

ASSESSING ATTITUDINAL CHANGE IN AN ENGINEERING TEACHER PROFESSIONAL DEVELOPMENT PROGRAM

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Abstract-WISE Investments (WI) is a three-year National Science Foundation (NSF) project designed to encourage young women in middle school, high school, and community college to pursue engineering and related careers. A major component of this grant are two, two-week summer workshops that introduce middle, high school, and community college teachers and guidance counselors to engineering. These educators are then charged with integrating what they learned in the workshops into their classrooms in a way that attracts young women. This has the effect of introducing students as young as 12 years old to engineering as a career option.

The educators were surveyed before and after the workshop to evaluate their change of perception in engineering through a pre-/post- questionnaire. Part One of the questionnaire was qualitative. It consisted of questions that measured the participants' perception of engineering in general and engineering disciplines in particular. To further evaluate any attitude changes, the final perceptions of the educators were evaluated relative to the intent of the engineering faculty who conducted the training labs in their engineering disciplines. Therefore, it was essential to determine the faculty's definition of engineering (including their specialty) and to compare it to the teachers' perception. Through individual interviews the faculty were asked to provide definitions and key words to describe their specialty. In addition, they were asked to state their objectives and observations of any of the participants' attitudinal changes relative to their lab. The engineering faculty also provided suggestions on program development and ideas for related pre-/post assessment.

An analysis of the data revealed a unique relationship between faculty interviews and teacher responses. The structure, objectives, and goals of the workshop will be discussed. Examples of the pre-/post-questionnaire and assessment outcomes will be given. The final analysis will also demonstrate how faculty input was used to determine whether WISE Investments' goals and objectives were met.

Index Terms---Assessment, Attitudinal Change, Engineering Perceptions, Teacher Professional Development.

INTRODUCTION

The Science and Engineering Equal Opportunities Act states that it is the policy of the United States to equally encourage men and women to obtain skills in science, mathematics, and engineering. The act was passed to promote equal opportunity in education, training, and employment in

scientific and engineering fields. Its goal is to improve scientific and engineering literacy and the full use of human resources [1]. The problem of under representation emerges from the data provided by the National Science Foundation on graduates as well as employment levels and trends. Women constituted 51% of the U.S. population and 46 percent of the labor force in all occupations, but only 22% of the science and engineering labor force [2]. Women earned 20.6% of all bachelor's degrees, 21.1% of all master's degrees and only 15.8% of doctorates from U.S. engineering schools in the 1999-2000 academic year [3]. Women make up 3% of the faculty in engineering [4] and 8.6% of the working engineers [2]. Lower salaries, higher unemployment rates and limited opportunities to advance are proportionately higher for women and minorities in engineering, computer science, and the physical sciences. In 1995, under represented minorities were 23% of the United States population and only 6% of the science and engineering labor force [2].

Part of the task for creating a diverse community in science and engineering includes professors and K-12 educators. Higher education can make a difference by opening doors for recruitment and providing academic support for retention. Two-year institutions are also important for providing access to higher education for traditionally under represented groups. They enroll almost half of the students entering higher education as first-year students and more than fifty percent of students from under represented student groups [1]. Community colleges attract more minority (particularly Hispanic) and low-to-moderate income students, veterans, and those students with lower grade point averages and SAT scores [2].

Advances science and mathematics courses are basic for college preparation. However, girls and minorities begin to lose interest in science and mathematics during elementary and secondary school. Higher levels of science proficiency indicated a gap between girls and boys at age 13. This gap becomes larger at age 17. Higher percentages of females than males reported having been advised not to take senior mathematics (34% female, 26% male) or science (32% female, 26% male). There was also a sizeable difference in the number of students who had taken eight or more semesters of mathematics in high school. The largest difference in science courses appeared in physics. Sixty-four percent of Asians took physics compared to 45% of whites, 43% of Latin Americans and less than forty percent of other groups [1]. Career expectations indicated that only six percent of public high school seniors reported pursuing a career in science, mathematics, or engineering. Male

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students were more than three times as likely to choose a career in these fields.

WISE Investments (WI) is committed to the professional development of pre-college educators in engineering and issues related to under representation. This paper will provide a program description along with examples of activities used in the workshops facilitated by the ASU engineering faculty. Qualitative and quantitative data will be used to discuss assessment outcomes in meeting the goals and objectives of the engineering workshops.

PROGRAM DESCRIPTION

Participants in the WI program were exposed to eight fields of engineering that included chemical, biomedical, civil/environmental, computer science/systems, electrical, industrial, materials, and aerospace engineering. The goal of the workshop was to encourage and assist middle school, high school, and community college faculty to integrate engineering into existing math and science curricula through hands-on labs. The transference allows pre-college students to experience real world applications to solve problems involving people and the environment. Guidance counselors are responsible for incorporating engineering information in their career counseling and implementing outreach programs to encourage students to enroll in advanced math and science courses to pursue careers in engineering and related careers.

The following list includes examples of activities used in the engineering labs:

- Chemical engineering created personal care products based on the properties of specific chemicals.
- Biomedical engineering examined how the angle of the knee changes the force placed on the knee joint.
- Computer Science engineering modified an existing program to change the direction, gait, and speed of a robot.
- Industrial engineering modified the parameters of a catapult to identify the best design for distance control.
- Civil engineering used the geotechnical lab to perform sieve analysis, plasticity, liquefaction, dilatancy experiments.
- Electrical engineering predicted outputs of circuit design and built circuits to test the predictions.

During the workshops engineering career information was given in each of the labs as well as through industry tours and a series of keynote speakers from engineering related industry partners. Participants are also given an opportunity to complete an industry internship with one the industry partners. The internship enhances the educators' understanding of the role of an engineer with experience in job related applications. In addition, teachers received training on issues related to gender in the classroom and the use of email and the internet to explore resources relevant to

engineering and education. In the second week of the workshops, teachers worked in teams to brainstorm and plan engineering applications for their classrooms. Engineering faculty served as consultants during this development process. Each team of teachers presented their engineering applications to the cohort. The presentations facilitated supplementary knowledge and support for integrating engineering into math and science curricula.

Saturday Academies were designed to give the middle school and high school teachers additional experience using engineering applications. The teachers were divided into teams and assigned a particular engineering discipline. The teacher teams were responsible for planning and implementing hands-on engineering activities for girls enrolled in middle school and high school at a Saturday Academy held once each month during the school year. The teams worked with the engineering faculty during the two-week workshop to design activities that encouraged the students to participate more in math and science while enhancing their understanding and exposure to engineering and related careers. In addition, the engineering faculty continued to be available throughout the school year to provide support and assistance during the Saturday Academies and for classroom applications.

Before the orientation to the workshops, pre-college educators were given an open-ended questionnaire to assess their perception of engineering and other workshop topics. The participants were administered the same instrument to measure the effectiveness of the treatment. Below is a description of the questionnaire and the participant outcomes.

THE QUESTIONNAIRE

Forty-four educators participated in the questionnaire used to engage their perceptions of engineering. Thirty-two percent were community college faculty, nine percent were middle school and high school counselors, and fifty-nine percent were middle school and high school teachers. Each group of participants was asked to write their reactions to the items on the questionnaire. The questionnaire is included below in Figure 1. The encouragement to respond was prompted by *not looking for any "right" answer*.

Please complete the following sentences:

1-Engineering is: _____

2-Bioengineering is: _____

3-Chemical engineering is: _____

4-Materials engineering is: _____

5-Industrial engineering is: _____

6-Computer science is: _____

7-Electrical engineering is:	_____
8-Mechanical engineering is:	_____
9-Aerospace engineering is:	_____
10-Civil engineering is:	_____
11-Environmental engineering is:	_____

FIGURE 1. PRE- AND POST-QUESTIONNAIRE FOR TEACHERS AND COUNSELORS

THE RESEARCH PROBLEM

Evaluating the response to the questionnaire was on onerous effort. The instructions indicated "reactions" to the items based on the participants' perception of engineering and other workshop topics. There were no "right" answers. A scoring rubric had not been developed before the administration of the test.

In order to assess attitudinal changes in the educators' perception of engineering, interviews were conducted with the engineering faculty members responsible for the labs to create a framework for the assessment. It was important to determine the faculty's definition of engineering to compare with the responses from the teachers. Furthermore, the faculty was asked to provide feedback on their observations of participants during the workshop and suggestions for program development and ideas for related pre-/post-assessments. A standard questionnaire of eight items was used during the faculty interviews to provide an overview of the two, two-week workshops. The questionnaire is given below in Figure 2.

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| <ol style="list-style-type: none"> 1. How do you define engineering? 2. How do you define your specialty? 3. What are key words that would symbolize an adequate description of your specialty? 4. What were the objectives of our lab/workshop? 5. Describe the attitudinal changes, interest, understanding, and enthusiasm of the participants, 6. Did you design your workshop with the coordinator from the WISE Investments program? 7. Could you recommend items for an adequate pre- and post-assessment? 8. Other suggestions and comments? 9. Examples of handouts included: |
|---|

FIGURE 2. FACULTY INTERVIEW QUESTIONS

Since defining engineering was the key questions for the teachers, the faculty provided one-sentence answers that were critical to evaluating the teacher responses. Some examples of the faculty definitions are: Problem solving using technical science and math; A discipline that requires applying tools of basic math and engineering to solve problems in a way to meet the needs and benefits of society;

Finding ways to fix things that are designed to solve practical problems.

Identifying key words in the definition of engineering and the faculty members' engineering disciplines proved to be helpful in further assessing the teachers' responses. More importantly, having the faculty state the objectives of the labs led to further understanding of the teachers' definitions of an engineering discipline. Figure 3 shows the responses from two faculty members to questions 2-4.

Aerospace Engineering:

Definition: Problem solving related to vehicles in air and space. Examples: Knowledge transfer (i.e., automobiles directly related to software development and alternative energies, such as windmills control systems).

Key Words: Aircraft, spacecraft, aerodynamics, orbital mechanics

Objectives: To understand propulsion systems, basic aerodynamics and stability. Community College faculty was provided information on ASU's program. They took data into the control system to test materials developed in the lab.

Chemical Engineering:

Definition: The subdiscipline of engineering concerned with solutions, chemical reactions, and chemical process. Chemistry, physics, and math are used to operationally design materials through chemical reactions. Materials are converted rather than information.

Key Words: Chemical, processing, converting, changing, or transforming the initial product.

Objectives: Assist participants in learning the breadth of chemical engineering and the multitude of fields to work in. Introduced demographics, gender diversity, and salaries. Demonstrate how fundamental chemical information and processing used in the field could integrate technical and non-technical information using safe materials. Cosmetics and hair care products were used to provide a female friendly environment. Contextual issues helped to make connections with global concerns.

FIGURE 3. SAMPLE OF FACULTY RESPONSES TO QUESTIONS 2-4 ON THE FACULTY QUESTIONNAIRE

The faculty's observations of attitudinal changes, understanding, and interest of the participants during the labs also determined whether the program goals and objectives were being met. Most of the participants enrolled in the workshops had little or no prior experience in engineering. Based on the faculty's observations, it was apparent that the participants' perceptions of engineering increased throughout the workshop. Most of the faculty remarked that the participants were enthusiastic about different aspects of the workshop. In addition, most of the teachers appeared fairly committed to the program and groups were competitive and excited about building models and being able to implement the workshop labs in their classrooms using a low budget.

Moreover, the teachers completed the workshops with an increased knowledge of engineering and the confidence to integrate what they learned into their classroom curricula in a gender-inclusive manner.

Given the qualitative nature of the questionnaire and the difficult task of scoring the responses to the questions, the faculty were asked to make recommendations for an adequate pre-/post-assessment. Examples of recommendations are below:

- Use web surveys with a Likert scale to address levels of competence.
- Attend each of the labs and design a related assessment.
- Each lab should provide a quantitative assessment that allows for success in the classroom.
- Frame questions so they match the learning process.
- Map outcome to activities
- Have teachers identify industries with specialties; tools needed for engineering; and job opportunity.
- Design experience and learning around objectives.
- Consider private consultation.
- Distinguish between an assessment for learning and an assessment for attitude.

In addition to providing recommendations for a pre-/post-assessment, the faculty was also asked to make suggestions and comments regarding program development and improvement. Their suggestions were:

- Request teachers to mail in a copy of their classroom projects.
- Organize a personal follow-up with a small class of enthusiastic teachers.
- Provide an interactive website. Expand the use of the web for those people who cannot travel to campus. Enroll teachers through the web and coordinate activities with an industry in the area. Try to exhaust the metro area.
- Prepare instructional templates for participants.
- Follow-up on attendance to the labs.
- Complete a longitudinal study to assess the number of students enrolling in engineering.
- Target parents and offer information to influence their children.
- Identify an approach that is most effective for learning.
- Use action words in presentations.
- Identify teacher effectiveness.
- Identify those items that may need to be expanded or emphasized within the constraints of the program.

PARTICIPANT OUTCOMES

As a result of the faculty interviews the assessment of the participant responses to the questionnaire became less arduous. The outcomes were reviewed in three groups: 1) community college faculty, 2) middle school and high school counselors, and 3) middle school and high school teachers. One point was given for an adequate response to any of the twelve items. Partial credit was given for some degree of accuracy (i.e., using key words). Rating estimates were used, instead of scores, to judge the participants' level of competence. Below are examples of the responses from the participant. Group scores and the results from the hypothesis tests follow the examples.

Sample responses:

1. Engineering is:

Pre-Test	Post-Test
The application of math and science in the creation (research and development) and maintenance of useful objects for the use of humanity (electronics, structures, airplanes, etc.)	Scientist who work in teams to solve problems (research and design/redesign and improve products). They manage others and communicate ideas.

2. Bioengineering is:

Pre-Test	Post-Test
Concepts of biology and math to better understand the world.	Design and problem solving of products mainly in medical applications to better our life (heart, dialysis, wheelchairs, etc).

3. Chemical engineering is:

Pre-Test	Post-Test
Utilization of science and technology in the areas of petroleum, plastics, and other areas to solve our society's challenging problems	The science of engineering concepts to help solve mankind's problems with chemical implications. Develops new compounds, mixtures, etc. to help mankind live.

StatGraphics was the software program used for the statistical analysis given in Table 1. A hypothesis testing procedure was used to examine significant differences between two data samples where the data were collected in pairs. A paired t-test of the null hypothesis determined whether the mean of the pre-test and the post-test was equal to 0.0 versus the alternative hypothesis that the mean of the pre-test and the post-test was not equal to 0.0. If the P-value for the group test was less than 0.05, the null hypothesis was

rejected at the 95% confidence level. Below are the raw estimates and the statistical analysis of the data for each of the groups.

TABLE 1. QUESTIONNAIRE
RESULTS OF PRE-AND POST-QUESTIONNAIRE ON ENGINEERING PERCEPTIONS BY TEACHERS AND COUNSELORS

Participants	Community College (11) Items		Counselors (12) Items		Teachers (12) Items	
	Pre	Post	Pre	Post	Pre	Post
Tests	9	9.5	6.25	9.5	12	9.75
	9	10.75	2	10	10.75	11.5
	2.5	9.75	8.5	12	0.25	8.25
	9.5	8	5.25	9.25	10	12
	11	10			7.25	12
	5.5	10.75			12	11.5
	5	8			1.75	9.5
	8.25	10.75			5.25	8.5
	9.75	10.75			6.25	9.75
	9.25	9.25			9.25	7.75
	2	9.5			7.25	9.75
	5.25	9			10.25	8.75
	10.5	11			4.25	9.5
	4.25	9.75			8.25	10.5
					9.25	11.5
					6.75	9.5
					8	11.25
					6	9.75
					5.75	8.75
					5.75	10.75
					2.25	9.75
					3	7.75
					2.25	8.75
P-Value	0.00585937		0.0245764		0.0000272	
Hypothesis	Reject the Null		Reject the Null		Reject the Null	

Each group demonstrated that their knowledge of engineering had improved at the P-level of .025 or less.

CONCLUSION

The interviews with the engineering faculty were an essential component for assessing the quality of the participant responses. In addition, the collaboration stimulated support for a continuous dialogue toward program development and improvement. Using the pre-/post-questionnaire more than 80% of the participants showed improvement. Approximately 8% demonstrated exceptional outcomes. The results from the tests suggested an overall positive relationship (or response) to treatment. The rubric developed for evaluating the understanding

gained by the participants in the workshop will facilitate the assessment aspect of the program. However, considerable attention should be given to the tool used to measure the effectiveness of the lab experience and the activities planned for classroom use.

In the future, both before and after the workshop, the faculty will be surveyed for their definitions of engineering and their specialty. It is expected that by asking the faculty to clarify their definitions before the workshop, they will be more focused in the presentations of their material during the labs. In addition, classroom observations and other follow-up activities would confirm the outcomes that sustain the long-term benefits of the program. WISE Investments will continue to research teacher needs and program effectiveness for future development and improvements to the program.

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