AC 2011-266: INVESTIGATING INFLUENCES OF THE MESA PROGRAM UPON UNDERREPRESENTED STUDENTS

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Investigating Influences of the MESA Program upon Underrepresented Students

The Mathematics, Engineering, Science Achievement (MESA) program supports educationally disadvantaged students and minority students in middle schools and high schools by providing pathways to help them succeed in science, mathematics and engineering.[1] MESA goals are to "1) increase the number of engineers, scientists, mathematicians, and related professionals at technical and management levels, and 2) serve as a driving force in encouraging minorities and females in achieving success in these fields."[2] MESA programs are based on a common co-curricular academic enrichment model that includes "academic planning, community service, family involvement, academic enrichment, hands-on engineering activities, career advising, field trips, competitions and workshops."[3] MESA programs represent an innovative way of linking a co-curricular learning environment to mathematics, engineering and science programs within the formal public school setting to enhance STEM education of students.

The first MESA program was founded in 1970 at Oakland Technical High School in Oakland, CA with a membership of 25 students. MESA's aim was to develop academic and leadership skills, raise educational expectations, and instill confidence in California students from groups that were historically underrepresented in engineering, physical science, or other math-based fields, with the aim of increasing the numbers who enroll in and graduate from a four-year university. The MESA effort was supported by the California Public School System, the state Community College System, and the California College System. "There may be other established programs, or programs under development, designed to increase Latino academic achievement in mathematics and science, but none has the longevity, organizational structure, network and academic rigor as does MESA."[4]

Over the past forty years, the California MESA effort has become a model for MESA-USA, a partnership that now involves MESA programs from eight states that are joined together to support disadvantaged and underrepresented students to improve their academic achievement in math, science and engineering. MESA-USA members are active in Arizona, California, Colorado, Maryland, New Mexico, Oregon, Utah and Washington. Additional information about the history and status of MESA are available on the Mathematics, Engineering, Science Achievement web site, http://mesa.ucop.edu/about/history.html.

Purpose

In order to identify the impact of specific features of K-12 engineering programs that appeal to underrepresented groups, researchers at the National Center for Engineering and Technology Education (NCETE) have endeavored to develop an instrument specifically designed to assess key outcomes. The approach to the development of a survey instrument to determine the impact of specific elements of the MESA program was built upon the Tierney, Corwin, and Colyar[5] framework for the evaluation of MESA. The purpose of the NCETE survey instrument development effort was to prepare and validate essential items needed to identify MESA activities that influence students' engineering self-efficacy, interest in engineering, and perceptions of engineering.

Theoretical Framework

Instrument development was guided by Social Cognitive Theory (SCT), which holds that knowledge acquisition is directly related to observing others within their context of social interactions, experiences, and outside media influences.[6] It proposes a relationship between outcome expectations and other behavior factors such as self-efficacy and interest. SCT is based upon the assumption that human ability is a dynamic attribute, and that competence in complex tasks requires both well-developed skills and a strong sense of efficacy to deploy one's resources effectively. Social Cognitive Career Theory (SCCT) provides a base for exploring the interaction among personal, environmental, and behavioral influences in career development.[7] SCCT emphasizes the role of self-efficacy, beliefs, outcome expectation and goals in career selection.

The instrument was designed to measure three constructs related to engineering: self-efficacy, interest, and perceptions. Self-efficacy refers to the composite beliefs about one's ability to execute successfully a given task or behavior in order to attain designated performances.[8, 9] Research has provided evidence that the lack of participation of minorities in STEM careers is due in part to low self-efficacy in science and mathematics. In a study that looked at successful men and women in STEM careers it was shown that participant's self-efficacy was a powerful contributor not only to the decision to pursue science and mathematics based careers, but it also was a major predictor of success in these areas.[10]

Interest is closely related to the development of understanding[11] and self-efficacy.[12, 13] If one seeks to account for the low numbers of underrepresented students in STEM careers, one need only look at the recent trend of tracking and the placement of minority students in lower academic tracks which has negatively impacted student interest in the sciences.[14]

Positive student perceptions about engineering greatly influence the likelihood that the students will pursue preparation in the field and enter the occupation.[15] Improving students' perception of the engineering field was a strong focus of the National Academy of Engineering study, *Changing the Conversation: Messages for Improving Public Understanding of Engineering*.[16] Students' interest in a field and their beliefs in their ability to perform tasks associated with that field are greatly impacted by the students' perception of that particular field.[17]

Methods

The developmental work that is reported here was built upon prior work by two of the investigators who developed surveys and analyzed results of qualitative and quantitative research efforts.[18-21]

Survey Development

The survey instrument was developed by modifying and building upon instruments used in prior studies. In almost every instance, it was necessary to modify questions so that they related specifically to the engineering focus of the instrument.

The subscale measuring students' self-efficacy was grounded in the work of Bandura, especially his “Guide for Constructing Self-Efficacy Scales” and his *Self-Efficacy Beliefs of Adolescents.*[22] The self-efficacy sub-scale related to motivational beliefs developed by Pintrich and De Groot[23] was modified for this study. Although the original items focused on courses in general, the researchers modified the questions to relate specifically to engineering. A third source of self-efficacy items was the Lent and Schmidt *Engineering Field Questionnaire.*[24] Although that questionnaire was designed for post-secondary-level students, a number of the items were relevant to the current population.

Development of the subscale for assessing interest in engineering was guided by principles outlined in Fouad and Smith’s “Test of a Social Cognitive Model for Middle School Students: Math and Science.”[12] Part IV of Lent and Schmidt[24] was also used in the development of interest questions. Again, although this survey was designed for post-secondary students, many questions are relevant for secondary students. Another source of items was the *Pittsburgh Freshman Engineering Survey* (PFEAS) developed at the University of Pittsburgh.[25, 26] This survey included items relating to engineering attrition and several questions related to interest in engineering. The perceptions subscale was adapted from Lent and Schmidt,[24] Besterfield-Sacre, et al.,[25] Hilpert, et al.,[26] and Hirsch, Gibbons, Kimmel, Rockland and Bloom.[27]

The survey instrument was also designed to collect background information, specifically: student gender, ethnicity, year in high school, number of years in MESA, and number of MESA activities participated in during the previous academic year.

Also, the survey instrument was designed to collect information about five MESA activities: field trips, guest speakers, design competitions, hands-on activities, and advisement. For each MESA activity, students were asked to indicate the number of their participations, e.g., the number of field trips in which they participated during the year. The survey also asked them to report their enjoyment of the activity, the extent to which the activity exposed them to engineering, and the extent to which the activity made them think about becoming an engineer.

Data

A total of 166 high school students completed the survey instrument at seven MESA sites in California and Utah during spring 2010. Survey data were entered on paper surveys at some sites, while computers were used to provide responses using SurveyMonkey[28] at other sites.

The respondents included 65.7% females and 34.3% males. Respondents indicated the ethnicity with which they primarily identified: 44.6% Hispanic; 14.5% African American; 12.7% White; 10.8% Asian American; 9.6% Pacific Islander, 1.8% Filipino; 3.0% Other; and 1.2% American Indian. No ethnic preference was identified by 1.8% of the respondents. The distribution of the responses is tabulated in Table 1 below.

	Female	Male	Total	Percentage
African American	13	11	24	14.5%
American Indian	2	0	2	1.2%
Asian American	11	7	18	10.8%
Filipino	1	2	3	1.8%
Hispanic	52	22	74	44.6%
Other	4	1	5	3.0%
Pacific Islander	12	4	16	9.6%
White	12	9	21	12.7%
No Response	2	1	3	1.8%
Total	109 (65.7%)	57 (34.3%)	166	

Table 1. Gender and Ethnicity Responses

Analysis

The researchers used SPSS 17.0 to analyze the data. The maximum likelihood method of factor analysis was performed using varimax rotation with Kaiser normalization on the three subscales: self-efficacy, interest, and perceptions. The cut off point for this analysis was .44 based on Sedlmeir and Gigerenzer's[29] 24-year analysis of power.

Two distinct factors were found in the self-efficacy scale, and 13 of the 14 items correlated at least 0.3 with at least one other item, suggesting reasonable factorability. Eight of the items loaded on factor one, five of the items loaded on factor two, and one item did not load. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.9, well above the recommended value of 0.6, and Bartlett's test of sphericity was significant (χ^2 (1310) = 91, $p < .05$). For the interest scale, there were three suggested factors and all 20 of the items correlated at least 0.3 with one other item. Ten of the items loaded on factor one, six of the items loaded on factor two, three items loaded on factor three, and one item did not load. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.9, well above the recommended value of 0.6, and Bartlett's test of sphericity was significant (χ^2 (2132) = 190, $p < .05$). On the perceptions scale, there were three suggested factors and all 17 of the items correlated at least 0.3 with one other item. Nine of the items loaded on factor one, five of the items loaded on factor two, and three items loaded on factor three. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.9, well above the recommended value of 0.6, and Bartlett's test of sphericity was significant (χ^2 (1593) = 136, $p < .05$).

The factor analysis results identify two factors for the self-efficacy subscale, three factors for interest, and three factors for perceptions. These results are described in detail in the following section.

Self-efficacy

Factor one, Understanding, Learning and Demonstrating, includes eight items that relate to performing tasks, understanding ideas, participating in activities, and design projects. Factor two, Communication and Problem Solving, includes five items. These items deal with communicating engineering knowledge, solving problems, and developing solutions. One item did not meet the 0.40 loading criterion required for inclusion within a factor. The results of the factor analysis of the self-efficacy items are reproduced in Table 2.

Engineering Self-Efficacy Scale		
Factor 1 – Understanding, Learning, and Demonstrating		
Item	Loading	Statement
2	0.800	Perform an engineering task in MESA
1	0.742	Understanding the engineering ideas taught in MESA
3	0.696	Learn new material relating to engineering
8	0.630	Design a project for a class assignment
5	0.600	Suggest an engineering activity to the MESA club advisor
4	0.582	Successfully interview for an internship with an engineering firm
10	0.533	Effectively participate in MESA despite having competing demands for my time
12	0.442	Continue participating in MESA activities even if I did not feel well liked by my classmates or advisor
Factor 2 – Communication and Problem Solving		
Item	Loading	Statement
13	0.820	Solve technically challenging problems
14	0.726	Develop creative solutions to difficult problems
9	0.692	Solve an engineering problem during a MESA activity
7	0.510	Explain what an engineer does in his/her work to a person who does not know
6	0.469	Carry on a conversation with an engineer about his/her profession

Table 2. Results of Factor Analysis of Engineering Self-Efficacy Scale.

Interest

The results of the factor analysis of the interest items are reproduced in Table 3. Factor one, Foundational Knowledge, includes ten items that relate to solving math and technical problems, reading articles about engineering, learning new equations, and exposure to aspects of engineering. Factor two, Global Sustainability, includes six items specifically related to occupational goal planning. These items deal with actions that will improve the sustainability of the world in which we live. Factor three, Computer Skills, has four items related to learning applications, solving problems, and reinventing computers. Item 5 attained the criterion level for inclusion in both factor 1 and factor 3, probably because it refers both to a general competence as well as to a specialized skill.

Engineering Interest Scale

Factor 1 – Foundational Knowledge

Item	Loading	Statement
4	0.729	Working on a project involving engineering principles
2	0.726	Reading articles or books about engineering issues
12	0.677	Listening to a famous engineer speak at a conference
8	0.676	Majoring in engineering
11	0.650	Learning new physics equations
10	0.642	Solving practical science problems
5	0.627	Solving complicated technical problems
7	0.580	Working on a project involving scientific concepts
1	0.558	Solving practical math problems
13	0.529	Visiting an aerospace museum

Factor 2 – Global Sustainability

Item	Loading	Statement
17	0.845	Making homes safer
19	0.789	Designing machines that allow blind people to see
16	0.762	Protecting the rainforest by developing new ways to farm that don't require so much land
18	0.685	Developing new foods
15	0.663	Using DNA evidence to solve crimes
20	0.559	Building the world's longest bridge

Factor 3 – Computer Skills

Item	Loading	Statement
3	0.740	Solving computer software problems
9	0.672	Making smaller, faster computers
6	0.596	Learning new computer applications
5	0.507	Solving complicated technical problems

Table 3. Results of Factor Analysis of Interest in Engineering Scale.

Perceptions

The results of the factor analysis of the perception items are reproduced in Table 4. Factor one, Traits and Values, includes eight items that relate to characteristic traits of engineers and values important to the field of engineering. Factor two, Categorization, includes five items related to descriptions of the job of the engineer and descriptions of people who enter engineering. Factor three, Subject Content, is comprised of three items related to definitions of the field of engineering and academic expectations for entering the field.

Perceptions of Engineering Scale

Factor 1 – Traits and Values

Item	Loading	Statement
6	0.889	Respected by other people
7	0.876	Enjoyable career
8	0.789	Contributes greatly to fixing problems in the world
1	0.670	Contribute more to making the world a better place than people in most other occupations
4	0.657	Concerned more with improving the welfare of society than most other professions
2	0.648	Innovative
9	0.622	Creative
17	0.463	Highly encouraged career by my counselors, teachers, parents, or mentors

Factor 2 – Categorization

Item	Loading	Statement
12	0.913	Consists of mostly white people
13	0.801	Consists of mostly men
16	0.629	Not a very social (people oriented) career
10	0.512	Boring desk job
14	0.511	Requires more years in school than most other professions

Factor 3 – Subject Content

Item	Loading	Statement
11	0.642	Solving computer software problems
5	0.582	Making smaller, faster computers
16	0.556	Learning new computer applications

Table 4. Results of Factor Analysis of Perceptions of Engineering Scale.

Results of the factor analysis provide strong evidence of the value of the NCETE Survey for assessments of high school student self-efficacy with regard to engineering activities and the study of engineering as well as interest in engineering and perceptions of the engineering profession. Other researchers may request permission to use it in their research.

Significance of the Work

As formal and informal learning environments are modified to appeal to a more diverse array of students, it is important to understand which instructional strategies appeal to diverse students and how the activities impact their self-efficacy, interest, and perceptions. While the survey instrument was developed specifically to investigate the influence of the MESA program upon underrepresented populations, the approach used in this developmental effort may be applicable to investigations of the impact of other informal education efforts which have similar goals in serving students from groups that are underrepresented in engineering.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 0426421. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors are also grateful for the support of Oscar Porter, Executive Director of California MESA, and Jeff Ojeda, Utah MESA Statewide Coordinator.

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