2006-925: A SUCCESSFUL STUDENT-INITIATED ASSESSMENT METHOD FOR AN ENVIRONMENTAL ENGINEERING GRADUATE PROGRAM

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A Successful Student-Initiated Assessment Method for an Environmental Engineering Graduate Program

Abstract

Obstacles in assessing academic conditions can include generating interest in assessment efforts in order to achieve high response rates, transcending communication barriers, preserving confidentiality, minimizing biases from numerous sources, and conducting meaningful statistical analyses. A graduate environmental engineering program needed to overcome these obstacles to create a valid assessment tool. Previous program surveys did not amply address specific student concerns. Those surveys had poorly designed questions and answer formats. Survey distribution had relied on students to retrieve and return surveys themselves. Data analysis had consisted of only computing mean values and compiling comments. Results of the surveys had suffered from low response rates, biases, and demographic underrepresentation.

A graduate-student committee designed a survey considering the aforementioned problems. "The improvement of research quality" was the overall survey theme, and four subtopics -- research resources, research preparation, research views and attitudes, and research-group support -- were created to generate specific question ideas from the student population at-large. Questions were included in the survey based on importance, the actionable nature of obtained knowledge, and other criteria. Background and control questions were included for categorizing respondents. Sensitive natures of some questions were addressed to reduce biases. The format of the survey was tailored to make respondents comfortable and interested in participating. Question quality was examined through a pilot study and reviews by professionals. Answer formats were mainly closed-ended with most open-ended questions providing supplemental information. Hand-distribution and hand-collection were intended to make the survey tangible, appreciable, and accessible for respondents. Univariate analysis produced meaningful findings regarding individual variables, while bivariate/multivariate analysis determined correlations among multiple variables. Sensitivity analysis was also conducted to uncover potential biases in answering behavior for students who both were involved in survey design and responded to the survey.

We submit that our survey effort was successful overall due to high response, accurate demographic representation, positive student feedback, reduced biases, and significance of findings. 50 students (greater than 75% of the population) responded to the survey. Some of the salient findings indicate deficiencies in communication and statistics education, deficiencies in overall research preparation for first-year and master's students, an overall failing of a laboratory course to provide research-skill education, and a lack of guidance from research-group members for some students.

Our improved survey has led students and faculty members in the program to appreciate internal assessment and encourage the student committee to continue its efforts. The committee is beginning to solve problems discovered in this study and will be continuing to use the successful method in further assessment. Our method is believed to be applicable for engineering programs that must deal with common obstacles in making a sound assessment tool.

Introduction

Obstacles in assessing engineering academic conditions validly and specifically are common and are well-documented. Olds et al.[1] in a review of engineering education assessment approaches noted the efficiency of conducting surveys with respect to other assessment methods as well as the drawbacks of using surveys. Extrapolating from documented drawbacks, it can be concluded that obstacles in conducting surveys to assess academic conditions can include generating interest in assessment efforts in order to achieve high response rates, transcending communication barriers, preserving confidentiality, minimizing biases from numerous sources, and conducting meaningful statistical analyses. Thus, researchers are still seeking methods for optimal assessment of engineering populations.

Response is usually the most important measure in determining the ability of a survey to extend the findings from a sample to the population at-large. A high number of responses reduces sampling error and consequently increases confidence in sample results to represent the population. As demonstrated by the recent engineering education studies given in Table 1, response rates seem to be mostly low to moderate in survey studies, creating potential validity concerns. Some of these studies were able to have decent numbers of responses due to somewhat large populations. However, another major validity concern common to most of these types of studies is possible underrepresentation of demographic/characteristic groups due to the low response rates. There are also other validity concerns that are more specific to particular studies.

Table 1. Responses generated by some recent engineering education survey studies.

Author(s)	Response	Rate
Napp[2]	109	21.8%
St. Clair & Baker[3]	369	14.8%
Zydney et al.[4]	155	43.7%
Baker et al.[5]	45	40.9%
Brawner et al.[6]	586 (511 usable)	36.2%
Puerzer & Rooney[7]	96	46.2%
Collofello & Ng[8]	53	35.3%
Chen et al.[9]	360	22.9%

The jeopardy to the validity of an assessment study increases significantly when dealing with a smaller and more diverse population like the one of the environmental engineering (EnvE) graduate program at the center of this study. This program consists of approximately 60 to 65 on-campus graduate students on average, a small population compared to those of studies listed in Table 1. (An exact count of students at the time of study was unavailable due to inaccurate records, but the 60-to-65 range is of high confidence.) Students are either in the master's or the Ph.D. degree program; Ph.D. students outnumber master's students by a relatively large margin. Master's students are given the choice of pursuing a coursework, a special-research-project, or a thesis curriculum. Most on-campus master's students pursue a research-oriented curriculum. There is a fairly uniform distribution of tenure consisting of first-year, second-year, third-year, fourth-year, and fifth-plus-year students. There exists a variance in home country among students, but the majority of students originate from the United States, South Korea, or Turkey. This program also has students from varied backgrounds; student undergraduate majors include environmental engineering, chemical engineering, civil engineering, chemistry, biology, and

others. There are approximately 12 research groups performing very distinct types of research within the EnvE program. Students are closely bonded and experience conditions in question at times of internal assessment making the student population sensitive for study. Thus, if an assessment of this program generated a response rate in the neighborhood of the studies in Table 1 (e.g., 20%), then the response sample would be really low (e.g., 13 responses at best for 20%) and would make analysis virtually meaningless due to sampling errors, potential biases, and possible underrepresentation from the limited response. Such validity drawbacks had been experienced by the program in past survey assessment efforts.

Upon examining these past program surveys and the ensuing results, several key observations were made. Some of the critical observations follow:

Specificity. Surveys had not specifically addressed critical student or faculty concerns. There had been no consensuses among students or faculty regarding the general themes of the surveys or the specific ideas for questions related to those themes.

Question Design. Questions were not well-designed. For instance, questions had often been either too vague, having no singular ideas and providing little specific information, or too specific, expecting respondents to provide input on subjects that they could not recall entirely or were not qualified for providing input. Other questions were too leading, inviting particular, biased response behaviors.

Answer Formats. Answer formats were also not well-designed. Closed-ended questions had, for example, imbalanced scales or expected too much precision from respondents. Open-ended questions were on average used at an excessive frequency causing discomfort for non-native English speakers, ambiguity for respondents regarding manners to answer questions, increases in survey lengths, and inability to quantifiably analyze results.

Distribution. Distribution and collection of surveys were inconvenient and not motivational for students. Survey distribution consisted of either e-mailing a particular survey to the student body or requesting through e-mail or flyer advertisement that students go to a distribution point to retrieve the survey. Follow-up was minimal, and collection was done by requesting that students return completed surveys to a box at a collection point. Sometimes, the distribution-collection process had no timetable apparent to potential respondents. In addition, surveys had been conducted at times of high stress (e.g., final-exams week) or of high distraction (e.g., immediately before a holiday) for students causing them to forego taking the survey or to produce biased results under stress.

Analysis. Analysis of results was typically superficial and not well-founded on statistical principles. It consisted of only computing sample means from relatively small sample pools, compiling comments from open-ended questions, and drawing overarching conclusions about the program's academic conditions from the simple computations and compilations.

Results. Results from those past surveys indicate many validity problems. The most apparent problem was low response rates. For example, the survey conducted just prior to the one of this study produced only 24 respondents (about 35% of the on-campus EnvE student population at

the time) with many of those respondents not answering the majority of open-ended questions. Biases were apparent in the ratings of some program academic attributes that were extremely high in contrast to negative opinions expressed by students through non-survey means. Non-native English speakers, Ph.D. students, and students of longer tenure were significantly underrepresented.

Clearly from the problems experienced in studies like those listed in Table 1 and the drawbacks observed from previous surveys conducted within the EnvE graduate program, careful methods for design, distribution, and analysis of a survey were needed that would validly assess the specific conditions of the program. This paper details the methods through which we produced a successful survey for the program.

Survey Design

The design of our survey instrument is addressed below. Each of the design deficiencies from past program surveys noted above was specifically considered in the design process.

Specificity

In order to properly represent and investigate student concerns, an EnvE graduate-student committee was formed in a manner similar to that of the study of Baker et al.[5] to create an improved survey. Committee members were of varied countries of origin, degree programs, years of study, and research groups in order to represent the diversity of students.

To guide generation of specific questions, the overall topic of "improvement of research quality" was chosen for the survey, and four subtopics -- research resources, research preparation, research views and attitudes, and research-group support -- were created. Ideas for questions relevant to the four subtopics were collected by committee members from the EnvE student population at-large, increasing student interest in hopes of consequently increasing survey response. From the pool of submitted ideas, questions were chosen for inclusion by the committee with additional input from a faculty advisor according to the following guidelines:

- importance of knowledge to be obtained,
- ability to use results to take action or to make viable observations,
- presence of shared curiosities or concerns among students (implying that those curiosities or concerns could be present on larger scale),
- potential for respondent understanding of what information is wanted[10], and
- potential for respondent to have adequate knowledge or insight to answer[11].

These guidelines were at times in conflict with each other, so the relative importance of guidelines was determined on a case-by-case basis. After we selected particular questions, we developed a rough draft of the survey and improved that draft according to the other survey design considerations.

Question Design

Principles used to design the structures and mechanics of questions were found in the works of Dillman[10], Fowler[11], and Suskie[12]. The important question-design considerations are discussed below:

Background Questions. Respondents were categorized by survey questions (A1) through (A6) according to home country, home department at the university, current degree program, current year-of-study, undergraduate major, and graduate degrees already earned. (Survey questions are displayed in the final survey instrument given in the Appendix.) The need for background information was balanced with the need to protect the identities of respondents. If it was felt that identities could be determined indirectly from the demographic/characteristic information, some information was sacrificed.

Other background questions were needed for analyzing attribute assessments from the survey with respect to independent factors. For example, the location of the respondent's office space (independent factor) was requested by question (B3) so that the ratings of office-space qualities (attributes) in question (B6) could be associated with particular locations.

Control Questions. "Control" questions were asked so that the degrees of influence of certain factors on respondents would be determined. These questions primarily inquired about the participation in and/or frequency of performing particular activities. Examples of these control questions are (B1), the "yes/no" question regarding having office space, and (B5), the question about the frequency of using office space.

Sensitivity Concerns. With a relatively small population of closely bonded students, it was paramount in this study to maintain as much as possible a large, unbiased sample. We asked sensitive questions in the survey regarding personal achievements and quality levels of EnvE-related attributes. Past studies have noted tendencies for the respondent to answer questions in erroneous manners relative to what are actual conditions when the respondent is asked sensitive questions[11]. The following were some of the measures taken to persuade respondents to honestly answer sensitive questions and subsequently reduce biases:

- providing written assurance to the respondent that answers would remain confidential,
- not asking peculiar background questions that would easily reveal the identity of the respondent,
- not asking for indications of the respondent's advisor or research group (though the ability to categorize data according to advisor or research group was justifiably sacrificed), and
- where possible, not making apparent parallels among (sets of) sensitive questions with other (sets of) questions.

Even with the above measures in-place, there may have existed degrees of biases due to the lack of privacy felt by respondents by having a relatively small student population.

Unlike the study performed by Puerzer and Rooney[7], this study did not have the advantage of respondents with a normalized perspective as that of alumni. This study involved sensitive topics current to the respondent, so it was considered possible that the respondent might be more

biased without the advantage of reflective perspective. For instance, a respondent in the second year-of-study may have believed he/she was prepared for research, but that respondent would perhaps believe that he/she was not prepared at the second year given an alumnus perspective.

Committee members who created the survey also participated in taking the survey in order to preserve a healthy sample size. However, committee members may have had unique perspectives on some questions and more incentive to create change through the survey causing them to answer in potentially biased manners. Sensitivity analysis was performed comparing students on the committee with all other student respondents so that the possibilities of biases for committee members in answering sensitive questions could be ascertained.

Overall Survey Format. The physical layout and appearance of the survey are important to making the respondent comfortable and interested in taking the survey as noted by Napp[2] and Collofello and Ng[8]. Respondents tend to be more willing to participate in a survey when initially asked about easily assessable concepts[11], so survey questions were mostly ordered in concept from more concrete (e.g., office-space attributes) to more abstract (e.g., research-group attributes). Survey questions were also grouped into blocks so that the respondent took the survey in shorter, more manageable segments as recommended by Dillman[10]. Mixtures of question types and answer formats were implemented to reduce monotony per Suskie[12]. The professional appearance of the survey was scrutinized and a cover letter was drafted for a potential respondent is more likely to participate if the survey appears diligently crafted[13]. In addition, our goal was to have the average respondent complete the survey within 10 to 15 minutes; a longer survey may have lost the interest of the respondent.

Quality Assurance. Several precautionary measures were taken in order to ensure that questions were designed comparably to those of professional efforts:

- Methods and examples of past surveys were explored in scholarly literature cited previously.
- Professionals with educational survey experience gave critical feedback during the survey design process as in the study of St. Clair and Baker [3].
- A pilot study was conducted with EnvE students from different research groups and of different nationalities in order to assess the significance and the quality of survey questions from student viewpoints. Student pilot-group members had to be pulled from the potential survey sample pool unlike studies such as the one of Napp[2] that could afford to have pilot group members outside of the sample pool due to larger study populations. (Since the group members participated in the actual survey later, students from the group were included with the committee members when conducting sensitivity analysis.)

Answer Formats

Optimal answer formats were sought for each question. Closed-ended formats were used where possible to provide more quantifiable information than open-ended formats would have. Open-ended formats were only used where closed-ended formats could not capture entire domains of possible answers effectively or where closed-ended questions could be supplemented by qualitative answers. The answer formats used throughout the survey are discussed below:

Multiple Choice. Multiple-choice questions required the respondent to select a discrete category that was best-associated with the respondent. If there was a chance that answers provided did not encompass all desired responses, then an "other" option was provided.

Five-Point Temporal Scale. For questions that required the respondent to indicate frequency, the five-point temporal scale was used. Five points seemed to approximate entire temporal scales well while providing temporal points that were mutually exclusive of each other. With more than five points, the precision probably would not have been valid considering the respondent's limitations in approximating frequency noted by Dillman[10].

Five-Point Rating Scale. A five-point scale was also used for the rating of attributes. The rating scale was balanced in design with a midpoint either implying neutrality or not strongly rating positive or negative, as Dillman[10] prescribes. No agree-disagree questions were used for attribute rating due to ambiguity and confusion associated with the agree-disagree format[11].

Short Answer. The short-answer format was used for questions that required relatively simple answers that could not be constrained to limited numbers of choices. Most short-answer questions in this survey were intended for concrete concepts that had reduced ambiguity.

Extended Answer. The extended-answer format was used for questions providing only supplemental information but was used sparingly to minimize survey length.

Distribution

Our distribution method differed somewhat from those of the studies listed in Table 1 and of the past program surveys which employed distance between survey distributor and respondent. The survey was distributed on paper and personally to as many students as possible and was retrieved personally as well. We felt that this method would make the survey more tangible and appreciable; we hoped that people that typically would not have been motivated to respond would respond to this method, eliminating purely self-initialized response that limits respondents to only duty-oriented individuals or individuals who wish to use the survey to create change in their favor[14]. The survey was advertised by e-mail and made available at a distribution point in case any potential respondents were missed in the hand-delivery process. Several studies have established the foundational principles of our distribution method: Puerzer and Rooney[7] speculated on the increase in response caused by personal ties, and Chen[9] preserved accessibility for respondents by using a paper survey over an electronic survey.

One drawback that had to be considered with this distribution method was the perceived loss of privacy by having respondents return surveys to committee representatives. Respondents were allowed to submit completed surveys anonymously to a collection box in an effort to reduce potential biases.

Distribution occurred during the first week of February 2005 in order to have respondents complete the survey during a relatively relaxed time in a manner similar to that of the Baker et al.[5] study. Later in the semester, responses may have been fewer and more biased due to increased respondent stresses. As inferred from the work of Dillman[10], students were given

approximately one week in which to complete the survey, providing a sense of urgency for them to participate.

Analysis

This section describes the analysis steps taken with responses from the survey. As it can be seen, there was much potential analysis beyond the simple computations and compilations of the past program surveys. Analyses were conducted using Microsoft Excel and with the aid of the works of Alreck and Settle[15] and DeVore[16].

Univariate Analysis

Each part of each question was treated as an independent variable in univariate analysis (UVA). Results were analyzed in one of three ways depending upon the answer formats of particular questions. If answers for a given closed-ended question were to be interpreted in a discrete or categorical manner (e.g., degree programs), then UVA entailed simply breaking down the numbers and percentages of respondents who answered in certain ways. If answers were to be interpreted as parts of a numerical scale (e.g., satisfaction rating), then descriptive statistics were computed. With regard to open-ended questions, common comments were noted, but no formal quantitative analysis was performed.

The statistical measures and concepts utilized in UVA were sample mean, standard deviation, two-sided 95% confidence interval (CI), skewness, kurtosis, heavy-tail phenomena, histograms, and the central limit theorem. Sample mean, standard deviation, and CI gave descriptive information about the sample distribution assuming Gaussian-distribution behavior. Skewness, kurtosis, heavy-tail phenomena, and histograms gave metrics for checking the validity of the Gaussian-distribution behavior assumption. The central limit theorem was the means by which we assumed Gaussian-distribution behavior given an adequate sample size. This theorem implies that as sample size increases, the distribution of any population's sample means will tend toward Gaussian behavior. Thus, other Gaussian-based descriptive statistics have greater meaning with larger sample sizes.

Bivariate/Multivariate Analysis

In order to fully analyze each variable in the survey, the effects of other variables on a particular variable's responses were examined. Through bivariate/multivariate analysis (MVA), biases held by respondents due to background or control factors in answering given questions and correlations in response behavior among different variables were sought.

Variables for which UVA results obviously indicated that further analysis would yield no greater insight were excluded from the MVA stage. For example, almost all respondents rated highly research-topic satisfaction, addressed in question (H4), so there seemed to be no need to categorize or correlate these results with respect to independent variables.

The MVA tools used in this study were tabularization, *t*-tests, paired *t*-tests, single linear regression (SLR), and multiple linear regression (MLR).

The *t*-tests and the paired *t*-tests were performed with a significance level of 0.05, making the p-value of the statistical difference-indifference threshold 0.05. The *p*-value range of 0.01 to 0.1 is often taken as an inconclusive range, and caution was used in this study in making judgments when *p*-values fell into that range. A basic assumption when using *t*-tests is that the distributions being tested are approximately Gaussian. In this study, normal probability plots and visual inspections of histograms were used to verify Gaussian behavior. All *t*-tests in this study also assumed unequal variances. If we had been sure that distributions had equal variances, the analysis-of-variance (ANOVA) method would have utilized which would have been much more efficient.

In this study, specific regression model equations were not wanted. The correlation coefficient (r) for SLR or the multiple correlation coefficient (multiple R) for MLR was only needed in order to assess the degree of correlation of a given dependent variable to an independent variable or multiple independent variables.

Sensitivity Analysis

As mentioned previously, some respondents either took part in the creation of survey questions or participated in the pilot study creating the potential for biases when those respondents answered sensitive questions. To assess the potential for this type of bias, *t*-tests were performed on some sensitive questions in the survey with the attributes of questions as dependent variables and the presence/absence of involvement in survey design or the pilot study as the independent variable for all *t*-tests. Statistical differences in distributions of involved respondents versus uninvolved respondents were indicators of potential biases. The questions for which sensitivity analysis was conducted along with resulting indications of potential biases are given in Table 2.

Final Survey Instrument, Results, & Observations

We submit that our survey effort was successful overall due to high response, positive student feedback, accurate demographic/characteristic representation, reduced biases, and significance of findings. A small number of drawbacks also surfaced. The final survey instrument is detailed below accompanied by salient results and observations concerning the successes and drawbacks of the survey effort.

Final Survey Instrument

Our final survey instrument is provided in full in the Appendix. The first set of survey questions (Block A) was designed to categorize respondents into demographic/characteristic groups. The second set of questions was designed to assess student satisfaction with the resources they need to perform research. These questions were divided into three categories: office space (Block B), lab space (Block C), and computers (Block D). The third set of questions (Blocks E and F) was designed for student self-assessment of preparedness to perform EnvE research successfully. These questions examined how prepared students felt they were for research when they began the program, how well the program has prepared students for research, and how well a laboratory course has benefited student attainment of research-related skills. The fourth set of questions

(Blocks G and H) was designed to ascertain student views and attitudes toward research. The final set of questions (Block I) was designed to assess the quality of support from research-group relationships -- both between respondent and advisor and among respondent and research-group members.

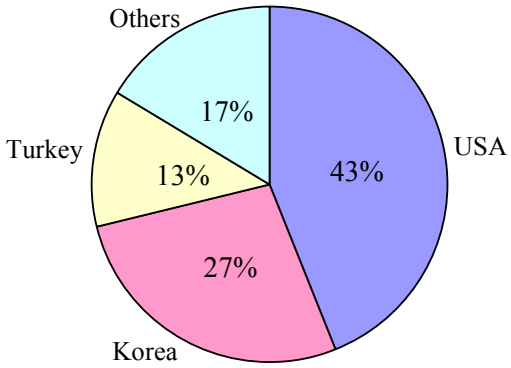
Survey Response & Respondent Feedback on Survey Effort

Fifty students completed and returned the survey. Respondents mainly utilized the hand-delivery and hand-collection methods, but three respondents did retrieve the survey from the distribution point, and eight respondents returned it to the box at the collection point. A total of 57 surveys were distributed by hand or from the distribution point. The seven surveys distributed but not returned were likely not returned due to forgetfulness or preoccupation as no committee representatives reported student discomfort in taking the survey. The response rate only considering the 57 distributed surveys is 87.7%, though we assumed that the entire population (60 to 65 students) had the opportunity to take the survey. Considering the entire population, we estimate that the true response rate was between 76.9 and 83.3%.

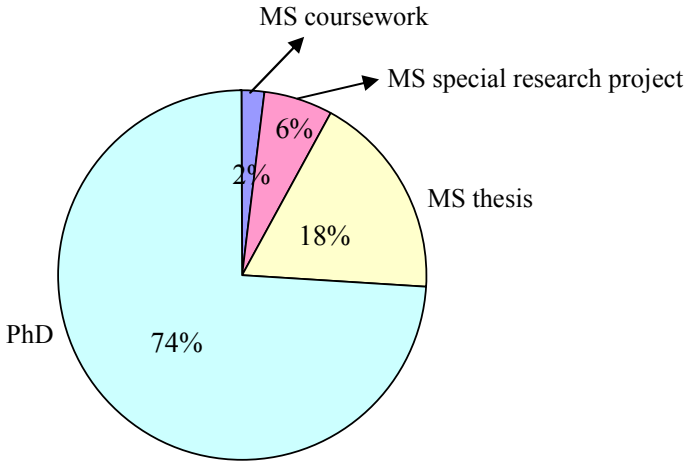
Two surveys looked hurriedly completed, but the potential noise in data created by these two surveys would be negligible. The possibly hurried responses may be a byproduct of our distribution method; the respondents may have wanted to please committee representatives by completing the survey but may not have given the survey ample time.

Overall, student feedback regarding the survey itself was very positive. During informal discussion sessions, students seemed excited that important issues were assessed. Students were also impressed with the professional nature and the meticulous design of the survey. The only major negative commentary consisted of slight discomfort of some respondents regarding sensitivity and anonymity, but there was not enough discomfort to compromise overall validity. It is difficult to isolate a particular factor we implemented or a particular combination of factors that led to the high response, though we speculate from student feedback that our personal distribution method and the time of distribution contributed most to the high response.

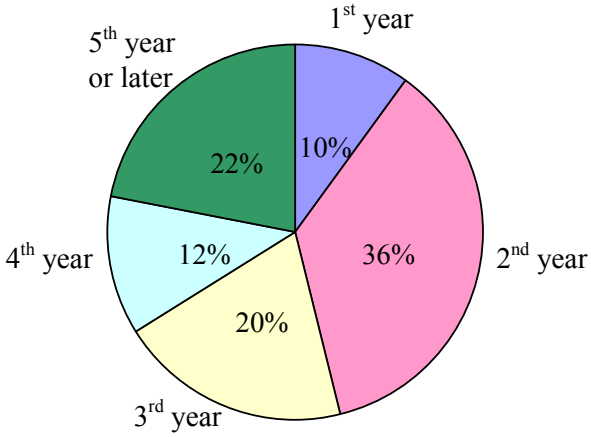
The sampled group was diverse both internationally and academically and mostly representative of the overall EnvE student population. Figure 1 summarizes the breakdown of the 50 respondents as obtained from questions in Block A according to nationality, degree program, year of study, and undergraduate degree.



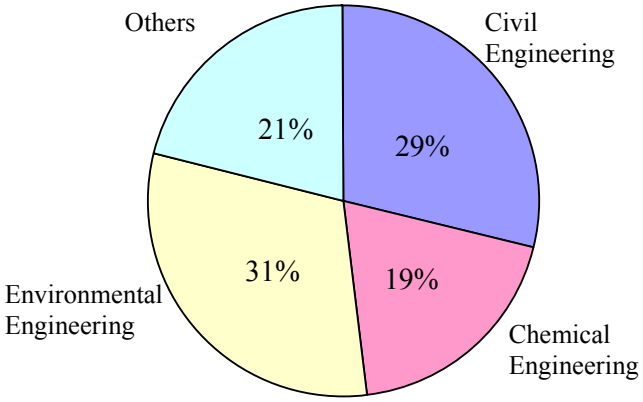
(a) Home country
(others: China, Taiwan, India, Bolivia , Jamaica)



(b) Current degree program



(c) Year-of-study



(d) Undergraduate major
(others: Ag. Engr., Chemistry, Earth Sci., Physics, Appl. Math)

Figure 1. Demographic/characteristic profile of the 50 survey respondents.

When compared to the previous program survey efforts, it is especially encouraging that there was a balanced distribution of years-of-study and that the major nationalities of the program were well-represented. Considering the response rate and the balanced demographic breakdown of respondents, survey results were assumed to be valid for the EnvE student population as a whole.

Evaluation of Survey Components

Demographic Questions. The questions in Block A provided useful information with the exception of (A6). Some respondents did not mention fields of study or degree type in

answering (A6). In future surveys, the domain of responses for (A6) will be incorporated into a closed-ended answer format.

Research Resources. Overall, questions in Blocks B and C provided conclusive data regarding office-space and lab-space conditions and produced no major validity concerns due probably to the concrete nature of the questions. Questions (B4) and (C3) were needed specifically at the time of this study since a major move of some research groups to another building had been conducted just prior to this study. A shorter time of occupancy in a new office space or a new lab space was thought to cause possible bias, though no significant bias surfaced in analysis. Question (B7) gave specific, overlapping comments useful as supplements to the answers of (B6).

To keep survey questions as concrete as possible, we decided to assess computer resource usage in Block D instead of opinions. Question (D3) asks for the most frequently visited computer lab/cluster of the respondent for we believed that one lab/cluster would be visited significantly more than others. However, we felt that all computer-related activities in question (D4) had been performed by students at varying degrees of frequency justifying the five-point temporal scale. There was danger that the respondent could indicate some lab/cluster usage for (D3) but could also answer "rarely" or "never" for all activities in (D4) which would be invalid; this type of response behavior, fortunately, did not occur. Questions (D5) and (D6) provided specific commentary. On the whole, it appears that Block D provided valid data for analysis.

Research Preparedness. Block E had abstract, sensitive questions with increased validity concerns. There were three different concepts addressed in the Block E questions -- experience (E1), preparedness (E3 and E4), and benefit (E5) -- for it would be difficult due to lack of hindsight perspective for a student to assess how prepared he/she was for research before beginning his/her graduate degree program and how prepared he/she was at the time of the study. Also, question (E2) appeared to confuse some respondents in the same manner that (A6) did, and some respondents showed that they did not entirely understand question (E3) by answering for years of study they had not yet completed. In addition, questions (E4) and (E5) gave skills that are listed as required competencies in EnvE; no "N/A" option was provided for any skill in those questions, though a few respondents chose not to answer for "conducting experiments" for their research involved computational modeling. Even with these validity concerns, valuable information was obtained from Block E.

Only the respondents who had taken the EnvE laboratory course (12 of 50 total respondents) answered the questions in Block F. The sample size of 12 respondents made it difficult to assume a Gaussian distribution by utilizing the central limit theorem, but there were such strong, negative consensuses among respondents regarding all five skills causing no need for Gaussian-distribution-based results.

Research Views and Attitudes. The questions in Blocks G and H appear to have provided valid data with respect to expected results. Results of the importance of research success criteria for students are consistent with expectations based on student idealism and priorities suggested by students. It is also not surprising that master's students in general cared less about the number of papers they published and where their papers are published considering that such achievements

typically are not as important to their career goals as they are to goals of Ph.D. students. Questions (H3) and (H6) produced specific, overlapping comments.

However, there were some potential validity issues associated with Blocks G and H. At least one student was confused by the term "methodology" in (G1). Several respondents selected multiple answers in (G2) suggesting that they were considering with equal weight multiple career options for after graduation. In future surveys, (G2) would need to direct the respondent to check all answers that apply. For Question (H4), the vast majority of respondents rated their satisfaction with their research topics very highly. This result may indicate potential bias or simply too trivial of a question.

Research-Group Support. The questions in Block I were the most sensitive of the survey and the most prone to bias. Responses for all research group attributes in (I1) were mostly at the high end of the scale, and the few comments given for (I2) and (I3) were mostly positive as well. Some students in informal discussion groups thought that the ratings of (I1) attributes were higher than expected based on their own personal experiences in the program. A factor possibly contributing to bias was the use of a "good-bad" five-point scale which could have invited more emotional responses than, for example, the more objective "satisfactory-unsatisfactory" scale would have.

Significant Findings

Research Resources. From the results of question (B6), it was concluded that some respondents were less than satisfied with temperature and storage in their offices. Storage concerns, though, seemed to be associated only with two of four possible buildings based on results from an MVA of conditions in (B6) versus buildings in (B2). Some respondents were less than satisfied with noise and temperature in the labs as seen from results of question (C5). In the case of lab spaces, though, MVA yielded no correlations of lab-space conditions to particular buildings.

The questions in Block D provided the following enlightening insights:

- Many students primarily have used their own computers to do their academic work.
- Printing appears to be the most frequent activity performed in computer labs/clusters.
- A particular computer lab stood out as the most frequently used.

Research Preparedness. Both UVA and MVA brought forward crucial findings regarding research preparedness (Block E). Some of the more important UVA findings follow:

- A significant number of students did not feel prepared to do research when they started the program based on prior experience ratings (E1) and initial skill levels (E3).
- The EnvE program has benefited students overall in the development of skills but has not been very beneficial with respect to certain skills. The lower-rated skills seem to be statistics, communicating in writing, and communicating orally.

The salient MVA findings follow:

- Paired *t*-tests indicated no significant increase in preparedness for individual respondents overall during the first year of study, but there were significant increases indicated for the second year and the third year. (Experience level before starting the current graduate program was assumed to be synonymous with initial preparedness.)

- Master's students overall rated program benefit lower than Ph.D. students did in five research-related skills. "Critically analyzing information and arguments," "communicating in writing," and "communicating orally" received especially concerning ratings from master's students.
- There were notable positive correlations:
    - The benefit to statistics and to analyzing and interpreting data from EnvE-program work may be directly related to initial skill levels of students in those competencies.
    - The benefit to communicating both in writing and orally may be directly related to the respondent's time in the program.

The deficiencies of the lab course with respect to all attributes of question (F2) were made apparent through strongly negative results.

Research Views and Attitudes. UVA provided specific and enlightening information on the abstract concepts of Blocks G and H:

- There were high numbers of respondents who indicated some concern with research progress and research methodology organization.
- There seemed to be much advisor involvement in research topic selection overall for students.
- Learning achieved and thesis progress seemed to be much more important to students than advisor approval and publishing-related criteria.
- Other research criteria of importance provided were professional development, practical application of research, and personal satisfaction in research endeavors.
- There was significant diversity indicated in goals after graduating from the program.

MVA was able to supplement the UVA well with the following findings:

- Master's students overall indicated less organization than Ph.D. students did in research methodology and less satisfaction with research project progress.
- Ph.D. students rated the publishing-related criteria as more important to themselves than master's students rated those criteria.
- Noteworthy correlations of variables:
    - Research-methodology organization was found to be weakly positively correlated to student-advisor communication (from Block I) and to guidance from advisor regarding research methodology.
    - Progress satisfaction displayed some positive correlation to research-methodology organization and significant correlation to student-advisor communication.

Research-Group Support. Though we believe the results to be somewhat biased, some concerns did surface from (I1). It seems that communication between students and advisors and communication between students and research-group members were lacking for some students. The overall guidance provided by other research-group members seemed to be the lowest-rated attribute.

Sensitivity Analysis

A sensitivity analysis determined if being involved in survey design or in pilot testing could have potentially caused bias. This sensitivity analysis was imperative for 15 of 50 respondents (30% of respondents) were involved in survey design or in pilot testing. Table 2 lists the sensitive questions tested for potential bias and gives the conclusion for each question.

Table 2. Sensitivity analysis results (PB = potential bias, + = strong potential).

Variable	Parts	Conclusion
(E1) previous research experience		
(E4) skill before starting program	conducting experiments	
	locating literature	
	learning from literature	
	critically analyzing information	
	analyze and interpreting data	PB
	statistics	PB+
	communicating in writing	
	communicating orally	
(E5) benefit of EnvE to skills	conducting experiments	
	locating literature	PB
	learning from literature	
	critically analyzing information	
	analyze and interpreting data	
	statistics	PB
	communicating in writing	
	communicating orally	
(G1) research methodology organization		
(H1) research progress satisfaction		PB
(H2) topic development contributions		
(H5) importance of research criteria	number of papers published	
	progress toward thesis	
	journals where papers published	
	learning achieved	
	advisor approval	PB
(I1) research group attributes	communication/advisor	
	guidance/advisor	
	guidance/group members	
	guidance/advisor/writing	
	guidance/advisor/research methodology	PB

If the *t*-test for a given question listed in Table 2 implied inconclusiveness or statistical difference between students involved in the survey process and students uninvolved, the potential for bias was assumed. The only occurrence of strong potential for bias (i.e., large statistical difference indicated by *t*-test) was with regard to the "statistics" attribute of question (E4). From sensitivity analysis results, we assumed that the results for students involved in the survey process mostly coincide with results for the student population at-large.

Method Summary

A valid assessment method was needed in order to address specific student concerns of our EnvE graduate program. This method had to overcome the well-known obstacles of low response rates, communication barriers, preserving confidentiality, biases, and conducting meaningful statistical analyses. Past surveys for assessment of our program had experienced those obstacles, creating problems with regard to specificity, question design, answer formats, distribution, and analysis and leading to invalid, unusable results.

To solve specificity issues, we formed a diverse committee of graduate students in the program, collected question ideas from the student population at-large relevant to a major topic and four specific subtopics, and selected questions for an improved survey using a set of inclusion criteria. Background and control questions were included for respondent categorization. Sensitivity concerns, overall survey format, and quality assurance were also considered in question design. Answers formats were primarily closed-ended for the purposes of quantifiable analysis, while open-ended formats were used mainly for gaining supplemental information. Hand-distribution and hand-collection of the paper survey were utilized to make the survey tangible, appreciable, and accessible. Distribution took place during a relatively relaxed time when stress would not limit or bias responses. Univariate and bivariate/multivariate analyses were used to produce meaningful findings regarding individual variables and correlations among multiple variables. Since students involved in survey design also responded to the survey, sensitivity analysis was conducted to uncover potential biases in answering behavior for those students.

Our survey effort yielded a high response of 50 students (greater than 75% of the population) with accurate demographic representation. Student feedback concerning the survey itself was largely positive. Involvement in survey design did not affect results significantly. We believe that biases were reduced greatly relative to past surveys for results were more congruent with true student opinions. The significance of findings regarding all four survey subtopics also demonstrated the success of the survey effort. Some of the salient findings indicate deficiencies in communication and statistics education, deficiencies in overall research preparation for first-year and master's students, an overall failing of a laboratory course to provide research-skill education, and a lack of guidance from research-group members for some students. The results of the survey and the evaluation of our survey method have convinced us that our survey was overall the valid, specific assessment needed for our particular EnvE graduate program. We believe that employing the method with some minor modifications would be beneficial for future studies as well.

Impacts & Applications

The impacts of our improved survey effort have been significant and encouraging. There is now more appreciation for internal survey assessment by both graduate students and faculty members in the program. Faculty members have encouraged the graduate-student committee to continue its assessment of academic conditions on a continuous basis. The committee has incorporated lessons learned from conducting this survey into an updated survey in order to track changes over time with regard to the concerns discovered in this study and to assess new issues of concern. Also, the committee has begun to organize discussion groups, workshops, and seminars

in order to help students address academic deficiencies in group settings. Faculty members even encouraged the committee to write a proposal for revamping the laboratory course after learning of the negative assessment of the course.

There are many potential benefits to be had by similar programs in applying or extending our assessment method. Of course, not every engineering program has the composition or characteristic factors of our program. For instance, there are even smaller programs for which our method would not be practical. Other programs may not have as many communication barriers that would limit open-ended responses to the extent of this study. Our distribution method may be too inefficient for some programs due to physical separation from respondents or to sample pool size. However, the assessment drawbacks addressed in this study probably exist to different degrees for all relatively small engineering programs, and we have submitted a method that appears to have mostly navigated those drawbacks and has led to characterization of and improvements to academic conditions. Further study is desired, though, to determine the applicability of our method to other programs.

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Appendix

Final Survey Instrument

Note: All questions from the survey are given below, but the survey has been altered in physical appearance for the sake of brevity.

****

GT-EnvE Student Feedback Survey

We first would like to ask you for some background information so that we can properly analyze the responses you give later in the survey.

(A1) What is your **home country**? _____

(A2) What is your **home department** at GT? _____

(A3) What is your **current degree program** at GT? ***(Check only one, please.)***
- □ Master's (coursework option)
- □ Master's (special research project option)
- □ Master's (thesis option)
- □ PhD

(A4) What is your current **year-of-study**?
□ 1st year □ 2nd year □ 3rd year □ 4th year □ 5th year or later

(A5) What was your **undergraduate major**? _____

(A6) Please list any **graduate degrees** ***(with field of study)*** that you already have ***(if none, write N/A)***:
Answers: _____, _____, _____

The following set of questions has been designed to assess the current conditions of the resources you have to perform research.

(B1) Do you have **office space** assigned to you in GT-EnvE? □ YES □ NO

If you answered **"NO"** in **(B1)**, please **skip** to question **(C1)** below.
If you answered **"YES"** in **(B1)**, please **answer** the following questions:

(B2) In which **building** is your **assigned office space** located?
□ ES&T □ Daniel Lab □ SEB □ Mason □ other_____

(B3) Which of the following **best describes** this **assigned office space**? ***(Choose only one answer.)***
□ shared office □ cubicle □ other_____

(B4) For about **how long have you had** this **office space** assigned to you? _____

(B5) Approximately **how often** do you use this **assigned office space**?
□ everyday □ a few days per week □ once per week □ once per month □ once per year

(B6) Rate your **satisfaction** with the following aspects of your **office space** (N/A = not applicable):

	Very Satisfied	**Satisfied**	**Neither Satisfied nor Unsatisfied**	**Unsatisfied**	**Very Unsatisfied**	**N/A**
Noise	□	□	□	□	□	□
Temperature	□	□	□	□	□	□
Storage	□	□	□	□	□	□
Location	□	□	□	□	□	□
Sharing Space with Officemates	□	□	□	□	□	□

(B7) Please provide any **other comments** you have regarding your **office space**:
Answer: _____

(C1) What type of **lab space** is assigned to you in GT-EnvE?
□ none □ experimental lab □ computational lab

If you answered **"none"** in **(C1)**, please **skip** to question **(D1)** below.
If you answered **"experimental lab"** or **"computational lab"** in **(C1)**, please **answer** the following questions:

(C2) In which **building** is your **assigned lab space** located?
□ ES&T □ Daniel Lab □ SEB □ Mason □ other_____

(C3) For about **how long have you had** this **lab space** assigned to you? _____

(C4) Approximately **how often** do you use this **assigned lab space**?
□ everyday □ a few days per week □ once per week □ once per month □ once per year

(C5) Rate your **satisfaction** with the following aspects of your **lab space** (N/A = not applicable):

	Very Satisfied	Satisfied	Neither Satisfied nor Unsatisfied	Unsatisfied	Very Unsatisfied	N/A
Noise	□	□	□	□	□	□
Temperature	□	□	□	□	□	□
Storage	□	□	□	□	□	□
Location	□	□	□	□	□	□
Sharing Space with Labmates	□	□	□	□	□	□

(C6) Please provide any **other comments** you have regarding your **lab space**:
Answer: _____

(D1) On which of the following do you do **most** of your **computer work (**for research or classes) at GT?
□ a computer that you own □ a computer supplied by GT used by you only □ a shared computer at GT

(D2) Approximately **how often** do you use a **computer lab** or **computer cluster** (outside of your assigned office/lab space) on the GT campus?
□ everyday □ a few days per week □ once per week □ once per month □ once per year

(D3) What is the **location** of the **computer lab** or **cluster** you **most frequently** visit?
□ ES&T 3rd Floor □ Daniel Lab □ SEB □ Mason □ GT Library
□ other _____

(D4) How much do you **perform** the following activities in the **computer lab** or **cluster**?

	Always	Often	Sometimes	Rarely	Never
homework	□	□	□	□	□
leisure activity	□	□	□	□	□
printing documents	□	□	□	□	□
research-related work	□	□	□	□	□
checking e-mail	□	□	□	□	□
group class projects or other group work	□	□	□	□	□

(D5) What is the **biggest problem** that you experience related to **computer hardware**….
in your **office/lab space**? _____
in the **computer lab or cluster**? _____

(D6) What is the **biggest problem** that you experience related to **computer software**….
in your **office/lab space**? _____
in the **computer lab or cluster**? _____

In the following questions, we need your input regarding how prepared you are to perform research.

(E1) How **experienced** were you in doing **research before you started** your graduate program at GT-EnvE?
□ very well-experienced □ well-experienced □ experienced
□ somewhat experienced □ not experienced

(E2) What **past activity** was **most beneficial** to your **research experience before starting** your graduate program at GT-EnvE?
Answer: _____

(E3) How **academically prepared** did you feel you were to **do research after**….

	Very Well-Prepared	Well-Prepared	Prepared	Somewhat Prepared	Not Prepared	N/A
1 year of study at GT-EnvE?	□	□	□	□	□	□
2 years of study at GT-EnvE?	□	□	□	□	□	□
3 years of study at GT-EnvE?	□	□	□	□	□	□

(E4) How **prepared** were you in the following skills **before starting** your graduate program at GT-EnvE?

	Very Well-Prepared	Well-Prepared	Prepared	Somewhat Prepared	Not Prepared
conducting experiments	□	□	□	□	□
locating technical literature	□	□	□	□	□
learning from literature you've read	□	□	□	□	□
critically analyzing information & arguments	□	□	□	□	□
analyzing & interpreting data	□	□	□	□	□
statistics	□	□	□	□	□
communicating in writing	□	□	□	□	□
communicating orally	□	□	□	□	□

(E5) How **beneficial** has your **graduate work** in **GT-EnvE** been in **preparing** you in the following skills?

	Very Beneficial	Mostly Beneficial	Beneficial	Somewhat Beneficial	Not Beneficial
conducting experiments	□	□	□	□	□
locating technical literature	□	□	□	□	□
learning from literature you've read	□	□	□	□	□
critically analyzing information & arguments	□	□	□	□	□
analyzing & interpreting data	□	□	□	□	□
statistics	□	□	□	□	□
communicating in writing	□	□	□	□	□
communicating orally	□	□	□	□	□

(F1) Have you taken the **EnvE laboratory course** (CEE 6319)? □ YES □ NO

If you answered **"NO"** in **(F1)**, please **skip** to question **(G1)** below.

(F2) If you answered **"YES"** in **(F1)**, how **beneficial** was the **EnvE laboratory course** in **developing** the following laboratory skills?

	Very Beneficial	Mostly Beneficial	Beneficial	Somewhat Beneficial	Not Beneficial
designing experiments	□	□	□	□	□
conducting experiments	□	□	□	□	□
analyzing & interpreting data	□	□	□	□	□
writing scientific reports	□	□	□	□	□
making oral presentations of findings	□	□	□	□	□

(G1) How well do you feel your **research methodology** is **organized**?
□ very organized □ mostly organized □ organized □ somewhat organized □ not organized

(G2) What is your plan **immediately after graduating** from your current GT-EnvE degree program?
□ continue your education □ post-doctoral research □ professorship
□ research at a government-sponsored institution (e.g., CDC, USGS) □ research at a private company
□ design/consulting work □ non-engineering/non-scientific work
□ other _____

In the following questions, we would like to know some of your views regarding your research.

(H1) How **satisfied** are you with your **progress** in your **research project**?
□ very satisfied □ satisfied □ neither satisfied nor unsatisfied □ unsatisfied □ very unsatisfied

(H2) Which of the following best describes the **amounts of contribution** from both **you** and **your advisor** in **selecting** your **research topic**?
□ all yours, none advisor's □ mostly yours, some advisor's □ yours and advisor's equal
□ mostly advisor's, some yours □ all advisor's, none yours

(H3) Please provide any **other comments** you have regarding the **selection** of your **research topic**:
Answer: _____
_____

(H4) How **satisfied** are you with your **research topic**?
□ very satisfied □ satisfied □ neither satisfied nor unsatisfied □ unsatisfied □ very unsatisfied

(H5) How **important** do you feel that the following **criteria** are in research?

	Very Important	**Mostly Important**	**Important**	**Somewhat Important**	**Not Important**
number of papers published	□	□	□	□	□
progress toward thesis/project completion	□	□	□	□	□
particular journals where your papers are published	□	□	□	□	□
learning achieved	□	□	□	□	□
advisor approval	□	□	□	□	□

(H6) Are there any **other criteria** not listed in **(H5)** that you feel are **important** in your research?

Answer(s): _____

_____

We would like you to provide us with some input regarding various aspects of your research group.

(I1) How would you **rate** the….

	Very Good	**Good**	**Neither Good nor Bad**	**Bad**	**Very Bad**
communication between you and your **advisor(s)**?	□	□	□	□	□
communication between you and your **research group members**?	□	□	□	□	□
personal respect between you and your **advisor(s)**?	□	□	□	□	□
personal respect between you and your **research group members**?	□	□	□	□	□
overall **guidance** provided by your **advisor(s)**?	□	□	□	□	□
overall **guidance** provided by other **research group members**?	□	□	□	□	□
understanding of **what is expected** of you by your **advisor(s)** in your work?	□	□	□	□	□
helpfulness of commentary about your work from your **advisor(s)**?	□	□	□	□	□
guidance from your **advisor(s)** regarding **writing** and **making arguments**?	□	□	□	□	□
guidance from your **advisor(s)** regarding your **research methodology**?	□	□	□	□	□

(I2) Please provide any **other comments** you have regarding your **advisor**:

Answer: _____

_____

(I3) Please provide any **other comments** you have regarding your **research group**:

Answer: _____

_____