Middle school students' attitudes to and knowledge about engineering

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Abstract — *Middle school is a critical time for young people to begin thinking about future careers. While many middle school students still long to be football players, actresses or rap singers, they are also beginning to consid er realistic options. In order to effectively explore all realistic options middle school students need to have accurate information about specific careers. The literature on recruitment into engineering careers suggests that students may not know about engineering careers, have few adults or peers discussing engineering with them, and therefore do not explore engineering as a career option or prepare for it academically in these crucial middle school years. Because the demand for engineers is expected t o increase both nationally and in New Jersey the Pre -Engineering Instructional and Outreach Program was established to enlarge the future pool of engineers. The program focuses on implementing pre -engineering curricula in middle and high schools and inform ing students, teachers, parents, and school counselors about the rewards of engineering careers. Along with increased enrollment in college engineering programs, successful outcomes include increased knowledge about engineering careers and more positive a ttitudes to engineering in middle and high school students. A survey to measure middle school students': 1) attitudes to mathematics, science and engineering, 2) knowledge about engineering and engineering careers, 3) recent academic performance and 4) wh o has talked to them about engineering as a career option has been adapted from a similar survey previously developed for high school students. The current paper describes the development of the middle school survey. The validity and reliability of the s urvey will be presented along with a summary of significant findings which include: students' overall attitudes to engineering, mathematics and science, their knowledge about engineering careers, and who has been talking to them about careers in engineerin g.*

Index Terms — *Attitudes to engineering, knowledge about engineering careers, middle school students' attitudes*

INTRODUCTION

In the next few years the demand for engineers is expected to increase three times faster than for all other fields combined [12] but the number of students pursuing careers in engineering is not increasing to meet the demand [13]. In New Jersey the number of baccalaureate degrees conferred in engineering has been declining [13]. One of the reasons many students do not pursue engineering as a career is lack of academic preparation, especially in science and math. Adequate preparation should begin as early as middle school. But even those students who are adequately prepared and initially choose engineering often do not persist. From their investigation of first year dropouts from engineering colleges and universities, Besterfield-Sacre et al, [4] argue that grades, while important, only partially explain why students quit engineering. Students who left engineering in good standing had grades similar to those that stayed, but had significantly poorer attitudes to engineering: they had lower general impressions of engineering; less positive perceptions of the work engineers do; valued engineering work less; enjoyed mathematics and science less and; placed a lower value on engineering compared to other majors. Thus Besterfield-Sacre and her colleagues conclude that students' attitudes to engineering upon arrival in college are an important predictor of persistence in the major.

The work of Besterfield-Sacre et al [3-5], Moreno et al [11], Fuller et al [8] and Hartman [9] with college students suggests a number of other possible reasons why students do not choose engineering as a career. Many students have negative stereotypes about engineers (e.g. engineers are nerds) or have exaggerated positive stereotypes about engineers (e.g. engineers have to be geniuses). Another possible reason why students do not pursue careers in engineering may be that they simply do not know what engineers do. Unlike legal and medical careers, engineering careers are rarely depicted in TV and movies, and parents, teachers and school counselors often do not discuss engineering as a possible career. Blaisdell [6] suggests that high school students attending an engineering college recruiting event have sufficient knowledge about engineering to have formed opinions, but the extent to which they are accurately informed about engineering has yet to be

investigated. Thus an instrument that measures not only high school students' attitudes to but also knowledge about engineering and engineering careers was developed. And because middle school is a critical time for students to begin thinking about future careers an instrument that can be used as early as middle school is also needed.

The current paper describes the development of a survey with attitudinal scales to measure middle school students' attitudes to mathematics, science, engineers and jobs in engineering, as well as their knowledge about engineering careers, adapted from a previously developed version for high school students. The survey also includes measure(s) of academic success, pertinent demographic information and questions on who has talked to them about engineering as a possible career. Both surveys have been developed as part of the Pre-Engineering Instructional and Outreach Program (PrE-IOP), a three-year project funded by the New Jersey Commission on Higher Education, to increase the number of students, particularly those from groups traditionally underrepresented in engineering, who enroll in engineering schools in New Jersey. One of the project's main objectives is to increase the knowledge and awareness of engineering in middle and high school students, as well as their teachers, parents/guardians, and school counselors and to promote more positive attitudes to engineering. Knowledge gained during this project is being used to shape program interventions and provides data to determine whether the attitudes to and knowledge about engineering, of students and the adults who advise them, are changing in a more positive direction.

DEVELOPMENT OF THE SURVEY

The Middle School Students' Attitude to Mathematics, Science and Engineering Survey was adapted from a previously developed survey to measure high school students' attitudes to and knowledge about engineering [10]. The high school survey had five measures: 1) the Attitudes to Engineering Scale, 2) the Engineering Skills Self-Efficacy Scale, 3) the Self-Confidence in Academic Subjects Scale, 4) an Academic History, 5) a Knowledge About Engineering and Engineering Careers measure and a short demographic section. The middle school survey has four parts: 1) the Attitudes to Mathematics, Science and Engineering Scale, 2) the Knowledge About Engineering and Engineering Careers measure, 3) questions about who has talked to them about engineering as a career option and 4) a measure of recent academic performance as well as a short demographic section.

For the Attitudes to Mathematics, Science and Engineering Scale many of the items from the high school Attitudes to Engineering Scale were changed to reflect age-appropriate language for middle school students. Items for which the content was considered too spohisticated for middle school students, for example gender equity, were eliminated. Others items about mathematics, science or engineering type tasks that did not explicitly mention engineering (e.g. I would like to help plan bridges, skyscrapers & tunnels) were either constructed by the authors, or borrowed and adapted from websites aimed at middle school students [1-2].

The Knowledge About Engineering and Engineering Careers measure is the same (see [10] for details on the development of this measure). The high school Engineering Skills Self-Efficacy Scale was considered too sophisticated to include though some of the items on the middle school attitudes scale ask about similar skills and form two subscales identified as confidence in problem solving and technical skills (see below). The high school students' Self-Confidence in Academic Subjects Scale and Academic History have been replaced by a measure of recent academic performance for the middle school students.

The high school version of the survey includes the question "Which, if any, of the following have talked to you about engineering as a possible career? Choose ALL that apply: Teachers, parents/guardians, school counselors, friends". For the middle school version this question has been expanded to include hearing about engineering jobs on television or in the movies. The middle school survey distinguishes between whether their teachers have talked to them personally or as part of a whole class and asks students to indicate how often the event has occurred: "Never", "1 or 2 times", "Many times".

Survey Format

For the Attitudes to Mathematics, Science and Engineering Scale students are asked to indicate the degree to which they agree or disagree with statements about mathematics, science, engineers and the kinds of things that engineers do using a modified five point Likert scale. The typical five-point scale (1=Strongly disagree, 3=No opinion, 5=Strongly agree) has been altered to include a sixth point, "0" (zero) to indicate, "I don't know". Research on survey development suggests that when people are asked to indicate responses on a scale, they will do so, even if they feel unable or unqualified to respond [14]. Allowing the "I don't know" option will help assess the extent to which students do not have knowledge about engineering and will provide data to measure changes in their knowledge as a result of PrE-IOP. Decreases in the number of "I don't know" and "No Opinion" responses would indicate an increase in knowledge or the formation of an opinion, negative or positive.

Pilot Testing

The Center for Pre-College Programs at New Jersey Institute of Technology provided the opportunity to survey middle school students from its many outreach initiatives and summer programs. An initial version of the survey was given to 349 students from various socio-economic and race/ethnic backgrounds attending urban and suburban schools in New Jersey: Seventy-one percent were female, 29% were male. The high percentage of female students is a result of the FEMME program [7] an intense summer program designed to provide fourth to eighth grade girls with the opportunity to enhance their mathematics, science and technological academic achievement and to encourage them to choose careers in technological fields such as engineering.

Items on the Attitudes to Mathematics, Science and Engineering Scale were subjected to a principal component factor analysis. Results suggested a ten-factor solution accounting for 60% of the variance, but several of the factors contained only two or three items that did not really reflect a single construct. Cronbach's alpha was calculated to determine the internal consistency of each factor as well as the whole scale. Internal consistency measures the extent to which responses to items within a factor are consistent with responses to all other items within the same factor. Internal consistency ranges from zero, being the lowest, to one being the highest. Items that were found to lower the internal consistency of their factor or the whole scale were examined and either revised, replaced or eliminated. A revised version of the survey has been used extensively.

RESULTS FROM THE REVISED VERSION

The revised version of the survey has been given to 1701 middle school students in New Jersey who attended: schools in which NJIT conducted outreach programs, federal and state funded summer programs at NJIT and schools in which their teachers attended PrE-IOP training programs. Fifty percent were 8^{th} graders, 26% were 7^{th} graders, 21% were 6^{th} graders and 3% were 5^{th} graders. Forty-six percent were female and 54% were male. Again, the high percentage of female students is a result of the FEMME programs. Thirty-one percent of the students were White, 24% were Hispanic, 20% were African American, 4% were Asian, 1% were Native American, 5% indicated biracial and 15% indicated other or did not respond to the question. Sixty-five percent reported that they got As or Bs in both mathematics and science on their last report card and 91% indicated that when they were old enough they would go to college.

Factor Structure and Reliability Analysis

Results of a principal component factor analysis of the Attitude to Mathematics, Science and Engineering Scale found subscales similar to those identified in the initial pilot study but, as expected, the revisions changed the overall factor structure of the scale. Six strong factors (used to form subscales) accounting for 44% of the variance were identified: Interest in engineering: stereotypic aspects (Stereotypic), Interest in engineering: non-stereotypic aspects (Nonstereotypic), Negative opinions of mathematics & science (Negative), Positive opinions of mathematics & science (Positive), Problem Solving (Problems), and Technical Skills (Technical). See Table 1 for the items included in each subscale. Six items that contribute to the internal consistency of the total scale, and provide important information, did not load on any of the factors were retained. Cronbach's alpha was calculated to measure the internal consistency of the six subscales and the Total scale (Stereotypic .86, Nonstereotypic .70, Negative .71, Positive.70, Problems .73, Technical .65, and Total .88).

Attitudes to Mathematics, Science and Engineering

To examine students' responses to the individual items on the Attitude to Mathematics, Science and Engineering Scale agree and strongly agree responses were combined into Agree, disagree and strongly disagree were combined into Disagree and I don't know and No opinion responses were combined into Don't Know (see Table 1). Responses to many of the items were positive. Forty nine percent said they think they know what engineers do, 61% agreed that engineers make people's lives better, and 70% agreed that scientists make people's lives better. Fifty-six percent said they think that having a job in science or math would be fun and only 7% agreed that math & science have nothing to do with real life.

TABLE 1

ATTITUDES TO MATHEMATICS, SCIENCE AND ENGINEERING ITEMS*

	% Agree	% Disagree	% Don't Know
Interest: stereotypic aspects			
I would like a job where I could invent things	50	23	27
I would like to be an engineer when I grow up	21	42	37
I think I am good at technical things	43	24	33
When I grow up I would like to build computers	23	49	28
I would like to help plan bridges, skyscrapers and tunnels	31	43	27
I would like a job that lets me build robots	36	41	23
I would like a job that lets me design cars	45	32	24
Interest: non-stereotypic aspects			
I would like a job in which I could design clothes to be worn in outer space	24	48	28
I would like to build & test machines that could help people walk	45	23	32
I would like a job helping make new medicines	36	33	31
I would like a job in which I could help protect the environment	50	19	31
Positive opinions			
I think that having a job in science or math would be fun	56	16	29
I would like to study science\math because I could make more money when I grow up	43	26	31
I would like a job that lets me do a lot of math & science	33	35	32
People would look up to me if I had a job in science or math	23	32	46
Negative opinions			
To be good at math or science you have to be very smart	38	44	18
People who do a lot of science & math are boring	11	62	27
Math & science have nothing to do with real life	7	82	11
Kids who do science & math spend little time with other kids	16	59	26
Only nerds spend a lot of time doing math and science	13	72	15
It scares me to have to take math classes	16	66	18
It makes me nervous to even think about doing science	21	71	17
Problem Solving			
I am good at solving word problems in math	56	24	20
I think I could do well in an advanced math or science class	54	21	26
I am good at problems that can be solved in many different ways	54	18	29
Technical Skills			
I would like a job that lets me figure out how things work	59	18	24
I like thinking of new and better ways of doing things	79	5	16
I like knowing how things work	80	7	14
I am good at putting things together	65	13	21
Additional Items			
To get a job doing math or science you have to be good at solving problems	79	9	12
Scientists help make people's lives better	70	8	22
Engineers help make people's lives better	61	8	31
I think I know what engineers do	49	18	33
I would like a job that would let me spend time working on computers	51	25	24
When I am old enough I will go to college	91	2	7

* Due to rounding the percentages for each item may not sum to exactly 100.

The average response to all items on the Attitudes to Mathematics, Science and Engineering Scale was 3.5 with a standard deviation of .52. Higher averages (close to 5) on the subscales that emphasize positive aspects of engineering (Stereotypic, Nonstereotypic, Positive, Problems, and Technical) are desirable while a lower average (close to 1) was desirable for the subscale that emphasizes negative aspects (Negative). For the Total scale, negatively stated items have been reversed so that higher average scores indicate more positive attitudes. Although it was desired that some of the positive subscales be higher than those obtained and for the negative subscale to be lower, the average subscale responses were all in the desired direction.

Average responses to items on the positive subscales were greater than 2.5 (the middle of the scale) and the average response to the negative subscale was less than 2.5 (see Table 2).

TABLE 2

MEANS AND STANDARD DEVIATIONS FOR THE ATTITUDES TO MATHEMATICS, SCIENCE AND ENGINEERING SCALE AND SUBSCALES

	N	Mean (SD)
Attitude to Mathematics, Science & Engineering Total Scale	1700	3.5 (.52)
Interest in engineering: stereotypic aspects subscale	1695	3.0 (.98)
Interest in engineering: non-stereotypic aspects subscale	1680	3.1 (.95)
Positive opinions of mathematics & science subscale	1690	3.1 (.89)
Negative opinions of mathematics & science subscale	1696	2.2 (.73)*
Problem Solving subscale	1667	3.5 (.99)
Technical Skills subscale	1696	3.9 (.72)

* For this subscale items are phrased negatively. Therefore a lower mean is desirable.

Knowledge About Engineering

The Knowledge About Engineering and Engineering Careers measure is a two-part, open-ended question. Students are asked to name five different types of engineers and to give an example of the work each type of engineer does. Space is provided to list five types of engineers and an example of work done by each type of engineer. Responses to the first part "Name a type of engineer" were coded as incorrect and given a score of "0" (zero) or correct and given a score of "1" (one) according to the protocol developed for the high school version of the survey [10]. Possible total scores range from zero to five. Correct responses to the second part "Give an example of the work they do" are not as easily scored as responses to the first part. Responses can show some understanding of what a particular type of engineer does without being completely correct, yet the response is not necessarily incorrect. Therefore, answers to the second part of the question were coded as incorrect and given a score of "0" (zero), partly correct and given a score of "1" (one), or correct and given a score of "2" (two). Possible total scores range from zero to ten. During development of the scoring protocol all responses were coded and scored by two independent coders and compared for agreement. Inter-rater reliability (using a kappa statistic) was found to be .96 for the first part of the question and .91 for the second part of the question. All discrepancies were discussed until agreement could be reached and the coding protocol was revised accordingly. Responses from middle school students are scored using the same criteria used for high school students so that relative comparisons can be made between them (i.e. Higher average scores for high school students than for middle school students can be interpreted as high school students having more knowledge about engineers and engineering careers).

Of the 1701 students in the current sample only 54 (approximately 3%) could correctly name five different types of engineers. Another four percent (n=71) correctly named four different types of engineers, but eight hundred sixty-eight (51%) either gave no response or none of their responses were correct. The distribution of scores was not normally distributed so it was not possible to calculate a mean number of correct responses. The median of course was zero since less than 50% of the students named any correct engineering careers. The highest score for the second part of the knowledge question was 9: none of the students were able to give five completely correct examples of the kind of work each type of engineer does. Sixty-five percent (n=1109) of the students either gave no response to the second part of the question or all their responses were wrong.

Who Talked to the Students' About Engineering?

Students were asked how many times they had heard about engineering jobs on television or in the movies and how many times their friends, parents\guardians, teachers and school counselors had talked to them about engineering as a possible job when they grow up. Sadly students reported hearing about engineering jobs on television or in the movies more often than talking to their friends, parents\guardians, teachers or school counselors about engineering as a possible job. Eighty-six percent reported hearing about engineering jobs on television or in the movies: half reported hearing about engineering jobs many times the other half at least once or twice. But very few students reported talking to their friends (9%),

parents\guardians (22%) or school counselors (4%) many times about engineering as a possible job. Eighteen percent reported that many times their teachers talked to the whole class about engineering as a possible job but only 8% reported that a teacher often talked to them alone. The percentage of students that reported their friends, parents\guardians, teachers and particularly their school counselors never talked to them about jobs in engineering was disappointingly high (friends 65%, parents\guardians 44%, teachers personally 68%, and school counselors 79%).

DISCUSSION

The current sample of students is not necessarily representative of the general population of middle school students in New Jersey. Many of the students participated in outreach and/or summer programs conducted by NJIT or some of their teachers attended a PrE-IOP training program that could eventually familiarize students with engineering concepts in the classroom. More notably, they earned good grades and most of them (more than 90%) indicated they would probably go to college. Therefore, they are typical of students who are likely to be recruited for engineering programs in college and eventually into the engineering workforce.

Most students indicated some particularly positive attitudes to mathematics, science and engineering type skills. For instance, approximately 80% agreed that they liked knowing how things work and liked thinking of new and better ways of doing things. But for many of the items on the Attitude to Mathematics, Science and Engineering Scale the percentage of Don't Know responses was fairly high (over 25%) and for all but four of the items the percentage was at least 15 which means that although many middle school students may have positive attitudes toward mathematics, science and engineering they may not know as much about careers in engineering as is desirable if the number of students pursuing careers in engineering is to increase. The same conclusion can be drawn from examining students' responses to the Knowledge about Engineering and Engineering Careers measure. Very few students were able to correctly name five different types of engineers and none of those were able to give completely correct examples of the type of work done by each type of engineer. But these results are not surprising in light of how infrequently students reported hearing about engineering from their classroom teachers or from the other adults who advise.

More research is needed to investigate parents', teachers' and school counselors' attitudes to engineering and determine why they may not be talking to students about careers in engineering. Other versions of the survey have been developed for these populations and data have been collected but to date, except for school counselors [15] most data have not been analyzed.

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