal an increase in teachers' noticing of design factors associated with an object especially around the areas of design that was explicitly targeted during the study. Increasing teachers' awareness of the design process is a one of the major goals of the summer academy.

These results are encouraging that teachers notice important structures, function and behaviors before coming to the academies. As preparation for the academy teachers were asked to maintain a photo journal of engineering ideas. In this activity teachers are asked to take pictures of engineering in their everyday life and make entries into their diaries. This could have a bias effect on teachers noticing skills as well. We are analyzing these results as part of another study and will triangulate these results with that study. It is quite possible that the photo journaling is a useful treatment for preparing teachers for the workshop.

Additional testing needs to be conducted on this instrument. We plan to conduct a reliability study on the coding categories. In addition, we would like to validate the images as stimulus for noticing by replicating this study in conjunction with interviews. Also, we would like to evaluate the potential of these images for stimulating noticing engineering by asking engineers to evaluate these images. This could provide a norm reference in which to determine if our instruments have a ceiling effect. That is, teachers are coming to the academies with the ability to notice the same categories of engineering characteristics in the images as an engineer would notice.

We are encourage with the potential of the coding methods for this project as it relates to other important aspects of engineering thinking, the ability to evaluate complex systems.

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