Designing a Survey for Engineering Undergraduates using Free Listing - An Anthropological Structured Technique

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Designing a Survey for Engineering Undergraduates using Free Listing - An Anthropological Structured Technique

Abstract

This paper describes the use of *free listing* in engineering education research. Free listing is a cognitive anthropological structured technique often used to gather rich preliminary data to improve the validity of survey instruments and interview protocols that explore complex concepts such as cultural models. Cultural models are internalized cognitive schemas that individuals within a culture share to varying degrees and draw upon to form and organize their beliefs, meanings, and practices. Anthropologists use free listing to systematically collect data on participants' knowledge and beliefs about specified *cultural models* as a means to insure that the constructs under investigation are clear and well-defined. We illustrate the use of the free listing in our study as a means of showing its potential use in engineering education research.

In our National Science Foundation (NSF)-funded study, we used free listing to understand the cultural model of "success" in undergraduate engineering programs, as defined by our target population. The free listing was used to refine the survey instrument that we will use to answer the question, "What are the effects of social capital and cultural models of engineering success on the retention and degree attainment of women and minorities in engineering?" We present our approach to using free listing to construct items for instruments that measure cultural models of success and social capital among engineering undergraduates. Specifically, free listing allowed us to determine which areas of a cultural model should be examined further and identify items that should be included in our surveys and interview protocols.

We also discuss the advantages and limitations of free listing for instrument development. The rich data obtained from free listing process can improve the design and validity of survey instruments and interview protocols. Specific examples of how we used free listing to refine the instruments to be used in our research study are described, along with implications and recommendations of how the technique can be adopted in other engineering education research. We propose that the free listing technique can be adapted by engineering education researchers to gather cultural model data about their study populations.

Introduction

As engineering education researchers explore how implicit factors impact the retention and degree attainment of women and minorities, theories and qualitative methodologies from anthropology become useful in elucidating complex concepts such as culture models and social capital. *Cultural models* are internalized cognitive schemas that individuals within a culture share to varying degrees and draw upon to form and organize their beliefs, meanings, and practices.[1] Social capital is refers to the social connections of students and the resources available through those connections. To examine these concepts, it is important to understand their meaning as interpreted by individuals who are members of a particular culture. *Free listing*, an anthropological structured technique, allows researchers to quickly and systematically collect data about a population's shared cultural knowledge in a specified cultural model. Qualitative free list data can be quantified and used by researchers in various ways. Traditionally, anthropologists used free list data to identify cultural beliefs and knowledge that

should be further examined and to guide the development of in-depth interview protocols. However, anthropologists are increasingly using free list data to inform the development of items for surveys rather than solely relying on literature reviews and previous research findings. We propose that the free listing technique can be adapted by engineering education researchers to gather cultural model data about their study populations.

Investigating cultural concepts using a survey instrument

In this paper, we discuss our approach to using free listing to refine a survey instrument developed to identify the "cultural model of engineering success" that contributes to retention and degree attainment of women and minority undergraduates in our National Science Foundation (NSF) funded study. Over the four year period of our mixed methods longitudinal research, we will administer four online surveys annually to a sample of engineering undergraduates at 11 colleges of engineering and conduct interviews with a subsample of women and minority undergraduates to investigate "cultural models of engineering success" and the role of social capital within these cultural models. We describe how we used free listing to refine our first survey which focuses on measuring the cultural models of success that these diverse engineering undergraduates bring from their high school experiences. We also discuss the advantages and limitations of using free listing in the development of surveys and interview protocols and propose its use in engineering education research.

Our study aims to examine cultural models, yet there has been an ongoing debate about how to systematically study *culture*, defined as knowledge, beliefs, values, artifacts, meanings, symbols, and practices shared and transmitted by a group. [2] According to cultural model theory proposed by cognitive anthropologists, culture is comprised of *cultural domains*, "an organized set of words, concepts, or sentences."[3] Within cultural domains there are *cultural models*, that is, which are internalized cognitive schemas that individuals within a culture share to varying degrees and draw upon to form and organize their beliefs, meanings, and practices[3]. These cultural models usually share similar characteristics with each other and those in other cultural domains. Also, within cultural models there are *dimensions (or elements)* that capture major conceptual areas of shared knowledge, meanings, and understandings.[4] Although some of the dimensions of cultural models can be gleaned from extant literature, the vexing question is how do researchers capture the variety of cognitive schemas or dimensions that might exist? In particular, how do we determine the concept under examination in our study, cultural models of engineering success?

Cultural model of engineering success

There is consensus among researchers that education is a cultural domain within which several cultural models exist, thus engineering education can be studied within this theoretical framework. The academy has a cultural model within the cultural domain of education that is shaped by its current and past members, institutional memory, and policies.[1] This *program culture* usually defines what it means to be a successful member (student, instructor, staff, and administrator) of the institution. While program culture might have written rules and guidelines, there are often important values and expectations that are unwritten, but are "understood" by insiders or those with access to this insider knowledge.

Other cultural models within the cultural domain of education can vary by gender and ethnicity.[5] For example, in predominantly white male academic programs such as engineering and other science, technology, engineering, and mathematics (STEM) disciplines, women encounter a "culture of romance" whereby male colleagues objectify women's sexual attractiveness and negatively stereotype women's academic aptitude, resulting in an uncomfortable environment for women.[6,7] In the case of ethnic-related cultural models, Fryberg and Markus[5] found that while American Indian, Asian American, and European American university students shared beliefs about the societal value of education, each group had different cultural models of education that could lead to misunderstandings with their college instructors and advisors. Examples of dimensions of the cultural model of education success include "student interactions with their peers" and "how the teacher-student relationship should function."[5]

Women and minorities entering engineering programs bring their own cultural models about how to achieve success which can lead to misunderstandings and conflicts with administrators, faculty, and other members who transmit and reproduce program culture.[5,8] We argue that the low retention and degree attainment of women and minorities in engineering programs suggest that engineering (and STEM) program culture should become welcoming of these differing cultural models of engineering success held of women and minorities rather than trying to "fix" them and "make them more like us."

In order to interrogate the meaning of cultural models as viewed by our target populations of minorities and women, it was important to ensure that our understanding of these cultural models were consistent with those of members of that culture if we were to develop an instrument to examine these issues. Free listing provided a process by which to refine an instrument based on insights gleaned from members of the culture that we wished to examine and understand.

What is free listing?

Free listing is an emic (i.e., participants' perspective) structured method developed by cognitive anthropologists drawing from psychometric theory to operationalize cultural models.[9] In free listing, members of a culture are asked to list as many items or beliefs that they can recall about one or more dimensions of a cultural model identified by the researcher, usually from previous studies and the literature. For example, a researcher can ask participants to list their beliefs about "how the teacher-student relationship should function," a dimension within the cultural model of education success. Free listing assumes that individuals 1) with extensive knowledge provide more responses than those with less knowledge, 2) list most familiar and meaningful responses first, and 3) provide responses that reflect their local cultural knowledge.[3] Ultimately, free listing measures the strongest beliefs shared by participants about this dimension.

Currently, free listing is widely used in medical anthropology, in particular, because the technique is reliable, quick, and can be conducted with small or large numbers of participants. Medical anthropologists have used it to identify 1) cultural explanatory models about diseases such as type 2 diabetes,[10,11] malaria,[12] and dengue[13] and 2) plants for healing in ethnobotanical research.[14,15] Free listing has been used to identify English-speaking Afro-Caribbean women's beliefs about type 2 diabetes causation, symptoms, and treatment.[11] These items were added to a cultural consensus questionnaire that found that these women shared a cultural model about type

2 diabetes. Free listing has also been used in key-informant interviews to elicit a list of key vitamin A-rich foods.[16] The free list data was used to develop guidelines for an ethnographic protocol used to conduct a community assessment of the natural food sources of Vitamin A.

Free listing provides researchers with additional insight into their study population's beliefs or knowledge about a specified cultural model. Free listing can reveal previously unknown data or a different interpretation of the data presented in the literature, thereby, indicating additional questions to add to surveys and/or interview protocols or new areas on which to focus research or the need to reassess interventions that target a population. For engineering education researchers, free listing can provide invaluable data to inform their research into various cognitive schemas that influence engineering program culture and the experiences of students and faculty. We propose that one use of free listing is the exploration of the cultural models of engineering success held by women and minorities to understand the conflicts that occur when they encounter the established engineering program culture. This understanding will allow researchers to make recommendations to change engineering program culture so that "space" is made to accommodate and welcome the cultural models of engineering success held by women and minorities.

Use of free listing to refine research instruments

To identify possible dimensions to examine in our survey which aims to measure the cultural models of success that diverse undergraduates bring to their engineering program, we created a preliminary survey building on a student survey used in a previously NSF-funded STEM grant and the engineering (and STEM) education literature. Using this process, we identified the following major dimensions in cultural model of engineering success: 1) academic preparation, 2) what it means to persist and achieve success, 3) programs, resources, and opportunities, 4) relationships and support, 5) department role, and 6) impediments. To ensure that our survey was comprehensive and addressed cultural models as interpreted by our target population, we next conducted a free list exercise to identify the "cultural model of engineering success" that stakeholders (e.g., faculty, advisors, and students) believe contribute to the retention and degree attainment of undergraduates in a typical engineering program.

Free list instrument development

We developed two free list instruments: one for undergraduates and the other for stakeholders, with each free list instrument having the same question phrased appropriate for the intended audience about each dimension. For example, **undergraduates** responded to the dimension question, "Prior to entering an engineering degree program, describe the academic preparation that contributed to your persistence and success in your undergraduate engineering program*?*" Whereas the **other stakeholders** version responded to the dimension question, "Prior to entering an engineering degree program, describe the academic preparation that contributes to students' future persistence and success in their engineering program*?*" On the free list instrument, below each question about a dimension were ~10 lines for the researcher to write down multiple participant responses.

Implementing the free list process

We administered the free list instruments to 31 stakeholders in an undergraduate program in a College of Engineering (CoE) at a large pre-dominantly White state university (see Table 1). We used the CoE student database to randomly recruit undergraduates to participate in the free list exercise. To ensure that women and under-represented minorities were over-represented in the sample, we identified and contacted a higher proportion of undergraduates from these subgroups than the other subgroups. As a result, of the 16 undergraduates, 13 were minorities and women; four minority men and nine women (representing six minorities groups). We then used purposive sampling to recruit 15 engineering faculty/instructors, advisors, and graduate students. One limitation to using free listing is that there is no definitive method to identify the appropriate sample size. A large sample size likely leads to more varied responses thus reducing the likelihood of agreement and the high salience of responses. However, for most studies of cultural models, 20 to 30 participants are sufficient.[3]

Table 1

Free List Participant Demographic Data

Stakeholders	**White**	**Black**	**Latino**	**Asian**	**Total**
Men (n= 13)					
Undergraduates	3	2	2	0	7
Faculty/Advisors/Grad. Students	2	1	3	0	6
Women (n = 18)					
Undergraduates	3	1	3	2	9
Faculty/Advisors/Grad. Students	4	2	2	1	9
Total	**12**	**6**	**10**	**3**	**31**

An interview was scheduled with each participant who was asked by the researcher to list their beliefs/knowledge about the question in a specific dimension. To elicit additional response to the question, each participant was probed as follows, *"Is there anything else you can think of?"* When participants did not offer explanations for their responses, the researcher would ask for an explanation to gain an in depth understanding of the participant's response. The free list sessions were audio-recorded so each response with the accompanying participant explanation could be reviewed (if necessary).

Analyzing the free list data to refine the survey

The responses to each question about a dimension on the free list instrument was entered in a text file separately and then, imported into ANTHROPAC 4.98 (Windows version), a menu-driven DOS program used for the collection and analysis of qualitative data.[17] Once the data is entered into the software, ANTHROPAC calculates the frequency, average rank, and salience of a given response. Salience, Smith's *S*, is the gross mean percentile ranking of a given response, that is, the frequency and rank of a response across all participants in a given dimension.[18]

We performed the analysis on the aggregated free list data and then on disaggregated undergraduate and other stakeholder (faculty, advisors, and graduate students) data before

running the free list analysis again. Next, our research team reviewed the analysis of aggregated and disaggregated free list data to determine which beliefs were repetitious. For example, we decided that the responses, "getting homework done on time" and "doing homework in a timely manner" were the same and should be merged as "do homework on time." After eliminating these repetitions, we re-analyzed the analysis of the aggregated and disaggregated free list data. Based on their high salience, we collectively decided which items in each dimension should be examined further as part of our study and added to items to the first survey to address them.

Below we present the results of the free list analysis on the dimension of *academic preparation* to illustrate the process used to refine the survey. The analysis of this dimension resulted in 104 items ranked by salience. After reviewing the free list analysis, our research team reached the consensus to include the 15 items with the highest salience in the dimension of academic preparation in our survey (see Table 2). Most of these 15 items were consistent with our previous research and the literature in the area of engineering undergraduates' academic preparation.

Table 2

Free List Analysis of Aggregated Academic Preparation Dimension

Item	Frequency (%)	Average Rank	Salience
Math and science courses*	93.3	1.07	0.92
Good study habits*	26.7	4.25	0.15
Engineering courses*	20	2.33	0.144
Advanced Placement (AP)*	20	2.67	0.139
Science fairs	20	4	0.123
Oral and writing skills	20	3.33	0.111
Time management*	13.3	2.5	0.072
Exploring beyond facts	6.7	2	0.053
Focused*	6.7	4	0.027
Good personality*	6.7	3	0.022
Do homework on time*	12.5	2	0.1
Dual Enrollment (DE)	12.9	2	0.086
International Baccalaureate (IB)	9.7	1.67	0.075
Robotic competitions	9.7	1.67	0.075
Teacher support*	9.7	2.67	0.065

Note: *Items already included in our preliminary survey

While many of the high salience items asterisked in Table 2 were already included in our preliminary survey, some items were not, thus we collectively decided how add to these items. For example, after reviewing the free list analysis about the dimension of academic preparation, we decided to break the question on the preliminary survey, "How often I participated in the following activities or programs while in high school" into two separate sections. One section addresses "Activities" and one that addresses "Programs" (see Table 3). We added high salience items from the free list analysis to response options of the two newly separated questions. We also changed the Likert Scale responses to be more appropriate for the two questions. We have completed the pilot and reliability testing of the survey and are in the process of finalizing the survey.

Table 3

Survey Question about Participation in High School Programs/Activities

Before Free Listing	
How often I participated in the following activities or programs while in high school	
Item	Rating
1. Math or Science camp	① Never ② Rarely ③ Sometimes ④ Often ⑤ Always
2. Math or Science study	① Never ② Rarely ③ Sometimes ④ Often ⑤ Always
3. Math or science tutoring (as a tutor or tutee)	① Never ② Rarely ③ Sometimes ④ Often ⑤ Always
4. Math or Science club/competition	① Never ② Rarely ③ Sometimes ④ Often ⑤ Always
5. Reading science books/magazines	① Never ② Rarely ③ Sometimes ④ Often ⑤ Always
6. Visited science museum, planetarium, or environmental center	① Never ② Rarely ③ Sometimes ④ Often ⑤ Always
7. Talent Search	① Never ② Rarely ③ Sometimes ④ Often ⑤ Always
8. Upward Bound	① Never ② Rarely ③ Sometimes ④ Often ⑤ Always
9. Gear Up	① Never ② Rarely ③ Sometimes ④ Often ⑤ Always
10. AVID (Advance in Individual Determination)	① Never ② Rarely ③ Sometimes ④ Often ⑤ Always

After Free Listing			
Part 1: I participated in the following <u>programs</u> while in high school		*Part 2: How often I participated in the following <u>activities</u> while in high school*	
Item	Rating	Item	Rating‡
1. Advanced placement	① No ② Yes	1. Math or science camp	① Never --- ⑤ Always
2. AVID (Advance in Individual Determination)	① No ② Yes	2. Math or science club/competition/fair	① Never --- ⑤ Always
3. Dual Enrollment	① No ② Yes	3. Math or science study group of any kind	① Never --- ⑤ Always
4. Duke University Talent Identification Program (Duke TIP)	① No ② Yes	4. Math or science tutoring (as a tutor or tutee)	① Never --- ⑤ Always
5. Engineering courses	① No ② Yes	5. Robotics club/competition	① Never --- ⑤ Always
6. Gear Up	① No ② Yes	6. Reading science books/magazines	① Never --- ⑤ Always
7. International Baccalaureate (IB)	① No ② Yes	7. Visited science museums, planetariums, or environmental centers	① Never --- ⑤ Always
8. MESA (Math, Engineering, Science Achievement)	① No ② Yes	8. Making industry tours and visits	① Never --- ⑤ Always
9. Talent Search	① No ② Yes	9. Oral and/or writing skills development	① Never --- ⑤ Always
10. Upward Bound	① No ② Yes	10. Visiting STEM-related web sites (e.g. Gizmo, NASA)	① Never --- ⑤ Always
11. Other programs, please specify	① No ② Yes	11. Other activities, please specify	① Never --- ⑤ Always

Note: ‡ The rating for Part 2 is similar to the rating of items in "Before Free Listing" section

The results from the free listing will also be used to guide the development of the follow up surveys (Survey 2 – 4) that will be administered in our study over the next three years. For example, the free list items from other dimensions that are directly related to engineering students' college experiences will be incorporated as part of the three remaining surveys. In

addition, the items gleaned from the free list process that we want to study in depth will be included in the interviews protocol that will be used with a subsample of women and minority undergraduates. For example, in our free list exercise, religion/spirituality had an unexpectedly high salience in the *relationships and support* dimension so we will include this item on our interview protocol as well as in future surveys.

Recommendations for using free listing in engineering education

Based on our experience, we make the following recommendations for researchers interested in employing cultural model theory and using the free listing technique to explore culture in engineering education:

- Review the relevant engineering education and anthropological literature to define the cultural model within the cultural domain of education and identify the dimensions within that cultural model,
- Narrowly specify the cultural model and dimensions explored so that participants can easily unpack their knowledge.
- Determine a reasonable sample size for the free list while making sure that all stakeholders in the culture are represented in the sample, and
- Design broad questions about the dimensions on the free list instrument so as not to limit participant responses.

Conclusion

Using the free listing process, we improved the design of our first survey, making it more comprehensive and relevant to the dimensions within the cultural model of engineering success from stakeholders' perspectives. By reviewing the salience of the free listing items, we were able to 1) identify items with high salience, 2) determine which items the undergraduate and other stakeholders considered more salient than others, 3) prioritize the items that should be included in the survey recognizing that we have to be judicious about its length to avoid overburdening participants, and 4) identify items that should be further explored in our subsequent interviews with women and minority undergraduates.

We propose that engineering education researchers use free listing to gather perspectives from their study population when investigating how an aspect of culture impacts the diversity and overall outcomes of engineering programs. In our study, we explore the cultural models of engineering success to understand why women and minorities feel isolated and a "lack of belonging" which increases their likelihood of switching to non-engineering majors.[19] Insights obtained from such research can be used to change engineering program culture and create pathways for women and minorities to be retained and attain their degrees.

The primary value of free listing is that participants, especially those from an understudied population, often identify beliefs or attitudes about the cultural model that were previously unknown or interpreted differently in the literature. By including newly gleaned items in a survey or an interview protocol, researchers can determine if these beliefs or attitudes are shared throughout the study population. Thus, free listing can be a valuable first research step in

engineering education studies where examining cultural models or other internalized cognitive schemas is crucial to understanding participants' shared beliefs and experiences.

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