NSF DR K-12 Proposal 1020019: The Influence of MESA Activities on Underrepresented Students

2012-2014 Study of MESA Participants

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Introduction to the Study

Mathematics, Engineering, Science Achievement (MESA) outreach programs are partnerships between K-12 schools and higher education in nine states. MESA efforts introduce integrated experiences in science, mathematics and engineering to K-12 students from groups that are traditionally underrepresented in the STEM disciplines. This exploratory study examined the influence of selected MESA activities on students' self-efficacy, their perceptions of engineering, and their interest in engineering and other STEM fields. Field trips, guest lecturers, design competitions, hands-on activities and student career and academic advisement were of specific interest in this survey. The project also investigated the relationship between student engagement in MESA and academic performance. The results are applicable to a number of organizations with similar aims and provide information for increasing the number of engineers from underrepresented populations. This project provides insights on activities used in informal settings that can be employed in classroom practice and instructional materials to further engage students, especially students from underrepresented groups, in the study of STEM.

MESA sites in California, Maryland, Utah and Washington participated in the survey. In some cases, one of the investigators met with a group of MESA advisers during a regional planning meeting to describe the purpose of the study and potential outcomes. In other instances, a member of the local or regional MESA leadership team was briefed about the MESA study by one of the investigators and then this leader described the study to a group of MESA advisers (or MESA teachers) during a planning meeting and suggested that they contact one of the investigators if they were interested in participating in the study. Utah school districts had an additional IRB process that had to be approved by the district assessment coordinator before MESA schools could participate. MD, WA and CA did not require any additional IRB approvals.

Protocol

Once advisers indicated interest in participating in the study, we sent a message describing the study and thanking them for their help. The message described the purpose of the study and outlined instructions for the administration of the survey. The advisers were asked to have their students complete the survey during a MESA meeting in a room that provided computer access to the Internet. A Letter of Information (LOI) was included, with the request that it sent home to parents/guardians. Some teachers needed hard copies of the LOI which were sent them via mail; others were willing to print copies from an e-mailed pdf file of the LOI. Advisers were informed that if a parent or guardian did not want their child to participate in the study, the parent or guardian should sign and return the form to the adviser. In such a case, the adviser did not allow the student to take the survey. The mailing also included a template for invoicing Utah State University for the stipend for participation with information that the check would be made out to the MESA program at the collaborating school. Each adviser was given an individual SurveyMonkey® link to enable participants to complete their individual survey responses and submit their responses electronically to the project office. An exception was made for one school, where the adviser requested paper copies to overcome the lack of student access to computers. The responses from that school were entered into the data base by a project staff member.

Development of the Survey Instrument

The survey instrument was designed to collect demographic information about the respondents and their parents or guardians, to gather descriptive information about experiences that the respondents had during their high school years (including specific information about their year-long MESA participation), their educational plans, and their career aspirations. In addition, four subscales were developed to assess participant self-efficacy, interest in engineering, perceptions of engineering, and outcomes attributed to participation in MESA activities. The development and revisions of these subscales were informed by pilot testing, factor analyses, item analyses, and substantive input from focus groups comprised of MESA participants. Successive revisions were also submitted to the Advisery Board for their comments and suggestions. Details on the development of the survey instrument were presented in an ASEE paper (Hailey, Austin, Denson, & Householder, 2011) and are not repeated in this report.

The Self-efficacy subscale included 11 statements, each of which asked respondents to indicate their level of agreement with the statement by indicating one choice: strongly disagree; disagree; neither agree nor disagree; agree; or strongly agree. The self-efficacy subscale consisted of these items:

- *I can understand engineering ideas.*
- *I can solve technically challenging problems.*
- *I can learn new material related to engineering.*
- *I can develop creative solutions to difficult problems.*
- *I can suggest an engineering project for a group.*
- *I can perform an engineering task.*
- *I can carry on a conversation with an engineer about his/her profession.*
- *I can solve engineering problems presented in my classes.*
- *I am like successful people in engineering.*
- *I can design an engineering project for a class assignment.*
- *I can use math and science to solve engineering problems.*

The Interest subscale was comprised of 12 statements. Respondents were asked to indicate their level of agreement with each statement by indicating one choice: very low interest; low interest; neither high nor low; high interest; or very high interest. The items on the interest subscale (which completed the statement, "*I am interested in* …." were:

- *Reading articles or books about engineering issues.*
- *Working on a project involving engineering principles.*
- *Making homes safer.*

- *Designing machines that allow blind people to see.*
- *Learning new physics equations.*
- *Majoring in engineering.*
- *Working on a project involving scientific concepts.*
- *Listening to a famous designer.*
- *Protecting the rain forest by developing new ways to farm that don't require so much land.*
- *Developing new foods.*
- *Solving practical science problems.*
- *Using DNA evidence to solve crimes.*
- *Solving practical math problems.*
- *Building the world's longest bridge*.

The Perception subscale involved eight statements. Respondents were asked to indicate their level of agreement with each statement: strongly disagree; disagree; neither disagree nor agree; agree; or strongly agree.

- *Engineers contribute greatly to fixing problems in the world.*
- *Engineers are well paid.*
- *Engineers are creative.*
- *Engineers must be good in math.*
- *Engineers contribute more to making the world a better place to live than people in most other occupations.*
- *Engineering is an enjoyable career.*
- *Engineering is respected by other people.*
- *Engineering is more concerned with improving the welfare of society than most other professions*.

The Outcomes subscale, comprised of 22 items, was developed to assess the effects of the MESA experiences of the respondents, who were asked to select one choice for each item: strongly disagree; disagree; neither disagree nor agree; agree; or strongly agree. Items on the outcomes subscale completed the statement, "*My experience in MESA allows me to*…." These items were included:

- *Feel supported in my choices in engineering.*
- *Connect engineering content to the real world.*
- *Discuss future plans with my MESA adviser/teacher.*
- *Establish professional connections/networking.*
- *Overcome embarrassment.*
- *Be more confident in tutoring others in science.*
- *Be more confident in tutoring others in math.*
- *Experience success.*
- *Feel supported in choices for my future.*
- *Socialize.*
- *Clarify my college goals.*
- *Study with friends.*
- *Increase my math level/understanding.*
- *Be more confident in seeking math help.*

- *Apply math I have learned.*
- *Breakdown stereotypes.*
- *Feel a sense of accomplishment.*
- *Clarify my career goals.*
- *Develop leadership skills.*
- *Overcome nervousness.*
- *Be recognized.*
- *Discuss personal problems with my MESA adviser/teacher.*

Survey Sample and Data Collection

Over 700 students responded to the survey. They came from 22 high schools in the states of California, Maryland, Utah, and Washington. Responses selected for analyses were from those individuals who had participated in MESA during the 2012-2013 school year. The responses from California, Washington, and most of Maryland schools included in this report were obtained during the 2013-2014 school year. The responses from Utah schools and several Maryland schools were obtained at the end of the 2012-2013 school year. Many individuals who started the survey failed to complete the instrument, but scrolled quickly through the items and exited the survey without providing any useful data. The data base of returns was scanned manually, and partial results from respondents who had not completed at least one subscale of the survey were not included in the analysis. After this screening, the final sample for the study was comprised of 484 students. Local MESA advisers administered the surveys, which the student respondents completed individually on their school computers and submitted via SurveyMonkey® to the project office at Utah State University, which established and maintained the data base for the project.

Unfortunately, educational funding suffered severe cutbacks during the period from 2012 to 2014, and a number of schools withdrew from participation in the study. Morale appeared to drop among teachers serving as MESA advisers, and future prospects for MESA dimmed substantially in the high school settings. Difficulties were experienced in scheduling and facilitating collaborations between the project staff and the collaborating MESA advisers. Consequently, the sample was not as large as originally intended.

The typical respondent completed the survey in about 15 minutes. The length of the survey and the degree of detail requested in the responses apparently discouraged a number of the participants, who opted not to respond to all relevant items on the survey. The researchers chose to retain surveys that lacked responses to every item in order to glean the maximum amount of information from the data. All responses to each item were tallied. Means, standard deviations, and other descriptive statistics were computed upon the data collected from all respondents in the sample. The number of non-respondents for each item has been included in this report in order to provide complete information for the reader.

Data from Tabulations of Survey Results

This section begins with demographic data to orient the reader to the characteristics of the sample of respondents. The data provide information about the genders of the respondents, their ethnicities, the occupations and the educational preparation of their parents or guardians.

Gender. When asked to indicate their gender, 211 respondents indicated that they were male (46.8%), 239 indicated that they were female (53.2%), and 34 did not respond to the request for gender identification. The distribution of the genders varied considerably across the years in high school in the sample. Females outnumbered males in freshman and sophomore years, while males outnumbered females in junior and senior years. These data are presented in Table 1.

Gender		Male		Female		Class
	N	Percentage	N	Percentage	N	% of total
Freshman	44	32.3	92	67.7	136	30.4
Sophomore	25	37.3	42	72.7	67	15.0
Junior	63	46.8	52	45.2	115	25.7
Senior	77	59.7	52	40.3	129	28.9
Total	209	46.8	238	53.2	447	
Missing data = 37						

Table 1. Gender representation in each grade level

Ethnicity. A total of 184 respondents indicated that they were Hispanic or Latino/Latina (42.6%), 58 indicated that they were White (17.1%), 26 reported being Black or African-American (8.1%), 117 indicated that they were Asian (27.6%), 7 reported that they were American Indian or Alaska Native (1.6%), and 13 indicated that they were Native Hawaiian or Pacific Islander (3.0%). The frequency distributions of ethnicities, genders, and grade levels are reported in Table 2.

		Hispanic or Latino/Latina	White	Black or African American	Asian	American Indian or Alaska Native	Native Hawiian or other Pacific Islander	Total
Freshmen								
	Male	24	7	4	5	0	4	44
	Female	43	21	5	11	0	5	85
	Total	67	28	9	16	0	9	129
Sophomore								
	Male	4	3	6	9	1	2	25
	Female	17	5	5	14	1	0	42
	Total	21	8	11	23	2	2	67
Junior								
	Male	24	16	6	15	0	0	61
	Female	12	7	4	23	4	0	50
	Total	36	23	10	38	4	0	111
Senior								
	Male	32	5	3	30	0	2	72
	Female	28	9	2	12	1	0	52
	Total	60	14	5	42	1	2	124
Total		184	74	35	119	7	13	432
		42.6%	17.1%	8.1%	27.6%	1.6%	3.0%	

Missing data = 52

Table 2 – Distributions of genders, ethnicities, and grade levels

The large proportion of the respondents from underrepresented groups is noteworthy, though not surprising in view of MESA's mission and goals. The distribution of ethnicities among the sample may be a function of the effectiveness of the MESA groups in attracting and serving a diverse clientele. Data recently released by the National Academy of Engineering (2014) on baccalaureate engineering graduates in the U.S. report that 8.1% were Hispanic Americans, 5.0% were African American, and 0.5% reported that they were Native American.

Occupations of Parents and Guardians. Occupations of parents or guardians are indicated in Table 3. The occupations are grouped according to the Hollingshead (1975) classification system. While there are numerous critiques of this classic but complicated system (Adams & Weakliem, 2011), it has not yet been displaced in sociological research. Respondents were asked to place their parents' or guardians' pursuits within that framework. The outcomes of their reports are tabulated in Table 3.

Which of the following best describes the occupation of your	Mother or female guardian?	Father or male guardian?
Senior manager or professional (for example: physician, college professor, minister) owner or CEO of a large business	8	17
Mid-level manager or professional (for example: architect, engineer, accountant, attorney), mid-sized business owner, military officer	42	65
Small business owner, farm owner, teacher, low level manager, salaried worker	55	45
Technician, semi-professional, supervisor, office manager	51	55
Clerical/Sales, small farm owner	19	10
Skilled manual worker, crafts person, police and fire services, enlisted military and non-commissioned officer	39	58
Machine operator, semi-skilled worker	46	63
Unskilled work, service worker	53	53
Farm laborer, day laborer	20	26
Unemployed	99	26
Total	432	418
Missing data	52	66

Table 3. Occupations of parents or guardians

In general, both genders are relatively equally represented in the respective occupational levels. However, females substantially outnumber males in the unemployed category. It is perhaps important to note that the Hollingshead classification system did not provide a category for stay-at-home parents responsible for managing the home and family. Consequently is seems likely that respondents reported such individuals as unemployed even though they were not seeking employment. Figure 1 is a graphic presentation of the distributions of occupations of parents and guardians.

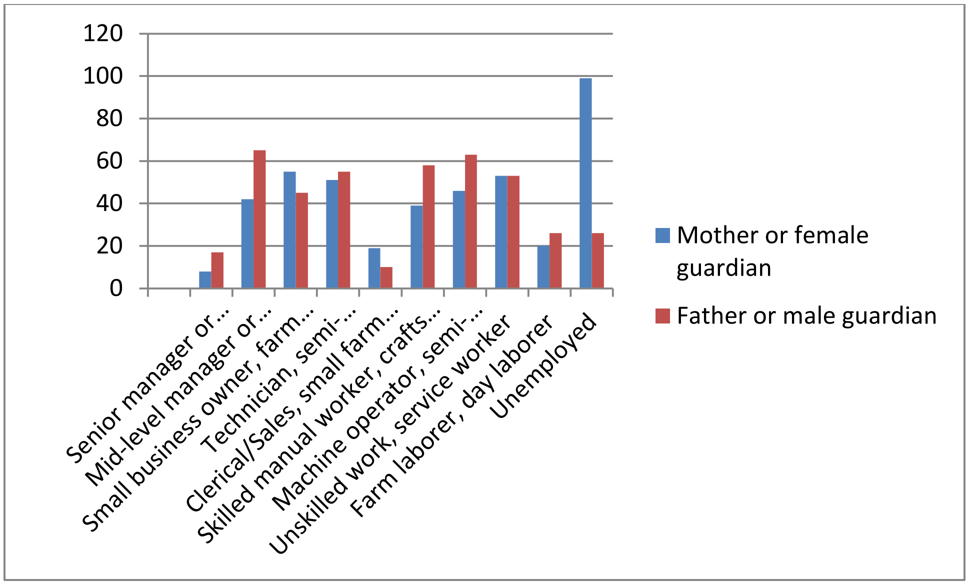

Figure 1. Distributions of occupations of parents or guardians

Education of parents and guardians. Respondents were asked to report the educational preparation or their parents or guardians using a seven-level scale. They could also indicate that they did not know their parents' or guardians' occupations. Results of the reports of respondents on the educational preparation of their parents are included in Table 4.

Please select the highest level of education completed by your	Mother or female guardian	Father or male guardian
Graduate degree	45	43
College degree	81	73
Partial college (at least one year)	53	49
High school graduate	91	96
Partial high school (10th or 11th grade)	53	48
Junior high (9th grade)	24	17
Less than 7th grade	41	38
I don't know	54	60
Not applicable	9	21
Total	451	445
Missing data	33	39

Table 4. Educational attainment of parents and guardians

The most frequently reported level of education was high school graduation for both genders of parents or guardians. College degrees were the next most frequently reported level of education. Those facts, coupled with the diverse distribution of reported educational attainment, might indicate that the MESA respondents come from relatively typical socioeconomic backgrounds. The relatively large number of “I don’t know” responses encourages caution in the interpretation of the data. Figure 2 is a graphic representation of the distributions of educational attainment among the parents or guardians.

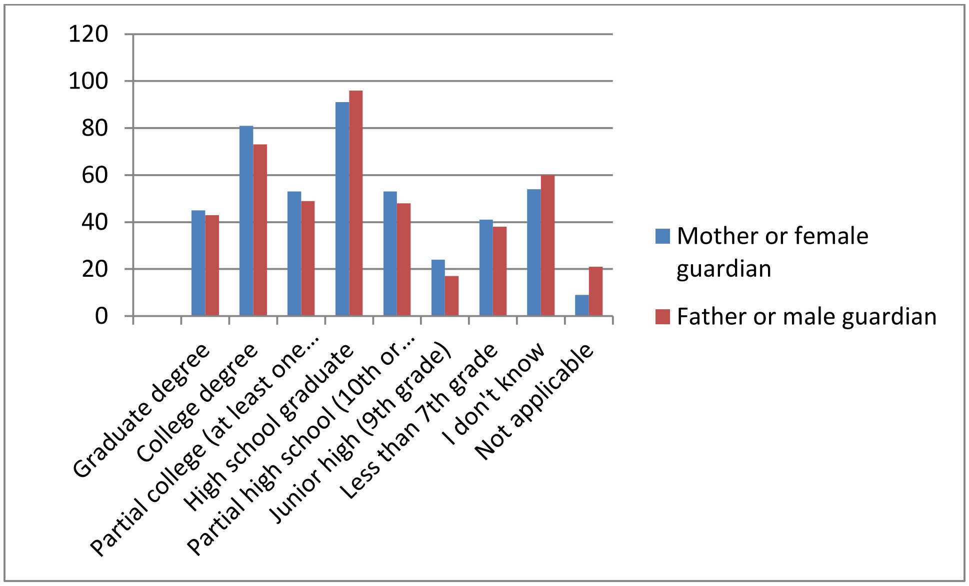

Figure 2. Educational attainment of parents and guardians

High School Experiences of Respondents

The survey reports the responses to questions on the STEM experiences of respondents – courses and activities in science, technology, engineering, and mathematics. Respondents were also asked to provide information about their experiences in MESA activities and competitions.

Science and Math Courses. Respondents were asked to indicate the number of high school science and mathe courses they had completed and to indicate the number of those courses which were Advanced Placement courses or International Baccalaureate courses. The results of those queries are reported in Table 5.

How many science courses have you taken in grades 9 through 12?

Courses	Freshmen	Sophomores	Juniors	Seniors	Total
1	122	13	2	1	147
2	7	39	6	6	63
3	7	9	75	25	131
4 or more	1	6	31	97	142

How many of the science courses were AP or IB classes?

Courses	Freshmen	Sophomores	Juniors	Seniors	Total
None	113	56	57	53	303
1	21	8	38	36	109
2	2	1	13	24	45
3 or more	1	2	7	16	27

How many math courses have you taken in grades 9 through 12?

Courses	Freshmen	Sophomores	Juniors	Seniors	Total
1	117	5	2	1	133
2	13	51	3	1	74
3	6	3	78	35	132
4 or more	1	8	32	92	145

How many of the math courses were AP or IB classes?

Courses	*Freshmen*	*Sophomores*	*Juniors*	*Seniors*	*Total*
None	115	54	76	34	318
1	17	9	21	40	97
2	3	2	10	27	46
3 or more	1	1	8	8	20

Table 5. Science and math courses completed in high school

While it might have been helpful if queries about completed math and science courses could have listed the specific mathematics and science topics studied and described the engineering-related experiences, such requests were not included to simplify the survey.

Technology and Engineering. High schools offer a range of courses in technology education. In addition, technological activities are components of an even wider range of courses across several subject fields. Rather than asking respondents whether they had completed courses in the respective areas of technological studies, the survey requested information about which of 15 technological activities that the respondents had pursued in high school. Respondents were asked to report their high school experiences in these technological areas: architectural design, biotechnology, computer drafting, computer graphics, construction, electronics, engineering, information technology, power and energy, principles of technology, manufacturing, robotics, technical communication, transportation, and video production. They were asked to indicate whether those technological experiences occurred as part of a MESA activity, part of another program or class, or were included both in MESA and in another activity.

Engineering activities were mentioned most frequently, followed by construction, architectural design, and robotics respectively. Engineering activities were reported in MESA programs by 189 respondents, in other programs by 73 respondents, and in both MESA and other programs by 98 respondents; a total of 360. Additional detail about these experiences would have been interesting and useful, but a reasonable compromise had to be reached between detail and survey length. Tabulated responses are presented in Table 6, arranged in the order of their reported frequencies in MESA programs.

Have you had any of the following experiences while in high school?

	Yes, in MESA	Yes, in Other Programs	Yes, Both in MESA and in Other Programs	Totals	No
Engineering	189	73	98	360	115
Construction	174	64	67	305	159
Architectural Design	145	55	54	254	208
Robotics	142	64	25	231	206
Power and Energy	95	93	51	239	219
Electronics	81	127	64	272	185
Transportation	75	56	39	170	271
Principles of Technology	65	81	48	194	252
Manufacturing	63	75	33	171	272
Information Technology	60	82	32	174	267
Technical Communication	58	73	39	170	270
Biotechnology	46	57	23	126	329
Computer Graphics	39	131	30	200	250
Computer Drafting	35	98	25	158	294
Video Production	32	134	29	195	252
Totals	1299	1263	657	3143	3549

Table 6. Engineering and technology experiences in high school

The relative frequencies reported for the engineering and technology experiences in MESA programs and in other programs provided the data for the graphic presentation in Figure 3.

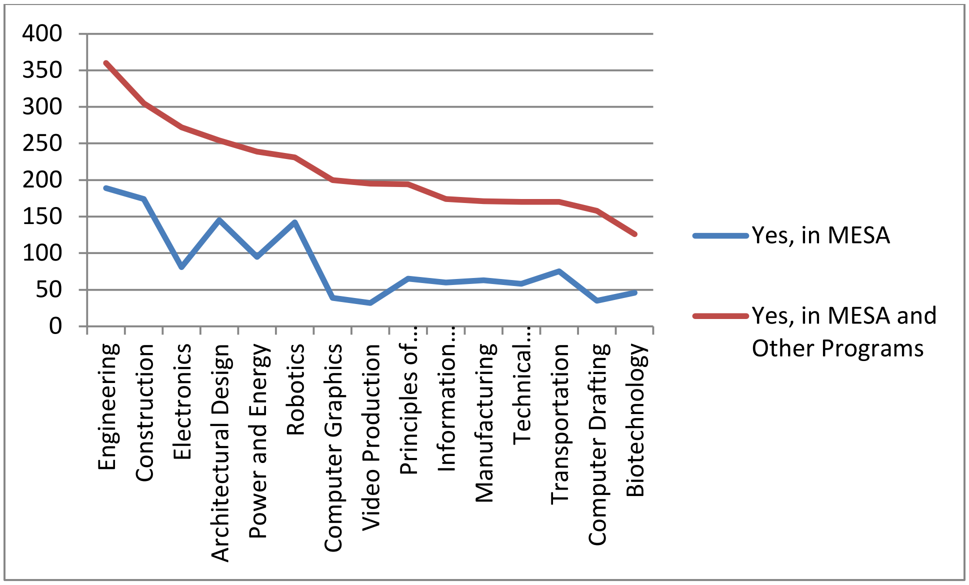

Figure 3. Engineering and technology experiences in MESA and in other programs

Respondents were asked if they had participated in Talent Search, Upward Bound, or Gear Up, compensatory programs that are intended to help prepare lower-achieving learners from underrepresented groups for enrollment in higher levels of STEM courses. A total of 80 of the 447 individuals who responded to this item (1.8%) had participated in one or more of those programs. In contrast, 367 respondents indicated that they had not been involved in any of the programs. A total of 37 respondents did not reply to the question. This level of participation in formal compensatory programs is probably lower than one might expect, but a lack of comparative data limits opportunities for interpretation. Their responses are included in Table 7.

Have you participated in Talent Search, Upward Bound, or Gear Up at any point during high school?

Yes	80
No	367
Total	447
Missing data = 37	

Table 7. Participation in Talent Search, Upward Bound, or Gear Up programs

MESA Competitions

Respondents were asked to describe the availability of MESA competitions in their settings, to indicate their participation in local, regional, and national MESA competitions (MESA activities scored by judges) during 2012-2013, to indicate whether they were successful winners in those competitions, and to estimate the average length of time they spent in preparing for each competition. It appears that most of the respondents had access to competitive events as part of their MESA experiences and a majority of them, 310, participated in one or more local competitions, with 206 successful competitions reported. Winning in a local competition is a prerequisite for regional competitions; only 149 respondents indicated that they competed at the regional level; 125 reported winning experiences at that level. There is an inexplicable outcome on the questions regarding national competitions: 40 respondents reported winning experiences in national competitions, but only 16 respondents indicated that they participated in national competitions. It is difficult to judge the degree to which this disparity casts doubt on other responses concerning MESA competitions. The data on MESA competitions are included in Table 8.

How often did MESA competitions happen during the last school year?

Never	1 time	2 times	3 times	4 times	5+ times
26	105	138	81	41	78

Please indicated whether you participated in MESA competitions	Yes	No
At the club or class level last school year	310	159
At the regional level last school year	149	167
At the national level last school year	16	133

Please indicate whether you had a winning experience	Yes	Not Applicable
At the club or class level last school year	206	245
With competitions at the regional level last school year	125	81
With competitions at the national level last school yea	40	89

Table 8. Participation in MESA competitions

Participants were asked to estimate the time they spent preparing for MESA competitions and report their estimates in one of seven categories, 1 through 6 hours or 7+hours. The extreme choices were most popular, with 21% of the respondents choosing 1 hour of preparation time and 31.8% of the respondents choosing 7+hours. Results are reported in Table 9.

On average, how much time did you spend preparing for each competition?

Hours	1	2	3	4	5	6	7+	Total
Number	95	53	45	59	18	19	144	453
Percent	21.0	11.7	9.9	13.0	8.4	4.2	31.8	

Missing data = 31

Table 9. Time spent preparing for MESA competitions

Future Plans

Several of the survey questions requested information about respondents' future educational plans, their anticipated activities the first year after high school, whether they planned to pursue a math, science, or engineering degree, and their career aspirations. Respondents reported high educational aspirations. The largest number of respondents, 264, planned to graduate from college, and 141 reported plans for graduate school. Only 3 indicated that they did not plan to complete high school, and only 15 had no educational plans beyond high school graduation. Table 10 is a compilation of the responses on educational plans.

How much education do you think you will complete?

I will not finish high school	3
I will graduate from high school	15
I will have some education after high school	12
I will graduate from college	264
I will go to graduate school	141
I don't know	11
Total	446
Missing data = 38	

Table 10. Educational plans

The first year following high school is a pivotal period in education and career preparation. Respondents were specifically asked about their plans for that year. Only 29 respondents indicated that they planned to be working full time, while 38 planned to attend a community college and 355 planned to attend a college or university. Responses to this question are tabulated in Table 11.

What do you expect that your main activity will be in the year after you leave high school?

Working full time	29
Attending a two-year college	38
Attending a four-year college, service academy, or university	355
Serving in the United States Armed Forces	13
Other	0
Total	435
Missing data = 49	

Table 11. Plans for first year after high school

In view of MESA's goals for increasing performance in math, science and engineering, there is a special interest in plans for college preparation in those fields. Most respondents indicated an interest in obtaining a degree in one of those fields: 139 indicated that they plan to attain degrees in math; 203 in science; 177 in engineering. These data appear in Table 12.

Do you see yourself pursuing one of the following degrees (choose all that apply)?

Math Degree	139
Science Degree	203
Engineering Degree	177
None of the Above	109

Table 12. Plans for degrees in math, science, and engineering

In retrospect, this survey item seems unusually focused. However, the substantial majority of the respondents selected these majors as their degree targets. Indeed, when the respondents were subsequently asked an open-ended question about their career plans, their responses cluster in the three MESA areas, particularly in science and in engineering. Those responses are reproduced in a subsequent section of this report.

Aspirations

Three items from the survey asked respondents to indicate their post high school plans: what they expected to be doing the first year after high school; their educational aspirations, and their interest in obtaining degrees in math, science, or engineering (the three STEM areas emphasized in MESA goals. In response to the question about their plans for the first year after high school, 3 indicated that they did not plan to finish high school; 15 indicated that they plan no further education after high school; 12 plan an unspecified post-secondary experience; 264 plan to graduate from college; 141 plan to go to graduate school; 10 did not select one of the options

Another survey item asked respondents to describe their performance in high school by selecting one of six choices: I get mostly As; I get mostly As and Bs; I get mostly Bs; I get mostly Vs and Cs; I get mostly Cs; or I get mostly below Cs. The numbers of individuals making the choice were: mostly As 152; mostly As and Bs 195; mostly Bs 36; mostly Bs and Cs 49; mostly Cs 10; mostly below Cs 3; and 39 individuals did not respond to the item.

In order to obtain an indication of the degree of realism of the future aspirations of the respondents, returns were analyzed by contrasting respondents' assessment of their high school performance with their aspirations for further academic preparation. This procedure provides a glimpse into the relationships between their self-reported high school achievement and their future plans. The relationships between self-reported high school performance and plans for the first year after high school are reported in Table 13.

What do you expect that your main activity will be in the year after you leave high school?

	Working full time	Attending two-year college	Attending four-year college	U. S. Armed Forces	Total
Mostly As	4	5	138	4	151
Mostly As and Bs	14	19	154	1	188
Mostly Bs	2	5	28	1	36
Mostly Bs and Cs	5	7	30	5	47
Mostly Cs	3	1	5	0	9
Mostly Below Cs	1	0	0	2	3
Total					434
Missing data = 50					

Table 13. High school performance and plans for first year after high school

The pattern of responses seems to be generally reasonable. Most of those planning to pursue higher education reported high school performance in the top two categories, mostly As or mostly As and Bs.

Relationships between plans for post-high school education and are self-reported high school performance are similarly reported in Table 14.

How much education do you think you will complete?

	Will not finish high school	Graduate from high school	Some education after high school	Graduate from college	Go to graduate school	I don't know	Total
Mostly As	0	0	2	78	69	3	152
Mostly As and Bs	1	5	6	125	55	3	195
Mostly Bs	0	2	2	25	7	0	36
Mostly Bs and Cs	1	6	1	29	8	4	49
Mostly Cs	0	2	0	6	2	0	10
Mostly Below Cs	1	0	1	1	0	0	3
Total	3	15	12	264	141	10	445
Missing data = 39							

Table 14. Relationships between high school performance and educational aspirations

The pattern of responses to this question on educational plans repeats the tendency noted above. Those respondents reporting the highest level of high school performance also reported the highest aspirations in terms of college graduation and graduate study.

Relationships between self-reported high school performance and plans to pursue degrees in math, science, and engineering are reported in Table 15.

Do you see yourself pursuing one of the following degrees (choose all that apply)?

	Math Degree	Science Degree	Engineering Degree
Mostly As	67	92	62
Mostly As and Bs	54	92	76
Mostly Bs	11	12	18
Mostly Bs and Cs	4	5	18
Mostly Cs	3	2	3
Mostly Below Cs	0	0	0
Total	139	203	177
Missing data	345	281	307

Table 15. Relationships between high school performance and interest in STEM degrees

Career Plans. An open-ended question on the survey asked respondents to describe their career choices. Responses to this question are tabulated in the following list. The first word in each response was used to alphabetize the list; semi-colons separate the responses from individuals. If multiple careers were named by a respondent, all the careers listed in the respondent's entry appear here in the order in which they were mentioned. In those cases where more than one respondent listed a specific career choice, the numbers of respondents making those choices appear (in parentheses). If the same career choice also appears in the response of another respondent who listed more than one career, that instance was not counted among the responses to the stand-alone choice of that career. For example, eight respondents indicated that they plan to be engineers. Many others listed engineering among their multiple choices or provided more specific answers, such as biomedical engineer, which was specifically reported as a career goal by four respondents.

These are the responses to the question, *What career(s) would you like to pursue?*

Accountant(3); accountant; acting, engineering, business; agriculture management; ag teacher, field scientist; aerospace engineer(6), aerospace, electrical; aerospace engineer, anesthesiology; animal biologist; animal science; animation artist, mangaka; animation, math, engineering; anthropology(2); applied (experimental) physicist, electrical, nuclear engineer; archaeology, paleontology; architect(3); architecture, chef, technician, artist; arts; astronaut; astronautical engineer; astrophysicist, astroengineer; automotive, diesel mechanic, engineer; automotive engineering; aviation engineer, video game designer; aviation engineering, military technology; basketball player, veterinarian; biochemistry; bioengineering; bioengineering, philosopher, doctor; biology(4); biology teacher; biomedical; biomedical engineer, biologist, biotech scientist; biomedical engineer(4); biotechnologist; botanist; business(8); business administration, physics; business, psychology; business, communications, graphic design, advertisement; business, engineering; business manager, business, lawyer; business management(3); business manager, medical professional, pastry chef; business, law, doctor; CEO; CEO, doctor, lawyer, stocks, pediatrician, scientist; chef(3); chemical engineer(3); chemical engineer, nuclear engineer, environmental engineer; chemical engineer, business, law; chemistry, biology, forensic science; chemist(2); chemist, artist, music teacher; chemistry major; civil engineer(9); civil engineer; mechanical engineer; clinical laboratory technician, scientist; comic artist; computer; computer animator; computer design; computer engineer(6); computer engineering, automobile engineering; computer engineering, computer science, electrical engineering; computer engineering, software engineering; computer engineering, virtual reality designer; computer hardware engineer; computer programmer(2); computer science(9); computer science, electrical engineering; computer science, reverse engineering; computer software engineer, electrical engineer; construction contractor; cop; cosmetologist; counseling psychology; crime scene investigator, lawyer; criminal justice; criminal lawyer, interpreter; criminology(2); cryptozoology, voice actor, animation, character design; culinary; culinary arts(3); culinary arts, music arts; cyber security; dance, health science; dance teacher, engineer; dental assistant; dental hygienist; dentist(2); dentist, engineer; dermatology, physician; designing; detective, computer design; diesel truck mechanic; dietician; doctor(18); drafter, engineer; economist(2); economist, civil engineer, systems engineer; elementary education; emergency physician; environmental engineer; environmental engineer, environmental consultant; electrical engineer(16); electrical engineer, systems worker; engineer(8); engineer, architect; engineer, mathematician, scientist, physician; engineer, physicist; engineer, technologist; engineering, science, math, business, musician, art teacher; engineering, business; engineering, business, computer science, economics; engineering, professional athlete; engineering, botany, other science fields; engineering, psychology; engineering, teacher, nurse, dental assistant; engineering, law enforcement; environmental engineering; environmental engineer; entrepreneur; epidemiology, biochemical engineering, farming(2); family physician; family physician, naturopathic doctor; fashion designer, teacher; film; food, nutrition; food science(2); foreign languages; forensic science; game design; genetic engineering; genetics, biology, computer science; graphic designer; graphic designer(2); graphic designer, automotive engineer, ironsmith; graphic designer, civil engineer; gynecological surgeon, obstetric surgeon, orthopedic surgeon; health science(2); health or medical career; hospitalist; law; law enforcement; law enforcement, undercover cop; lawyer(7); lawyer, artist, singer, animation; lawyer, nurse; marine biologist; marine biology; marine and freshwater biologist, robotic engineering; marine zoology; math teacher; mechanic; mechanical engineer(9) mechanical engineering, civil engineering, computer engineering; medical(6); medical illustrator; medical professional, pastry chef; medicine; medicine, music teacher; medicine, chemistry; music, physical therapist; music, interior design, marketing; neo-natal nurse, dental hygienist; nephrologist, doctor; neurology; neurosurgeon; nurse(8); OBGYN, pediatrician; occupational therapist, psychologist; orthopedic surgeon; pediatric neurologist; pediatrician(7); pediatrician, dentist; pediatrician, photographer; pharmacist(5); pharmacist, dentist, scientist; pharmacist, occupational therapist; photographer(2); physical therapist, professional hair stylist; physician(2); physics(2); police; police detective, pediatrician, photographer; police officer; political science; political science, politics; practitioner nurse; professional chef; professor; programmer(3); psychologist(2); psychology, lawyering, nursing; psychology, pharmacy, engineering; psychiatry; psychologist; psychologist, civil engineer; psychology and business; psychology, criminology; registered nurse(2); researcher; scientist(2); singer, dancer, office worker, doctor; skilled engineer; social work; software engineer(3); special education teaching; sports; stocks; surgeon(2); surgeon, general practitioner, food chemist; surgeon, computer engineer; teacher; teacher(2); teaching, FBI; teaching, engineering; theoretical physicist, cosmologist, nuclear engineering; traffic engineer, structural engineer; veterinarian, veterinarian or something with children; veterinarian, nurse; veterinarian, inventor; veterinarian, photography; veterinarian, preschool teacher; video game design; welding engineer, business degree; zoologist(3).

Some respondents provided noncommittal or indecisive responses:

any career that relates; anything interesting; I don't know; I don't know; I don't know; I don't know yet; I want to learn more on the human body; not sure; not sure; would like to pursue a career in human studies; undecided; undecided; undecided, but MESA has definitely not helped; undeclared;

A total of 102 respondents did not describe their personal career goals in response to this question.

Rigorous analysis of the patterns of respondent occupational aspirations has not been attempted; however, it seems abundantly clear that the majority of these young people have set high goals for themselves. It seems particularly impressive to consider respondents' plans in the light of their reports of their parents' or guardians' educational preparation and current occupational pursuits. While we do not have comparable data on other groups, it seems that this sample of MESA participants see themselves as upwardly mobile, both in terms of their educational plans and in terms of their occupational choices.

Results

Three criterion variables were the focus of the study: self-efficacy in engineering; perceptions of engineering; and interest in engineering. Each of these variables was the focus of a criterion subscale on the survey. Taken together, these subscales provided the fundamental data for probing the effects of participation in MESA activities on participant self-efficacy, perception, and interest.

Self-efficacy

In this study, self-efficacy was considered to be the confidence in one's ability to use math and science to solve engineering problems, individual self-confidence and competence in accomplishing engineering tasks. The self-efficacy scale builds on the dissertation work of one of the investigators (Austin, 2008). Scoring of the modified Likert items followed the pattern: Strongly disagree = 1; Disagree = 2; Neither agree nor disagree = 3; Agree = 4; and Strongly agree = 5. Mean responses were computed for each of the items, which are listed in Table 16 in the order of descending means.

	SD	D	N	A	SA	Means
I can use math and science to solve engineering problems	13	27	100	215	121	4.37
I can learn new material related to engineering	14	15	68	238	146	4.01
I can develop creative solutions to difficult problems	12	24	98	220	128	3.89
I can design an engineering project for a class assignment	20	57	128	194	79	3.85
I can perform an engineering task	20	25	102	216	117	3.80
I can understand engineering ideas	15	33	104	231	29	3.76
I can solve technically challenging problems	21	39	120	218	81	3.62
I can suggest an engineering project for a group	18	52	143	173	97	3.58
I am like successful people in engineering	30	74	180	130	64	3.53
I can carry on a conversation with an engineer about his/her profession	15	58	156	168	82	3.51
I can solve engineering problems presented in my classes	14	50	152	196	67	3.26

Table 16. Self-efficacy items ordered by means

A graphical representation of the patterns of responses to each of the self-efficacy items appears in Figure 4. It seems important to note that the “Agree” response is the mode (most frequently chosen alternative) in all but one of the items.

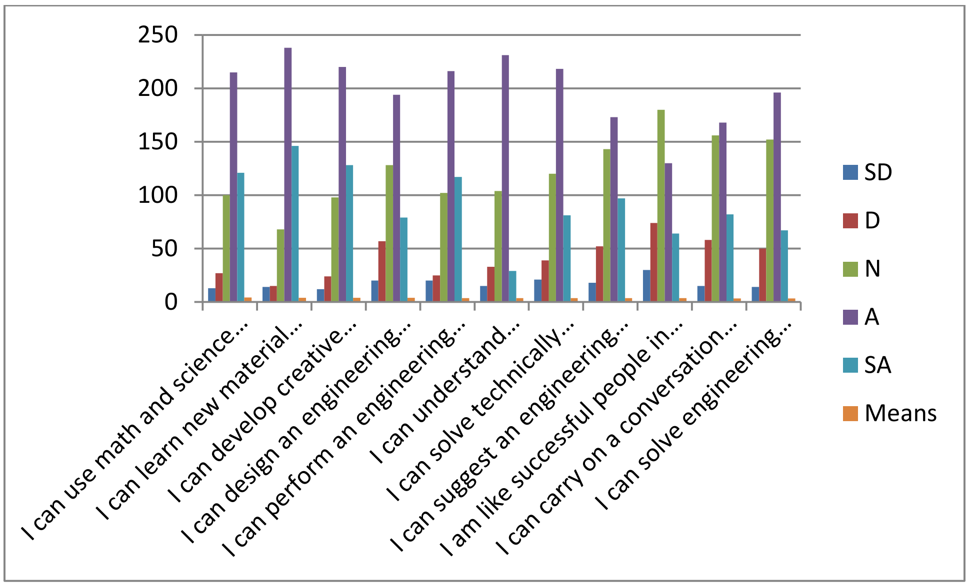

Figure 4. Patterns of responses to self-efficacy items

Interest in engineering

High values are placed on activities that appear to assist high school students to focus their interests on promising career goals and the formal educational programs leading to those career goals. Engineering, one of the interest areas emphasized in MESA, is a popular choice, though there is a substantial gap between the number of engineers needed each year and the number of graduates of formal programs in engineering education in the United States. The interest scale is comprised primarily of activities listed by the National Academy of Engineering (2008) as probable future engineering priorities. Taken together, they describe positive actions that represent contributions toward resolving many of the “grand challenges” facing engineering in the near future.

In analyzing the survey results, means were computed for each of the items on the interest subscale. The items are listed in Table 17 in descending order of their respective means.

I am interested in	Very low interest	Low interest	Neither low nor high interest	High interest	Very high interest	Means
Using DNA evidence to solve crimes	15	31	106	158	159	3.88
Designing machines that allow blind people to see	20	41	112	158	139	3.76
Making homes safer	16	34	125	186	108	3.72
Protecting the rain forest by developing new ways to farm that don't require so much land.	25	41	130	135	139	3.69
Developing new foods	22	32	142	147	125	3.69
Working on a project involving engineering principles	30	44	121	184	91	3.56
Working on a project involving scientific concepts	30	53	113	175	101	3.56
Solving practical math problems	35	45	126	152	111	3.55
Solving practical science problems	28	46	149	143	101	3.52
Building the world's longest bridge	44	65	131	110	119	3.42
Listening to a famous engineer	49	49	138	146	89	3.38
Majoring in engineering	61	64	122	111	113	3.32
Learning new physics equations	50	80	136	119	85	3.23
Reading articles or books about engineering issues	64	96	161	108	44	2.94

Table 17. Interest items ordered by means

A graphical representation of the patterns of responses to each of the interest items appears in Figure 5. It may be helpful to note that the “High interest” response is the mode (most frequently chosen alternative) in most of the items.

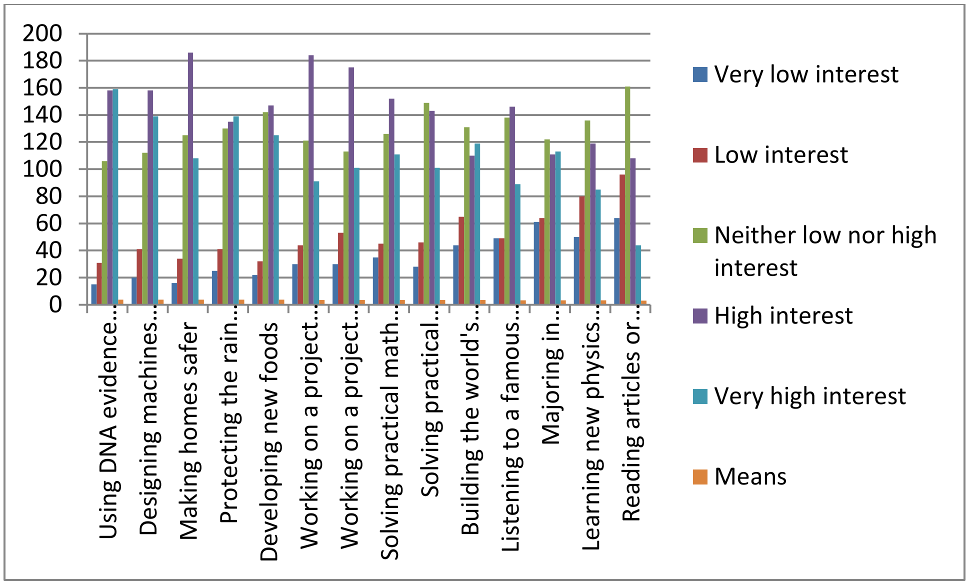

Figure 5. Patterns of responses to interest items

Tabulated responses to the items in the perceptions of engineering subscale are presented in Table 18. Items are listed in the order of their means; the item, engineers are creative, had the most positive response, while the item, engineers must be good in math, had the lowest mean among the eight items.

Perceptions of engineering	SD	D	N	A	SA	Means
Engineers are creative	8	3	31	173	259	4.42
Engineers contribute greatly to fixing problems in the world	11	7	29	176	254	4.37
Engineers are well paid	10	9	83	193	183	4.11
Engineering is respected by other people	9	11	107	226	121	3.93
Engineering is an enjoyable career	13	26	129	203	104	3.76
Engineers contribute more to making the world a better place to live than people in most other occupations	6	26	179	174	92	3.67
Engineering is more concerned with improving the welfare of society than most other professions	9	39	232	140	55	3.41
Engineers must be good in math	9	6	53	182	226	2.39

Table 18. Perception items ordered by means

A graphical representation of the patterns of responses to each of the perception items appears in Figure 6. It seems important to note that either the “Strongly Agree” response or the “Agree” response is the mode (most frequently chosen alternative) in all but two of the items.

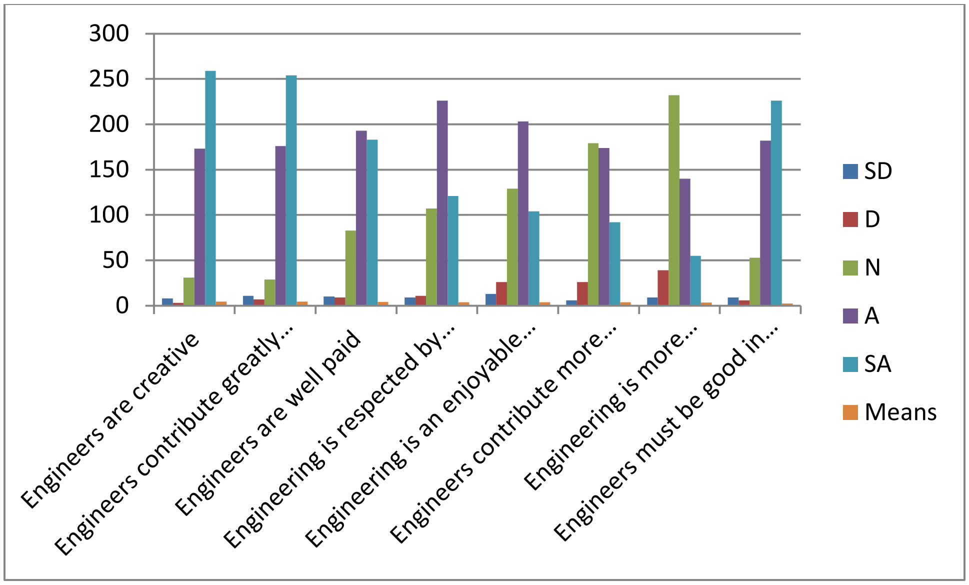

Figure 6. Patterns of responses to perception items

Gender differences in the responses to the criterion subscales are consistent across the criterion subscales, with male respondents responding more positively than female respondents on self-efficacy, perception, and interest in engineering. These data are presented in Table 19

	Male	Female
Self-efficacy	3.89	3.47
Perception	4.10	3.92
Interest	3.68	3.36

Table 19. Mean subscale scores by gender

A graphic representation of these data appears in Figure 7. Male respondents had slightly higher mean scores on each of the three criterion subscales.

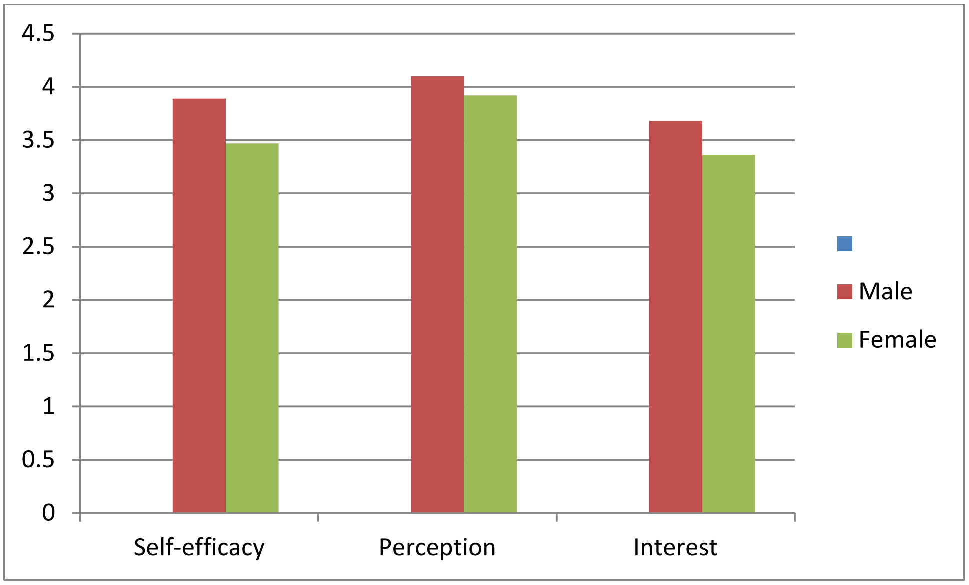

Figure 7 Mean subscale scores by gender

There were modest differences in mean responses to each of the criterion subscales among respondents from the respective ethnic groups. These data are tabulated in Table 20.

	Hispanic or Latino/Latina		White		Black or African American		Asian	
	N	Mean	N	Mean	N	Mean	N	Mean
Self-efficacy	185	3.57	74	3.76	36	3.83	120	3.75
Perception	185	3.97	74	3.98	36	4.05	120	4.06
Interest	185	3.48	74	3.35	36	3.67	120	3.67

	American Indian or Alaska Native		Native Hawaiian or Pacific Islander		Undesignated	
	N	Mean	N	Mean	N	Mean
Self-efficacy	7	3.34	13	3.31	49	3.73
Perception	7	3.95	13	3.86	45	3.93
Interest	7	3.26	13	3.61	38	3.64

Table 20 Mean subscale scores by ethnicity

A graphic representation of the mean choices by respondents from respective ethnic groups appears in Figure 8.

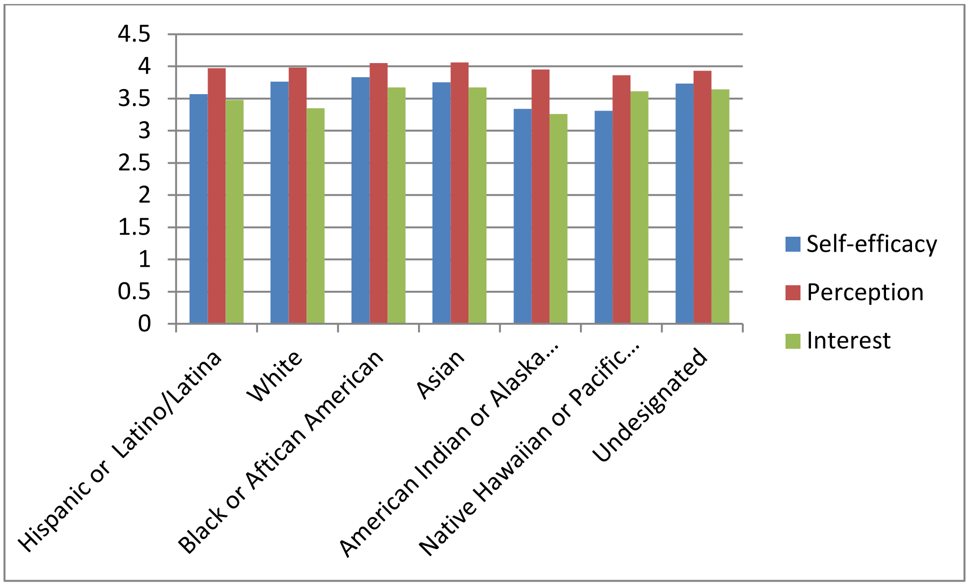

Figure 8. Mean subscale scores by ethnicity

Mean scores on each of the three criterion subscales increased slightly among respondents in the respective ascending grade levels. It is important to keep in mind that the differences did not necessarily occur within a specific school. Those data are presented in Table 21.

	Freshman	Sophomore	Junior	Senior
Self-efficacy	3.48	3.68	3.74	3.79
Perception	3.84	3.98	4.03	4.15
Interest	3.36	3.55	3.56	3.59

Table 21. Mean subscale scores by grade level

A graphic representation of these data appears in Figure 9

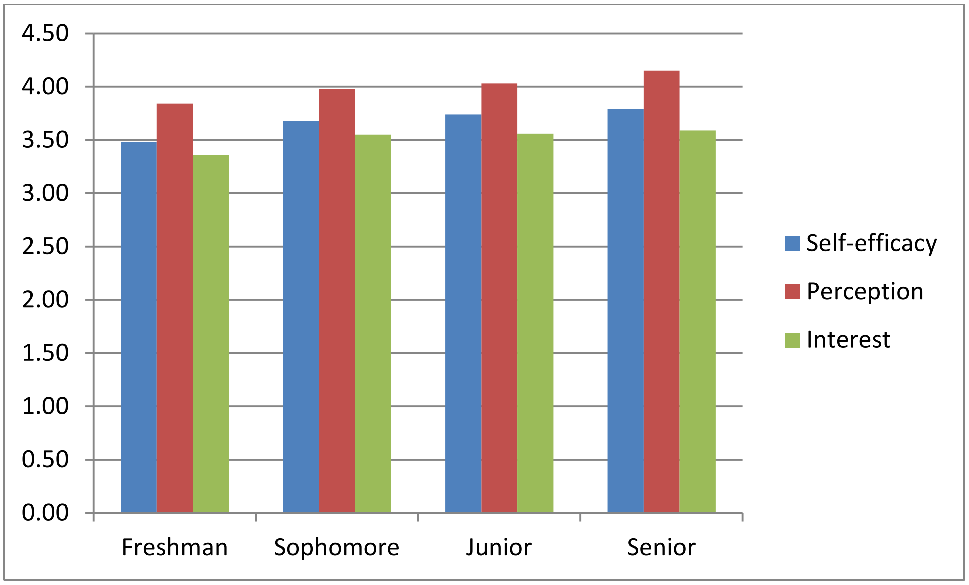

Figure 9. Mean subscale scores by grade levels

Outcomes Assessment

As the work of the project evolved, it became increasingly obvious that a variety of other outcomes (not included in the self-efficacy, perceptions, and interest subscales) resulted from MESA participation. However, the identification of those outcomes was neither as clearly specified in the literature and these outcomes were not as readily measured as the three generally recognized constructs -- self-efficacy, perception, and interest. A fourth subscale was developed for the assessment of these outcomes, which included specific areas of cognitive development, growth in affective dimensions; career choices, plans for career preparation, and continuing personal development. Analysis of the outcomes subscale provided several provocative insights that offer profound opportunities for further investigations.

Outcomes of MESA Involvement

The patterns of responses to each item in the outcomes subscale are included in Table 22, which includes the tabulated responses to the question: *My experience in MESA allows me to:*

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Mean
Feel a sense of accomplishment	9	8	57	203	168	4.16
Socialize	9	8	57	224	153	4.12
Experience success	13	13	71	188	165	4.06
Apply math I have learned	8	18	72	208	144	4.03
Develop leadership skills	7	17	95	191	141	3.98
Study with friends	13	11	80	214	130	3.98
Feel supported in choices for my future	10	12	90	209	131	3.97
Clarify my college goals	9	16	98	192	135	3.95
Be recognized	9	18	92	201	129	3.94
Increase my math level/understanding	10	16	106	189	129	3.91
Clarify my career goals	8	20	116	185	122	3.87
Be more confident in seeking math help	13	18	111	190	118	3.85
Overcome nervousness	10	30	112	170	128	3.84
Connect engineering content to the real world	10	33	110	204	95	3.75
Break down stereotypes	17	28	137	147	119	3.72
Discuss future plans with my MESA adviser	14	24	140	180	95	3.70
Feel supported in my choices in engineering	15	23	151	169	95	3.68
Be more confident in tutoring others in math	20	47	108	171	105	3.65
Overcome embarrassment	20	39	138	159	92	3.59
Be more confident in tutoring others in science	14	48	141	165	82	3.56
Establish professional communications	19	35	182	146	70	3.47
Discuss personal problems with my MESA adviser/teacher	31	50	155	122	90	3.42

Table 22. Responses to outcomes items ordered by mean scores

Responses to the items on the outcomes subscale were analyzed by gender and ethnicity. The results of the gender analysis are presented in Table 23. Male respondents had a mean score of 3.89 on the outcomes items, while female respondents had a mean score of 3.78.

Outcomes means by gender

Total	Male	Female
3.82	3.89	3.78

Table 23: Outcome means by gender

Respondents who identified as Hispanic of Latino/Latina and respondents who identified as Native Hawaiian or other Pacific Islander had the highest mean responses on the outcomes items, 3.88. Black or African American respondents and Asian respondents had mean responses of 3.82, White respondents had mean responses of 3.69, and American Indian or Alaska Native respondents had mean responses of 3.66 on the outcomes items. These results appear in Table 24.

Ethnic Selection	Mean
Hispanic or Latino/Latina	3.88
White	3.69
Black or African American	3.82
Asian	3.82
American Indian or Alaska Native	3.66
Native Hawaiian or other Pacific Islander	3.88

Table 24. Outcomes means by ethnicity

Specific Areas of MESA Activities

Four categories of MESA activities were studied in more detail: hands-on activities; meeting professionals; student advisement; and field trips. Four facets of each of these activities were explored, each with a statement in this portion of the outcomes instrumentation.

Respondents were asked to indicate whether they strongly disagreed (1 point), disagreed (2 points), neither disagreed nor agreed (3 points), agreed (4 points), or strongly agreed (5 points) with each statement. Tabulated responses and mean ratings for each of the items are presented in Table 25.

MESA Hands-on Activities	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree	Mean
MESA hands-on activities involve math and science I have learned in my classes	18	16	94	226	105	3.84
I feel that my contributions to the hands-on activities are valued by my group members	9	13	107	226	103	3.88
I believe the MESA hands-on activities provide a rewarding experience	10	10	76	200	162	4.08
Hands-on activities are an important part of the MESA experience	8	1	68	190	189	4.21
Meeting Professionals: My experiences with MESA allow me to						
Meet with and ask questions of an engineer	31	46	142	153	85	3.47
Establish a professional connection with an engineer	29	66	168	132	60	3.28
Identify with an engineer as a role model	29	53	164	139	70	3.37
Listen to exciting guest speakers	32	55	134	147	88	3.45
Student Advisement: MESA advisement has helped me						
Understand college entrance requirements	21	32	111	187	101	3.70
Complete a financial aid application for college	38	78	174	110	51	3.13
Select high school courses	27	43	128	171	82	3.53
Be confident that I can receive a scholarship for college	24	33	122	164	108	3.66
Field Trips: MESA has given me the opportunity to						
Go on field trips to a place where engineers work	25	51	112	150	110	3.60
Go someplace I would not otherwise go	18	32	93	181	125	3.81
Learn something new in a fun way on a field trip	19	26	79	176	146	3.91
Go on a field trip to gain an awareness of career opportunities	21	28	88	177	131	3.83

Table 25. Patterns of responses to items assessing effects of MESA activities

Correlations between Participation in MESA Activities and Means on Criteria Subscales

One of the most fundamental questions addressed by this study was the effect of involvement in typical MESA activities and subsequent measures of self-efficacy, perceptions of engineering, and interest in engineering. That question is answered most directly by the significant correlations between the means of the hands-on activities, meeting professionals, student advisement, and field trips sections of the survey and the self-efficacy, perception, and interest subscales. Each category of activities was closely correlated with each of the criterion measures. These correlations are reported in Table 26.

	Hands-on activities	Meeting professionals	Student advisement	Field trips
Self-efficacy	0.46	0.35	0.26	0.18
Perception	0.45	0.36	0.29	0.28
Interest	0.51	0.45	0.39	0.31

All probabilities <.05

Table 26. Correlations between categories of MESA activities and criterion measures

Competitive events are among the optional opportunities available to MESA participants. The survey probed several aspects of the individuals' involvement in MESA-sponsored competitive events. Respondents who indicated that they participated in competitive events had significantly higher mean scores on the self-efficacy, perception, and interest subscales of the survey. These results are included in Table 27.

Did you participate in competitions at the club or class level?

	Yes			No			*t*	p
	N	Mean	SD	N	Mean	SD		
Self-efficacy	309	3.77	0.72	161	3.46	0.77	4.23	<.05
Perception	309	4.07	0.54	161	3.88	0.66	3.15	<.05
Interest	309	3.60	0.75	161	3.31	0.76	3.94	<.05

Table 27. Effect of participation in MESA competitions upon criterion measures

While these findings cannot be characterized as surprising, they do appear to corroborate expectations that MESA activities and competitive events make substantial contributions toward the development of MESA participants.

The relationships between two areas of activity, engineering and technology, and the criterion subscales were explored more explicitly:. Respondents who indicated that they had high school experience in engineering activities had higher mean scores than respondents who indicated that they had no engineering experiences on each of the criterion subscales, self-efficacy, perceptions of engineering, and interest in engineering. These data are reported in Table 28.

Experience with engineering

	Yes			No				
	N	Mean	SD	N	Mean	SD	*t*	p
Self-efficacy	360	3.84	0.70	115	3.18	0.71	8.71	<0.05
Perception	357	4.06	0.61	114	3.82	0.61	3.66	<0.05
Interest	354	3.62	0.75	111	3.21	0.72	5.18	<0.05

Table 28. Mean subscale scores of individuals with and without experiences in engineering

Respondents who indicated that they had high school experiences in one or more of the technology areas had higher mean scores on each of the criterion subscales than respondents who reported that they did not have technology experiences in high school. These data are reported in Table 29,

	Yes			No				
	N	Mean	SD	N	Mean	SD	t	p
Self-efficacy	444	3.73	0.72	37	3.01	0.79	5.36	<0.05
Perception	441	4.03	0.60	36	3.57	0.73	3.68	<0.05
Interest	435	3.54	0.76	35	3.22	0.81	2.26	<0.05

Table 29. Mean subscale scores of individuals with and without experiences in technology

Reliability of Survey Instrumentation

The Cronbach Alpha reliability estimates for each of the subscales were considered to be satisfactory: self-efficacy = 0.93; perceptions = 0.85; interest = 0.90; and outcomes = 0.96. The overall Cronbach Alpha for the survey instrument was 0.96.

Summary

The MESA respondents in this study appear to follow the general pattern of positive outcomes attributable to participation in structured extracurricular activities reported by Eccles, Barber, Stone, and Huna (2003) and by Feldman and Matjasko (2005). The MESA experiences of the respondents were perceived as making contributions to their sense of self-efficacy in engineering, their perceptions of engineering, and their interests in engineering.

The majority of the MESA respondents set high expectations for themselves in their plans for higher education and the career goals they reported setting for themselves. The MESA respondents expressed strong interest in college educations in science and engineering, and they appeared to be well-prepared for those opportunities.

Participation in MESA activities and MESA competitive events has positive outcome in many dimensions explored in this study. Active involvement in these competitions and organized activities appears to contribute to the development of self-efficacy in engineering, to more accurate perceptions of engineering as a profession, as well as enhancing interest in engineering as a field of study and as a career.

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