# AC 2008-1348: APPLYING "CULTURAL CONSENSUS ANALYSIS" TO A SUBGROUP OF ENGINEERING EDUCATORS

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# Applying "Cultural Consensus Analysis" to a Subgroup of Engineering Educators


## Abstract

In this paper, we review the theoretical premises of cultural consensus analysis and offer a detailed description of its methodological components, including data collection and analytical procedures. We demonstrate how this quantitative method drawn from cultural anthropology could be used in engineering education research. Our findings indicate that a measurable amount of consensus regarding beliefs about effective teaching exists among the engineering educators in our study. According to the mathematical criteria of the cultural consensus model, this population constitutes a cultural group. Further, the beliefs listed and prioritized by respondents indicate that a coherent cultural domain exists for "effective teaching". The wider implications of this research include not only potential applicability of this method within engineering education research but also a critical analysis of variations among engineering educators and a contribution to the emerging discourses of engineering education as a "culture".


## 1. Introduction

Some researchers have suggested that engineering education may be described as a "culture" in which knowledge, beliefs and practices are shared.[1, 2, 3, 4, 5] Less attention has been paid to the nuances within engineering education, the variability in the degree to which members accept or share a base of knowledge, beliefs and practices. Quantitative methods can be used to test whether cultural constructs are shared among some engineering educators. One anthropological research method, "cultural consensus analysis,"[6] measures the extent to which group members agree or disagree about beliefs or practices. Specifically, to what extent do individuals agree or disagree with the group? In our case, do engineering educators share beliefs about teaching? Can we conceptualize them as a cultural group, based on their beliefs, or are their beliefs idiosyncratic and random? To answer these questions we began researching a subgroup of engineering educators. We identified attendees at the 2006 "Frontiers in Education" (FIE) conference as a "subgroup" of engineering educators because the annual conference is devoted to improving engineering education (for example, the conference theme for FIE 2008 is "Racing toward Innovation in Engineering Education"). Given this association, do these members share a cultural model about what constitutes effective teaching? And if so, how might their beliefs differ from other engineers who do not attend conferences specific to engineering pedagogy? These questions motivate us to study "intracultural variability" – the extent to which group members agree and disagree. We suggest, following cognitive anthropological theory, that agreement or "shared knowledge" can be measured and is an indicator of shared culture.

The culture of engineering education, however, is varied and diverse, contextual and dynamic. This analysis presents a snapshot of one cultural construct. Just as we specifically examine one subgroup of engineering educators (many of whom, in the qualitative interviews, expressed a fluency in pedagogical discourses and eloquently described situationally-specific modes of learning/teaching), other subgroups of engineers may have strongly differing ideas about how to effectively teach. One objective of this paper is to bring data to bear on the idea of an "engineering education culture". Based on evidence presented below, the "culture of engineering education" is not monolithic; rather, data show that pockets of instrumental actors embrace alternative methods of teaching, such as those characterized broadly as “active learning”.

In this paper, we review the theoretical premises of cultural consensus analysis and offer a detailed description of its methodological components, including data collection and analytical procedures. We demonstrate how this anthropological method could be used in engineering education research. Our findings indicate that a measurable amount of consensus regarding beliefs about effective teaching exists among the engineering educators in our study. According to the mathematical criteria of the cultural consensus model, this population constitutes a cultural group. Further, the beliefs listed and prioritized by respondents indicate that a coherent cultural domain exists for “effective teaching”. The wider implications of this research include not only potential applicability of this method within engineering education research but also a critical analysis of variations among engineering educators and a contribution to the emerging discourses of engineering education as a “culture”.

## 2. Overview of the Literature

Cultural anthropologists agree that shared knowledge is socially generated, disseminated and actively constructed. In the past three decades, anthropologists have eloquently critiqued essentialized portrayals of culture, portrayals that present culture as “homogeneous” and “static”.[7, 8] Cognitive anthropologists are especially interested in exploring variations, both between and within groups (“inter- and intra-cultural variation”) to measure the extent to which information is shared. They conceptualize knowledge as an “information pool”, with different group members sharing differing ideas based on both individual differences and social contexts.[9] A methodology developed by quantitative anthropologists may be used to rigorously examine cognitive variation among groups, and elucidate “intracultural variation”, the degree to which in-group members differ in their categories of knowledge/meanings. The mathematical model is called cultural consensus analysis, and it measures shared knowledge within groups and uses a score called “competence”[6] to estimate the degree to which group members agree and disagree with one another. Other researchers use terms such as “agreement”[10] or “estimated shared knowledge”[11] rather than “competence” because “competency” may be interpreted as a value judgment on the participant which the method is not intended to express.

Cultural consensus analysis has been used by a variety of researchers since it was developed by Romney, Batchelder, and Weller in 1986.[6] According to A. Kimball Romney, cultural consensus analysis provides researchers with a valid, replicable, and objective method to study social groups and their beliefs.[12] In fact, this method has been used across a wide variety of disciplines. In the field of cross-cultural management, consensus analysis has been used to measure shared knowledge among diverse members of business organizations. [13] Medical anthropologists have used the method to explore intracultural variation among physicians[10] and patients.[14, 15] Other researchers have used the method to explore variation among, for example, experts and novices,[16, 17] women and men,[18, 19] target populations for marketing research,[20] and parent-teacher interactions.[21] We use this method to measure whether a subgroup of engineering educators, specifically those who place a high value on teaching, can be considered a cultural group. Specifically, we test to see if agreement exists among them with regard to the cultural domain: beliefs about effective teaching.

## 3. Identifying the Subgroup

### 3.1. Sample Selection

Our research subjects were selected using a purposive sampling technique. Using the international 2006 "Frontiers in Education" (FIE) Conference held in San Diego as an opportune field site (because of the conference's explicit orientation towards innovation in pedagogy and engineering education), we identified a target population of engineering educators who present and/or publish on the topic. Prior to the conference, we accessed the list of faculty who had pre-registered and invited them to join a study on "effective teaching practices." To qualify for the IRB-approved project, participants were limited to faculty with engineering degrees who are currently tenured or in tenure track positions at four-year institutions in the U.S. or Canada. Our approach to selecting research subjects at the FIE conference involved 1) sending a mass-email to all participants scheduled to attend the conference, inviting them to participate in the study and 2) scheduling volunteer subjects for an in-person, qualitative interview. Interviews were conducted over a two-day period, on-site, at the conference hotel. All interviews were digitally tape-recorded and later transcribed.

The FIE pool is part of a larger research population. The entire pool consists of two distinct groups. In an earlier project, for example, we measured beliefs about effective teaching among one group we call "pedagogy experts" (non-engineers) who rely on critical models of pedagogical inquiry such as "liberative" or "feminist" approaches to teaching.[22] The second group includes faculty in engineering programs who may or may not be engaged in similar critical modes of teaching. Because some engineering faculty (i.e. FIE attendees) place greater value on teaching than others, we sought to explore these differences. Thus the category, FIE attendees, emerged as an authentic subgroup within the "engineering" pool of faculty members. In our larger study, we explore how FIE attendees differ from engineering faculty who have never attended a conference related to "innovation in engineering education".

The findings from this study of FIE attendees are not generalizable to all engineering educators because probability sampling techniques were not used, and were not conducive to the qualitative components of the project. A smaller sample size is typical of ethnographic research, which seeks to yield abundant, rich, in-depth information about a particular community.[23.] Such non-probability sampling techniques are important for building an exploratory, data-driven understanding of the FIE participants as a community. For the cultural consensus analysis component, a smaller sample size is appropriate: Weller[11] identifies 15 informants as an adequate number of informants on which to perform consensus analysis. The suitable sample size for consensus analysis is determined when certain conditions are met, both the degree of concordance among respondents and the desired level of validity, which is determined by the researcher and typically set at 95% validity for valid, replicable results. For this study twenty-six interviews were conducted; of these, twenty-four are included in the analysis (two provided incomplete responses), exceeding the acceptable standards for sample size.[24]

### 3.2. Characteristics of the Sample Population

The participants in our study came from a variety of disciplines including chemical, electrical, industrial, and mechanical engineering. They are employed at a range of institutions including public and private, small and large colleges and universities. As shown in Table 1, the average age of the FIE participants was 49 years with an average of 19 years of college level teaching experience. Our sample included 16 men and 8 women which correspond to about 67% male and 33% female. Note that women are overrepresented compared to national average of women in engineering education, however, FIE tends to include more women engineering professors than a typical engineering conference.

Table 1 Descriptive Statistics for Participants (N=24)

| | **Minimum** | **Maximum** | **Mean** | **Std. Deviation** |
|---|---|---|---|---|
| **Age (years)** | 30.00 | 67.00 | 49.22 | 9.33 |
| **Number of years teaching college** | 3.00 | 41.00 | 19.15 | 10.16 |

The participants in our study did indeed show a commitment to teaching. This is evidenced by the fact that 67% stated that they spend more energy on teaching than research; however, only 17% said that they were rewarded more for teaching than research. Participants reported regularly attending conferences such as FIE and ASEE (85%), having attended workshops on teaching on their campuses (89%), and reading articles about pedagogy (often or somewhat often, 82%).

## 4. Methodology

We used a triangulated approach to examine the cultural domain of beliefs about effective teaching from a multi-method perspective. The cultural consensus method involves several steps in both data collection and data analysis as summarized in Figure 1. In this section, we describe these steps in more detail. Greater detail on free listing and rank ordering techniques may be found in several key references.[23, 24, 25, 26, 27]

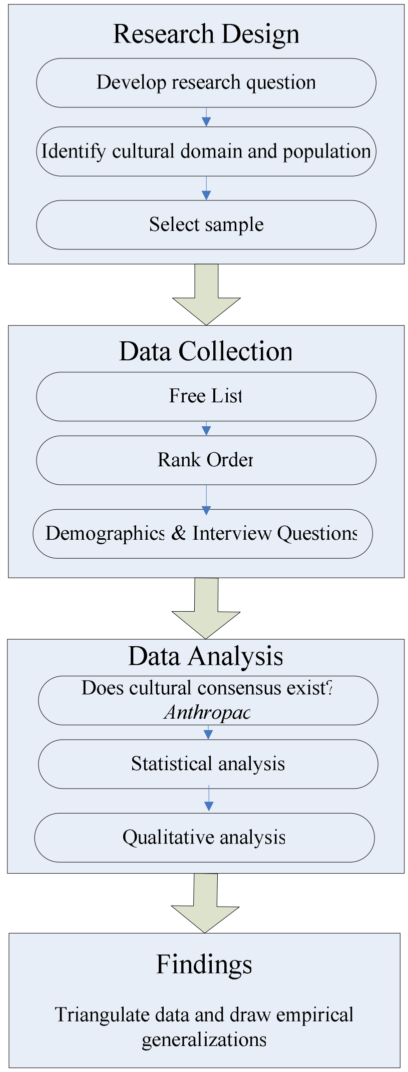


Figure 1 Macroview of Cultural Consensus Analysis Methodology

### 4.1. Data Collection

*Free list Method*

Free listing is a powerful methodological technique used to elicit a cultural domain (such as a belief system). The objective of the "freelist" activity is to enable the respondent to freely generate themes relevant to his/her experience, thus eliminating some researcher-imposed biases. In our research, we asked informants to list all of the practices they believe to be associated with "effective teaching" and all of the teaching practices they actually use. Specifically, we asked "Could you list the specific practices/techniques that you utilize in the classroom, when you are disseminating & generating information (**teaching**)?"

Prior to the FIE 2006 conference, we conducted preliminary freelisting exercise with members of two groups: 1) pedagogy experts and 2) engineering faculty members (both FIE attendees and non-attendees). Following Chavez et al.,[14] we reviewed all free listed items and selected those most frequently mentioned and printed each on a separate index card. These items are listed in Table 2 and were used in the rank order exercise.

*Rank Order*

We asked respondents to rank order the cards from most to least important based on their beliefs about the effectiveness of each. The rank-ordering method is a cognitive science approach designed to understand relationships between beliefs and provides quantifiable data to examine beliefs about our cultural domain, teaching effectiveness. Rank ordering measures not only the relative importance of each item according to individual respondent's beliefs, it also allows for the analysis of shared agreement for all respondents. Following the rank-order exercise, interviewees were given an opportunity to describe the ranking, and provide a rationale.

*Qualitative Probes*

To complement the freelisting and rank ordering, we elicited narratives using open-ended, structured and unstructured qualitative questions which sought to deepen our understandings of their beliefs and practices about effective teaching and investigate factors that might be interrelated.[22, 28] Participants also completed a demographic information form and answered other qualitative questions about their educational backgrounds and careers. The research team analyzed the qualitative responses by reading through transcriptions of the interviews. We then iteratively coded and categorized responses to uncover thematic categories, relate responses to the previously collected free list items, and comb for anomalies.

Table 2 Teaching Practices used in Rank-Order Exercise

| |
|---|
| Allowing questioning of course content; critique of what is being learned in class |
| Ask for student feedback ex: "what next?" Probe for understanding |
| Attention to gender & use of inclusive language in examples |
| Building a sense of community in the classroom |
| Community Service Learning |
| Electronic discussions (list-serve or internet-based course software ex. WebCT) |
| Emphasis on discussion and student voices |
| Empowerment of students; student as equal partner in learning |
| Guest speakers |
| In class demonstration (physical or computer-based) |
| Inquiry/inductive learning (driven by a question) |
| Lectures & writing on blackboard/whiteboard |
| Linking relevant course material to broader socio-political/environmental issues "intersectionality" |
| Lecture w/transparencies |
| Making course material relevant to personal experiences; incorporating student voices; use of narratives/stories |
| PowerPoint lectures |
| Role of professor is guide, rather than expert; professor shares power with students |
| Self-awareness of professor (make adjustments based on student feedback) |
| Small group work in class |
| Students help shape the syllabus |
| Student presentations; allowing students to occasionally teach the class |
| Use of multimedia (new technologies, films, music, Tablet PC excluding PowerPoint) |
| Use of space; consideration of seating arrangement in class |
| Use of examples relevant to students, Example: popular culture |
| Visit local industry; tour a facility |

## 4.2. Data Analysis: Cultural Consensus Analysis

To determine if agreement exists among engineering educators, we ran a cultural consensus analysis using *Anthropac*, a commercially-available statistical analysis program.[29] Output from this analysis includes graphical representations of similarities among respondents, an estimate of how well the cultural consensus model fits this data, and a data-driven model that assesses which beliefs are prioritized.

The data can be powerfully represented through a visual display using multidimensional scaling to show patterns of agreement among group members. According to the visual display (which presents the quantitative output of the application of a scaling routine to an agreement matrix of all respondents), each respondent is represented as further from, or closer to, other respondents based on how differently or similarly (respectively) they organize information about a particular cultural domain. Respondents who are represented as closer to each other responded similarly; those who responded differently from each other are spatially farther apart on the display.[i] For example, see Figure 2.

There are three basic assumptions that underlie cultural consensus analysis. Because we are dealing with human subjects, with inherent variabilities, not all respondents will conform to these assumptions.[12] These "ground rules" may be expressed as

- *Assumption 1: Common Truth*: Questions all belong to a coherent cultural domain and the same cultural reality exists for each participant. In this case, all participants are part of an engineering education culture, broadly conceived, and all are university faculty members.
- *Assumption 2: Local Independence*: Individual responses do not depend upon the responses of other participants. One participant's responses are independent of another's.
- *Assumption 3: Homogeneity of Items*. All items have the potential for a fixed "cultural competence" by respondents. No one item is intrinsically more "correct" than another.

Using these assumptions allows for formal mathematical modeling: researchers who use cultural consensus analysis generally use three specific mathematical criteria which must be satisfied to assert that the participants in the study share a single cultural model. Thus as part of the cultural consensus analysis within *Anthropac*, the data are compared to these three criteria:

1) Eigenvalue of the first factor loading (in principal component analysis) is at least three times greater than the eigenvalue of the second factor
2) Agreement scores are all positive
3) Agreement scores have a mean value above 0.5.

Agreement scores refer to a numerical value which estimates the amount of agreement that each respondent has when compared to the most common rankings of the data. This agreement score ranges between +1 and -1 for each respondent. The higher the agreement score, the greater the similarity between the individual's own responses and the overall comprehensive ranking by the group. If they satisfy these criteria, *Anthropac* states that a single cultural model applies.

The first criterion arises because the eigenvalues of the factor loadings in the mathematical model are used to estimate agreement among participants. If a single model is to explain the agreement between participants, its eigenvalue should be significantly (at least 3 times) greater

[i] Thus the axes for the proximity matrix plot are not, by themselves, meaningful. Rather they represent the variations among this particular dataset.

than the next eigenvalue. The second and third criteria are based on the idea that if there were negative agreement scores, this could indicate that Assumption 1 or 3 were violated. Requiring the agreement scores to be not only positive, but with a mean greater than 0.5, makes it more likely that the participants do share a common cultural model.[20] A negative agreement score or a mean lower than 0.5 suggests an incoherent model.

Once consensus has been established, the researcher can run further analyses using standard statistical techniques to examine the intracultural variation. Note that the types of analysis that can be performed will depend on the level of measurement of the data itself. For example, the agreement scores can be used as dependent variables and empirically tested for correlation with other factors in the analysis.[30]

## 5. Results and Discussion

To test for consensus according to cultural consensus analysis, we began with the graphical proximity matrix produced from our analysis using *Anthropac*. (A more detailed description of our procedure in using *Anthropac* is found in the Appendix.) To enable us to examine this data and distinguish patterns, we chose to run the analysis initially on the FIE participants plus twenty-five randomly generated rankings.[ii] The results of this are shown in Figure 2. The FIE sample (the blue diamonds) shows considerably more similarity than the randomly generated sample (shown as red squares).

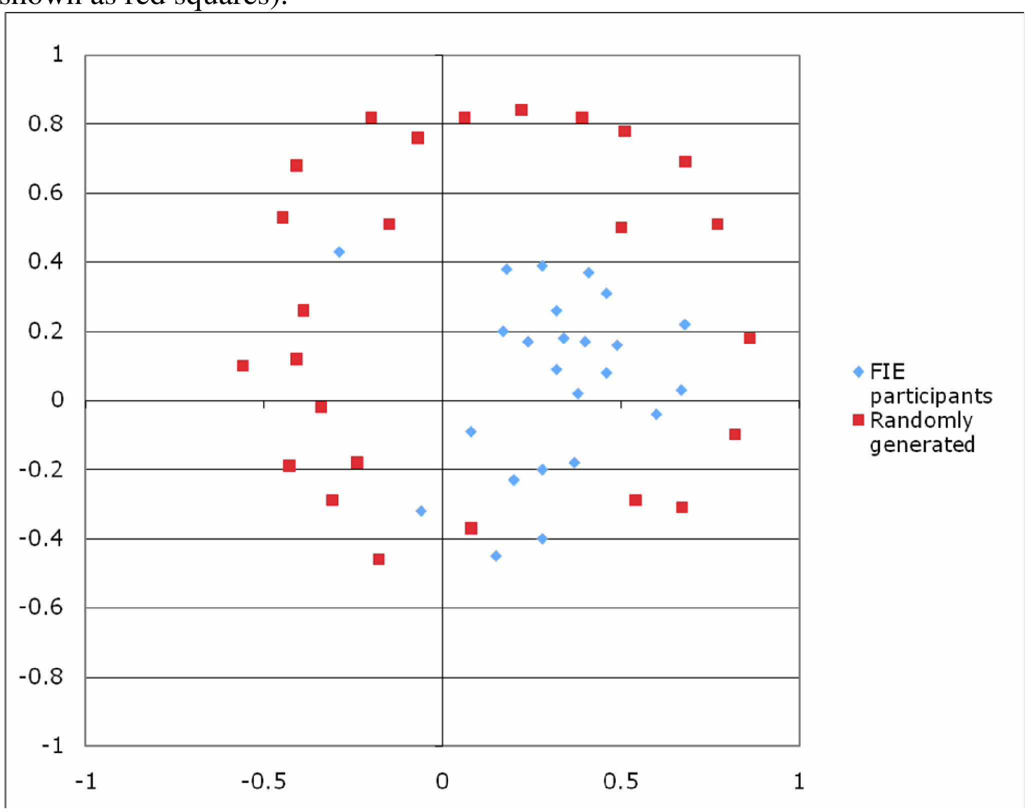


Figure 2 Visual representation of agreement of FIE sample (blue diamonds) and randomly generated sample (red squares.) Each dot represents one participant. The closer the dots, the more agreement exists between those respondents.

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[ii] Generated using the random number generator within *Excel 2003*.

As seen in Table 3, for our data, all three of the mathematical conditions for the consensus model are met for the FIE participants, so *Anthropac* states that the consensus model applies and we can claim that our sample of FIE participants constitutes a single cultural group according to the cultural consensus method. However, as expected, the randomly generated sample does not meet any of the criteria and can not be considered a cultural group. *Anthropac* produces the message seen in Table 3 for the Randomly Generated Data.

Table 3 Summary of Cultural Consensus Analysis Output
*Items in italics are criteria used in Anthropac to determine if a consensus model applies.*

| | **FIE Participants** | **Randomly Generated** |
|---|---|---|
| **Eigenvalue 1** | 9.874 | 2.550 |
| **Eigenvalue 2** | 2.281 | 2.155 |
| **Ratio of Eigenvalue 1 to Eigenvalue 2**<br>*Criteria 1: Ratio >3* | 4.329 | 1.183 |
| **Minimum agreement score**<br>*Criteria 2: All agreement scores positive* | 0.09 | -0.56 |
| **Maximum agreement score** | 0.89 | 0.72 |
| **Average agreement score**<br>*Criteria 3: Average > 0.5* | 0.611 | 0.043 |
| **Standard deviation of agreement scores** | 0.225 | 0.434 |
| **Consensus model applies?** | Yes | No<br>WARNING: your data are not well explained by a single factor. This condition violates the One Culture Assumption of the consensus model. |

Once we have established that the FIE participants are a cultural group, we can run further analyses using standard statistical techniques to examine the intracultural variation. For our data, we performed a regression analysis to examine the correlation between agreement scores and age as well as years of teaching college. As shown in Table 4, we found a statistically significant correlation for both of these factors. As expected, there is a very high correlation between age and years of teaching (0.938**). What is surprising is that the correlations were negative, implying that newer faculty are more likely to be in agreement. This may be related to the relatively more recent institutional changes brought about at many universities in the recent past supporting innovation in engineering curriculum and including, for example, programs sponsored by the NSF-funded Engineering Education Coalitions.

Table 4 Correlation of Agreement Score with Age and Number of Years Teaching College

| | | **Agreement Score** | **Age** | **Number of years teaching college** |
|---|---|---|---|---|
| **Agreement Score** | Pearson Correlation | 1 | -0.529(**) | -0.438(*) |
| | $R^2$ | | 0.280 | 0.192 |
| | Sig. (2-tailed) | | 0.009 | 0.032 |
| | N | 24 | 23 | 24 |

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Our findings indicate that a measurable amount of consensus exists among the engineering educators in our study. Their commonalities in beliefs about effective teaching support theorizing them as a cultural group according to this cultural consensus analysis method. Using the data produced for the consensus scores, we can examine which beliefs are most highly ranked. As seen in Table 5, as a group, they place the highest priority on "building a sense of community in the classroom", "inquiry/inductive learning", and "small group work in class". Interestingly, these answers represent innovative approaches, particularly for engineering education. What this implies is that their knowledge about effective teaching is context-driven especially since all respondents were sampled from the same education-related conference.

In general, a review of qualitative data produced from the interviews where participants explained their rationale for their ranking should follow cultural consensus analysis to triangulate the data. Qualitative interviews enliven free list and rank order data. Elsewhere, we provide a fuller consideration of what the top ranked items mean to the respondents.[28] Here we provide some quotes for the highest ranked item "building a sense of community in the classroom". Several respondents described the importance of building community as a "kind of umbrella that hangs over everything". They gave specific strategies used to achieve "community", including learning students' names (even in large classes), encouraging discussion and student questions, and having the physical environment (i.e. seating) conducive to building community. Building community was also seen as an effective practice for facilitating other items such as small group work or cooperative teams.

- *I can't imagine an effective classroom or an effective learning experience that somehow you haven't built some sort of sense of community. I don't know that you have to do that in a way that students are aware that's what you're doing, but I do think that that is always going to be a characteristic of effective experiences.*

- *You can't really get the students to work in groups and get anything out of it unless they feel like they are part of a community in the classroom. Because you can't say that you're in competition for grades but I want you to cooperate on this project. They're smarter than that. So they have to understand that it's a cooperative community and every one of them can succeed and not just a few of them.*

- *Again it's one of those things about them feeling welcomed or like they belong there or somebody cares about them so it's not directly related to what we're learning but I guess it really helps them to stay motivated and have more people that they feel comfortable talking to when they have problems either with content [or process].*

For some, discussions of "building community" triggered ideas of creating "cooperative" (vs. competitive) learning environments in which students felt "like they belong" and "comfortable". The theme of building community, and the four themes that follow in the rank ordering (see Table 5), are surprisingly ranked at the top, representing hands-on and interpersonal skills not typically associated with engineering education. It is important to note that there was not unanimity in the rankings. But the fact that the cultural consensus model does apply, as shown in Table 3, indicates that these top items are the ones that respondents preferred the most. We suggest that a possible explanation for these rankings is the context of FIE itself, which offers opportunities for faculty to explore innovations in education and which places a high value on "inclusivity" in the classroom.

Table 5 Consensus Rank Order of 25 "Effective teaching" items for FIE sample

| RANK | Teaching Practice |
|---|---|
| 1 | Building a sense of community in the classroom |
| 2 | Inquiry/inductive learning (driven by a question) |
| 3 | Small group work in class |
| 4 | Self-awareness of professor (make adjustments based on student feedback) |
| 5 | Making course material relevant to personal experiences; incorporating student voices; use of narratives/stories |
| 6 | Empowerment of students; student as equal partner in learning |
| 7 | Ask for student feedback ex: "what next?" Probe for understanding |
| 8 | Role of professor is guide, rather than expert; professor shares power with students |
| 9 | Emphasis on discussion and student voices |
| 10 | Use of examples relevant to students, Example: popular culture |
| 11 | Lecture w/transparencies |
| 12 | Attention to gender & use of inclusive language in examples |
| 13 | Allowing questioning of course content; critique of what is being learned in class |
| 14 | Student presentations; allowing students to occasionally teach the class |
| 15 | Use of space; consideration of seating arrangement in class |
| 16 | In class demonstration (physical or computer-based) |
| 17 | Community Service Learning |
| 18 | Use of multimedia (new technologies, films, music, Tablet PC excluding PowerPoint) |
| 19 | Students help shape the syllabus |
| 20 | Lectures & writing on blackboard/whiteboard |
| 21 | Guest speakers |
| 22 | Visit local industry; tour a facility |
| 23 | Electronic discussions (list-serve or internet-based course software ex. WebCT) |
| 24 | PowerPoint lectures |
| 25 | Linking relevant course material to broader socio-political/environmental issues "intersectionality" |

## 6. Conclusions: Implications

### Applicability of the Cultural Consensus Methodology in Engineering Education

The cultural consensus method has been used to measure the extent to which agreement exists in a variety of domains. The methods used in this analysis may be attractive and fruitful for researchers in engineering education who seek convenient modes of engaging human subjects. These methods make ethnographic research more accessible to researchers who are interested in rigorous research, but may not be extensively trained in qualitative methods. Other applications of this method that may be of relevance to engineering educators include: identifying common beliefs about students related to knowledge on a specific topic, the use of concept maps, measurement of misconceptions, and comparison of student responses with "expert" responses. Cultural consensus analysis provides a systematic and reliable research tool to collect and analyze data which may be particularly appealing to engineering educators.

### Significance of this Study

In this paper, we have examined intracultural variation among engineering educators. Our goal was to explain how members of a cultural group who share similar characteristics might agree/disagree about what is included in a cultural domain. We began with the premise that engineers are not all the same, and that while many researchers have suggested that an organizational "culture" might exist, it is dynamically shaped and differentially marked by variations in values, beliefs and practices. Thus, how do engineers organize their beliefs about teaching? Is there consensus about effective teaching beliefs or are beliefs about effective teaching idiosyncratic and random?

We found that a cultural model for effective teaching does exist among this population, indicating that knowledge about effective teaching beliefs is distributed, shared and represents one aspect of the culture among FIE attendees. The data show that these members of the engineering education community evaluate many elements about effective teaching in similar ways, as evidenced by the cultural consensus procedures and analyses. In addition, those elements ranked highest ("most effective") can be categorized broadly as facets of pedagogy emphasized at the FIE conference. We suggest the group's consensus is context-driven, and influenced by their mutual interest in pedagogy, evidenced by their attendance at FIE. One policy-relevant implication of this study suggests that if beliefs were random, the ability to have collaborative discussions regarding systematic pedagogical changes in engineering education would be weakened by an absence of a common discourse about what constitutes effective teaching.

Finally, while various researchers have suggested the idea of an "engineering culture," few of these discussions identify how beliefs about pedagogy are internally configured, created and shared. Many excellent studies have examined specific facets of teaching and its efficacy[31, 32, 33,34] yet more research needs to be conducted to understand how widely accepted these ideas are among a wider pool of engineering educators and how they may be implicated in contributing to discussions about reforming the culture of engineering. Certainly beliefs about effective teaching are important elements that affect the cultural production of engineers and the social process of the engineering education experience.

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## APPENDIX Instructions for Using *Anthropac* for Cultural Consensus Analysis

1. **Creating a Text File**

Our data was obtained by having different groups of people rank 25 items 1 through 25 with 1 being the best and 25 being the worst/agree with the least. We first saved our ordinal data in a text file.

2. **Importing a Data File**

The data file is imported into *Anthropac* using the *input/data/freelist* function. The output is known as the FLMAT and is a dataset containing a respondent-by-item matrix indicating which informant mentioned which item and in what order.

3. **Normalizing Matrix**

There are many different methods that can be used to normalize the matrix. The normalization criterion that we choose to use was Maximum which standardizes the rows, columns, or matrix to each have a maximum value of 100. This is achieved by dividing the matrix or each row or column by the current maximum and multiplying by 100.

4. **Using the Consensus Tool to Test the Cultural Consensus**

Given a respondent-by-item matrix representing answers to a series of questions on a given topic (in our case the rankings of the teaching techniques), the Consensus tool evaluates the agreement among the respondents, identifies the "culturally correct" answers to the questions and estimates the level of "shared knowledge" for each respondent. This tool also provides the eigenvalues of the analysis and states whether or not the consensus model applies.

5. **Metric MDS Scaling**

Metric MDS Scaling is a multidimensional scaling of a proximity matrix. For our data the proximity matrix that we will be using is the AGREE matrix that is generated using the Consensus tool. We choose to look at the similarities amongst the respondents. We used the Classic approach (which performs Gower's classical metric ordination procedure[35]) to generate the initial location of points in space. We choose this option because it produced the same graph each time. The output to this analysis is a LOG FILE which begins with a numerical display of coordinates of each point in space, which is followed by the MDS map. This is a scatter plot of the first dimension against the second.

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