Students' Conceptions of their Engineering Discipline: A Word Association Study

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Abstract

A goal of engineering education is to prepare students for professional practice by helping students acquire important knowledge and skills as well as an overall schema of engineering practice. In this paper, we report on an exploratory study to investigate civil engineering students' schemas of civil engineering. In our study, 30 graduating civil engineering students completed a word association task using the probe "civil and environmental engineering." In this paper, we describe and interpret some results from this experiment, focusing on the relationships of student's schemas to the engineering schema implicit in the new ABET learning outcomes.

Introduction

A goal of engineering education is to prepare students for professional practice. This preparation involves helping students acquire the skills, knowledge, and attitudes associated with being a professional engineering practitioner. In a typical engineering curriculum, students begin acquiring the knowledge, skills, and attitudes through course experiences. Additionally, students acquire knowledge, skills, and attitudes outside the classroom through work experiences, mentoring relationships, undergraduate research experiences, and other opportunities.

As engineering educators, we hope that students will be able to integrate lessons from these experiences. However, this may not be the case. Concern that engineering school graduates are not sufficiently prepared for professional practice has led to calls for engineering education reform and reports on how this can be carried out [1, 2]. One of the most prominent results of these engineering education reform activities has been the changes in accreditation standards for engineering programs. Specifically, ideas about the nature of engineering, and the skills and knowledge of a proficient engineer, led to the identification of eleven ABET learning outcomes [3].

Yet, being prepared for professional practice is more than being competent in each of the areas identified by the eleven ABET learning outcomes. The professional engineering practitioner is one who understands how each of these skill and knowledge areas is related to engineering activity. This suggests that the eleven learning outcomes embodied in the new ABET accreditation standards represent the components of a schema of engineering practice, where *schema* refers to the set of ideas and relationships among ideas that define a concept [4, 5].

The observation that the ABET learning outcomes imply a schema of engineering practice suggests some questions: What are our students' schemas of engineering? Do our students' schemas of engineering include the skills and knowledge that are embodied in the ABET learning outcomes. If we accept Ausebels's single guiding principle of education - "If I had to reduce all of educational psychology to just one principle, I would say this: The single most important factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly"[6] - then these questions are important. An understanding of our students' schemas of engineering should provide insights that can guide engineering education. What is needed is a way to probe students' understanding of, or schema of, their engineering discipline.

In this paper, we make one step in this direction by reporting on a study that explored civil engineering students' schemas of civil engineering. In particular, we sought to understand the relationship between students' conceptions of civil engineering and the schema implicit in the ABET learning outcomes. In this exploratory research, we used a word association task to develop initial insights. In this paper, we provide details on the word association method, the analysis of the data, and the results for a sample of five subjects. We close with some implications of this exploratory study.

Method

We explored students' engineering schemas using a word association task. In a word association task, a subject is presented with a term (the *probe*) and then records all of the ideas that come to mind (i.e., that he/she associates with the probe). The data resulting from this process include the specific terms that the subject provides, the number of terms provided, and the sequence of the terms provided. This information can then be used to characterize a subject's understanding of the probe concept.

<u>The Word Association Task</u>

There are a variety of different approaches for exploring a student's schema of a concept such as engineering. One approach is to conduct a "concept" interview with a student [7]. In such an interview, the interviewer asks the interviewee to talk about their ideas about the concept under consideration (e.g., engineering). The interviewer monitors what the interviewee is saying, asking for clarification when something seems unclear. The interviewer can come prepared with questions that can stimulate the interview. Focus groups, essentially an open-ended interview with multiple participants, are a related technique.

A strength of such an open-ended interview is that the interviewer can pursue topics brought up by the interviewee and ask questions about ambiguities in order to resolve them. On the other hand, conducting interviews and analyzing interview data are extremely time-consuming, thus limiting the number of subjects who can be explored through such a technique.

In our exploratory work, we chose to use word association [7]. In a word association task, the goal is for the student to create a list of concepts related to the target concept. The basis of a word association task rests on the associativeness of memory. The theory of associative organization of memory is that related concepts are linked and that activation of a concept results in activation of related concepts [8]. A word association task builds from that idea by suggesting that when subjects are doing the word association task, they are writing down the related concepts that have been activated by the target concept. Concept mapping, which involves having students not only list the concepts but also show the relationships among the different concepts, is a related technique [9].

The word association task, while not as thorough as interviewing, has some strengths that interviewing does not. The task can be completed quickly by students, and many students can complete this task at the same time. In this manner, a data set can be quickly created and analyzed to identify initial insights. Such an analysis can be used to generate hypotheses and questions to be further explored through interviews or another method.

Procedure

The word association data described in this paper was collected as part of a larger study. This larger study involved students responding on a series of tasks, where the tasks were chosen to provide insight into student's preparedness for professional practice. In addition to the word association task, the study included a professional advice task, a concept mapping task, a sorting task, and a demographic survey. The subjects completed the tasks in a specified amount of time and in a specified order.

The word association task was the initial task. The task began with the distribution of materials to the subjects and the reading of instructions. The subjects were told to use the probe "civil and environmental engineering" and to write down whatever comes to mind. The subjects were then given 15 minutes to work on the task.

Subjects

A total of 30 subjects participated in the study. All of the subjects were students in civil and environmental engineering. While most of these subjects were graduating seniors, a few were graduate students. The subjects represented each of the concentration areas included in the civil and environmental engineering program.

The subjects included both paid and volunteer subjects. The volunteer subjects were those who chose to complete the study tasks rather than participate in their normally scheduled class. The paid subjects completed the assessment tasks at the end of the exam week.

Analysis

The data resulting from the word association task include the number of terms each subject provides and the specific terms provided. By looking at the number of terms provided by each subject, one can get an initial sense of the dataset.

The specific goal of the analysis, however, was to uncover what the word association data indicates about students' schemas for civil engineering. In particular, we were interested in how the students' schemas compare to the schema implicit in the ABET learning outcomes. Thus, we decided to use the ABET learning outcomes to help us categorize the data. Each of the 11 ABET criteria were used to generate a code for our coding scheme. For example, the code "Technical

Table 1. Descriptions of the Coding Scheme. Outcome letters correspond to ABET learning criteria.

Outcome	**Explanations**	**Examples**
(A) Technical Knowledge	Terms that demonstrate student knowledge in mathematics, science, or engineering. These include areas of knowledge as well as things students learn to describe.	"Geotechnical" "Transporation" "Strength"
(B) Data Collection	Terms related to the process of experimentation and data analysis. This category excludes specific tools and equipment which fall into category K	"Trans-lake study" "Research"
(C) Design	Things that are designed. All the things that are designed fall into this category. It is not limited to things that civil engineers design.	"Waste water treatment" "Transit" "Trusses"
(D) Multi-disciplinary Teams	The people with whom engineers work, as well as the skills needed to work on a team. This category includes specific names as well as more general terms.	"Environmentalists" "Teamwork"
(E) Engineering Problems	Terms identifying problems engineers solve as well as goals of engineering.	"Movement of goods" "Bridge design"
(F) Professional	Terms expressing professional and ethical responsibility as well as things related to engineering as a profession.	"Budget" "Construction Crews"
(G) Communication	Communications skills and devices.	"Papers" "Presentations"
(H) Global and Societal Context	Terms that recognize engineering in a broad context. This includes terms recognizing society, as well as areas of knowledge that are not technical.	"Civilization" "History"
(I) Life-long Learning	Terms associated with education. This generally includes words associated with the students' schooling, such as professors and room numbers and school names.	"Grad school" "VLPA"
(J) Contemporary Issues	Terms that convey student knowledge of contemporary issues. This category includes contemporary engineering projects and opinions of those projects.	"Extending monorail" "Centennial fund"
(K) Tools and Techniques	Tools and techniques that engineers employ in the practice of engineering.	"Inspection-buildings" "Computers"
(L) Affective	Terms that convey student attitudes.	"Whoa!!" "Interesting"
(M) Other	Terms that do not fit into any other categories.	"Eggs"

Knowledge" stems from ABET learning outcome (a) – an ability to apply knowledge of science, math, and engineering to solve engineering problems. Two additional codes, *affective* and *other*, were added to the coding scheme to capture those word association items that did not naturally fit with one of the eleven ABET motivated codes. The coding scheme is presented in Table 1.

In the development of the coding scheme, we sought to ensure the reliability of the coding. Initially, the first two authors applied the coding scheme to the data from five subjects and then compared the coding results to determine the reliability of the coding. At the end of this first pass, the coding reliability was considered to be too low. Using the coded results from two of the five subjects, we refined the definitions of the problematic codes and identified a wider variety of examples to illustrate the coding. We then re-coded the data for the remaining three subjects and re-tested the reliability of the coding. On this second iteration, an acceptable level of reliability (>80%) was achieved.

In presenting the results of the coding, we focus on the coded results of five subjects. These five subjects were selected to represent a range in terms of number of items listed in the word association task. By focusing most of our attention on just these five subjects, we were able to explore individual students' conceptions of civil engineering.

Results

Across the group of thirty subjects, the subjects generated a mean of 51 items, with a standard deviation of 5.2 items. The median number of items generated, 42, reflects the skew of the distribution of number of items generated (see Figure 1). While a few subjects generated a large number of items, most generated around 30-50 items.

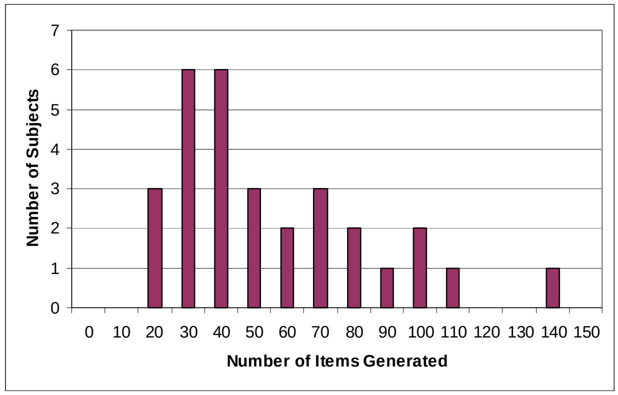

Figure 1. Distribution of Number of Items Generated during Free Recall

The data for the subjects differed in a number of ways. For example, students included technical topics such as "hydraulics" and "surveying" as well as ideas that did not seem specific to civil and environmental engineering. One student included personal information such as sleep deprivation, toward the end of the list and another student included personal information such as names. One student included seemingly random ideas, such as "eggs", that are difficult to relate to the topic of civil engineering without asking the student about the relationship. However, the relationship between most listed items and civil engineering was apparent.

In terms of format, one student (with a low number of generated ideas - 19) include phrases describing civil engineering. Another student (again with a low number of generated ideas – 14) include whole phrases describing what was learned. Most students listed their ideas as one long list. However a couple of students grouped the topics in their list. For example, one student grouped their ideas into two categories - "civil" and "environmental". Another student grouped their ideas into knowledge areas such as "hydraulics."

Coded Results by ABET Learning Outcome

In this section and the next section, we present the results from the selected group of five subjects. Figure 2 shows the percentage of each of the five subjects' responses that were associated with each ABET learning outcome. For example, consider the first set of data points above the "A" in Figure 2. These points represent the percentage of each of the five subjects' responses that were coded as associated with ABET learning outcome (A) – technical knowledge.

In Figure 2, the learning outcomes are ordered based on their prominence in subject responses. The majority of most subjects' responses fell into the category of technical knowledge. Items were coded as technical knowledge if they referred to an area of science, math, or engineering knowledge that a subject might know about. This result that most subject responses fell in this

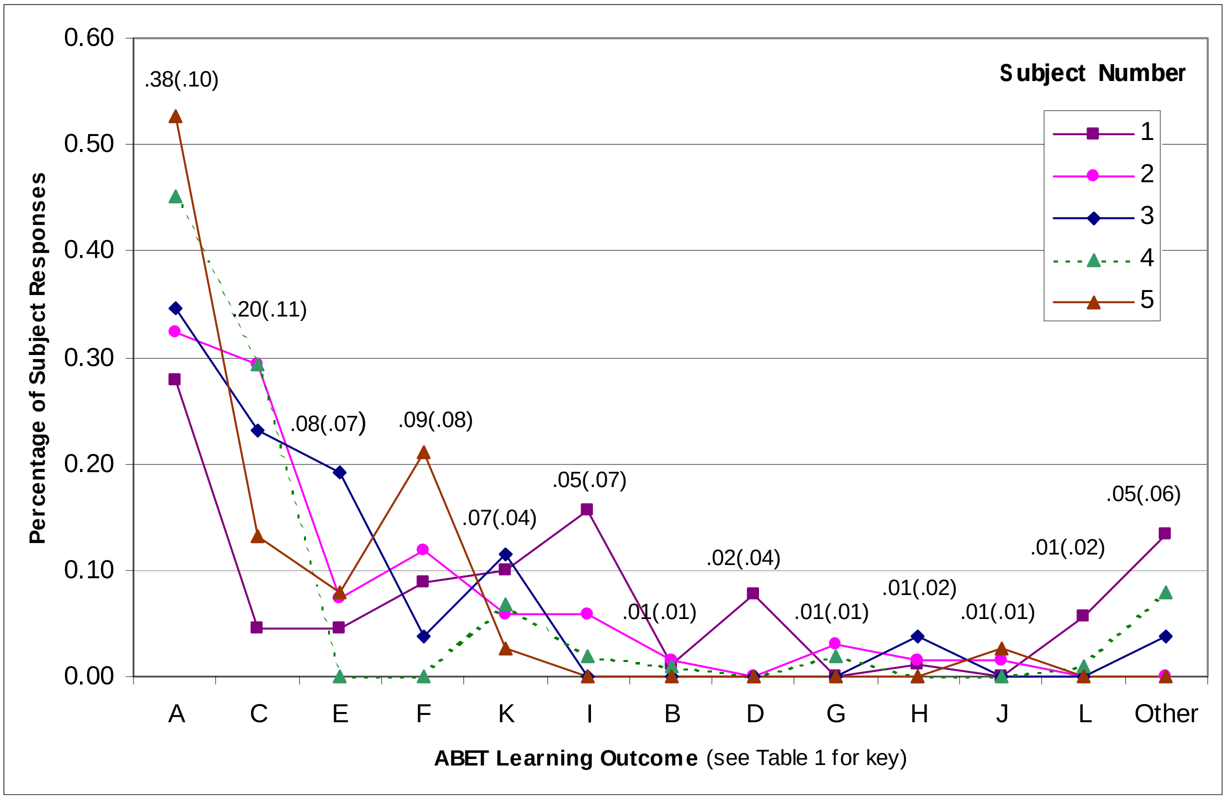

Figure 2. Distribution of Subject Responses across ABET Learning Categories (The numbers above the ABET Learning Outcome Letters represent the average, and standard deviation, in the percentage of subjects' items associated with that particular learning outcome.)

category is consistent with expectations – a large portion of student experiences in an engineering program focus on learning the technical knowledge required to be an engineer.

A large percentage of subject responses also fell into category (C) – Design. Items were coded as design if they represented something that a civil engineer could create. For example, bridges, trusses, and even bolts were coded as design since all could be designed according to some specification. That subjects included a larger percentage of these items in their responses also makes sense – many of the items in this category represent visible signs of civil engineering.

Three ABET categories received an average of about 10% of the items: (E) – Problem solving, (K) – Tools and Techniques, and (F) – Profession. Items were coded as problem solving if they referred to problems or goals for engineers to achieve. Example items included “Improve city quality,” and “Protecting populations.” Tools and techniques accounted for a similar number of items in the subject responses. Examples included tools such as Matlab, GPS, and Theodolite and techniques such as Seismic planning, recycling, and surveying. Subjects also seemed to have a significant number of items related to engineering as a profession. These included items such as “clients” and “building codes” as well as general references to the economics of business.

Also made more apparent by Figure 2 is the number of categories for which students had few responses. There were six categories that had an average of 1%-3% of the subjects' items (categories B, D, G, H, J, and L). This set included three categories in which three or more students had no responses: (J) – Contemporary Issues, (G) – Communication, and (D) – Multidisciplinary Teams. While an absence of items in the first category (contemporary issues) is not too surprising, the absence of items in the latter two categories seems much more important. Communication and teamwork are critical areas of ability for success in engineering practice.

The final category, (I) – lifelong learning, received all student items related to both learning in general and their current education in particular. The result is that the list of items reflects issues in students' current education rather than ideas about lifelong learning. Items mentioned by subjects included "classroom," "graduate," "Mannering" (a professor), and "quarter." The lists did not include items such as professional society journals, technical conferences, or other strategies that might be taken as a component of lifelong learning.

The above observations represent the average behavior of the five subjects. It is clear from Figure 2, however, that there is variability in the results for different subjects. The next section describes some observations made possible by viewing the results on a subject by subject basis.

Coded Results by Subject

Figure 3 shows the distribution of each subject's items across the ABET categories. In this representation we can see the differences in how these subjects covered the set of ABET categories. In the figure, the subjects are ordered from the most even distribution to the least even distribution.

Subject 1 had the most even distribution. This subject's responses covered 13 of 15 coding categories. The only two categories that were not represented in the subject's responses were (G) – Communication and (J) – Contemporary Issues. Two other categories had very few items – (B) – Experimentation and (H) – Global and Societal Context. For all other categories, the subject had 5% or more of his/her responses in those categories.

Subject 5 had a very different distribution. The subjects' responses covered only 6 of 13 categories. The majority of the subject's responses (53%) fell into the technical knowledge. This percentage of responses in the technical knowledge category represented the highest percentage of any subject. Subject 5 also had the highest number of items in category (F) – Profession.

Discussion and Concluding Remarks

This paper documents preliminary results of a study into students' conceptions of engineering. In particular, students' responses in a word association task were analyzed to determine the extent to which the listed items covered categories derived from the ABET learning outcomes. In this paper, the results for five subjects were presented in order to illustrate some of the potential patterns identified through the analysis.

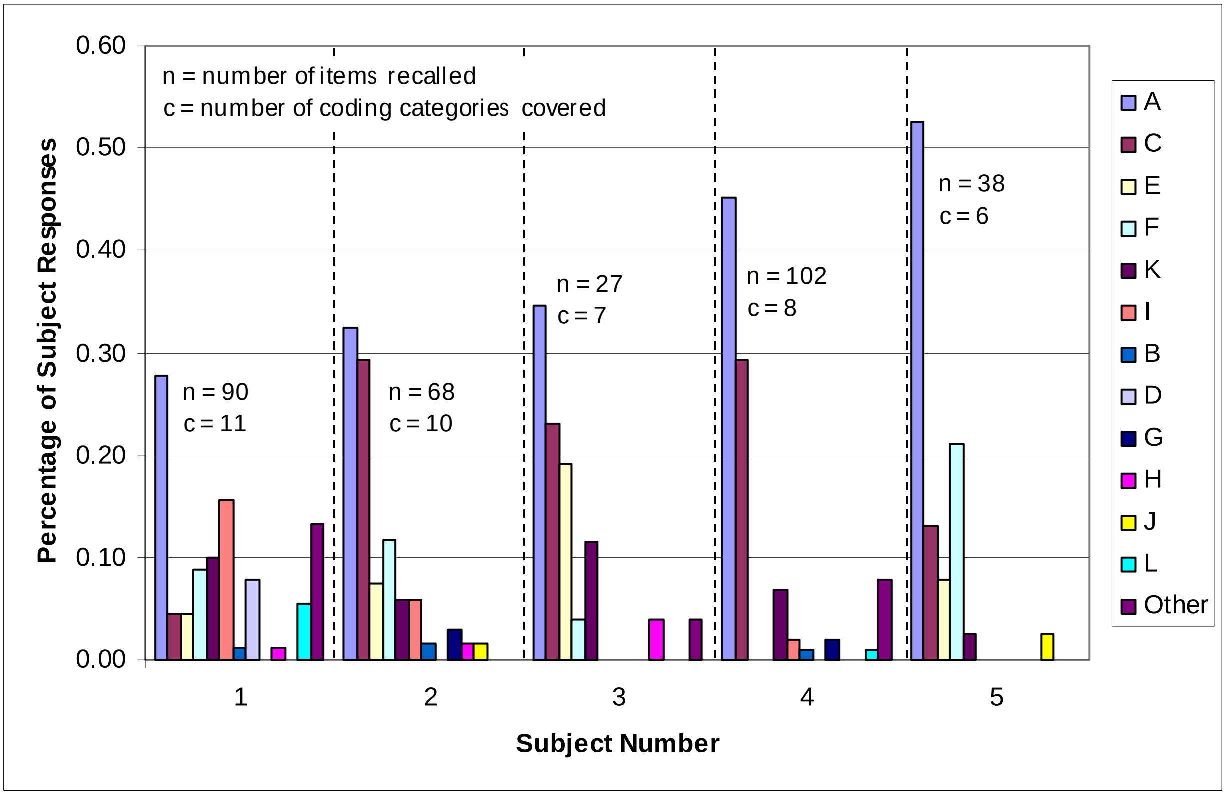

Figure 3. Distribution of Subject Responses Across ABET Learning Outcomes

One observation is that this sample of students seems to have a broad understanding of engineering. Their responses extend beyond the technical knowledge category. However, one might wonder whether the conceptions of engineering are broad enough. This type of analysis suggests that students may need support in understanding the importance of topics such as communication and teamwork in engineering practice. Even though these two particular concepts may frequently be stressed in engineering curricula, our small sample indicates that students may not understand the importance of these activities in engineering practice. We plan to further investigate this hypothesis when we complete the analysis with the entire dataset.

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