AC 2008-955: ENHANCING DIVERSITY IN ENGINEERING TECHNOLOGY: PHASE 2 OF NORTH CAROLINA JUNIOR ENGINEERING TECHNOLOGY SOCIETY (NCJETS)

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Enhancing Diversity in Engineering Technology: Phase 2 of North Carolina Junior Engineering Technology Society (NCJETS)

This paper describes the second phase of North Carolina Junior Engineering and Technology Society (NCJETS), which is a three-year project sponsored by the Department of Engineering Technology in the Lee College of Engineering at the University of North Carolina at Charlotte (UNC Charlotte), the National Science Foundation, and local partners. NCJETS involves over 30 middle and high schools from seven counties. The purpose of the program is to engage students in educational, interesting, and challenging activities that: (1) introduce them to various disciplines and career opportunities afforded by the engineering profession; (2) inform them about two- and four-year college admission requirements and actions they need to ensure their eligibility for admission; and (3) establish a sense of community with Lee College students and faculty prior to their graduation from high school. Week-long resident summer camps are provided for middle and high school students, where the high school students receive a simulated freshman engineering experience under the guidance of Lee College student mentors.

NCJETS specifically targets underrepresented minority students. This year, almost 550 students are expected to participate and, based on data from previous years, approximately 40% of the participants are expected to be underrepresented minority students. NCJETS is one of three integrated NSF projects within the Department of Engineering Technology that collectively offer a comprehensive strategy for educating students, teachers, guidance counselors, and parents about the engineering and engineering technology professions and curricula; recruiting female and ethnically diverse high school students; and providing financial assistance in the form of need-based and merit-based scholarship awards.

Literature Review

An essential component of any modern economy is a well-educated and versatile workforce able to design and produce innovative products, processes, and services.[1] The American engineering workforce demands special attention because of its importance in contributing to the nation's economy through research, design, development, and implementation of innovative products, processes, and services.[1] However, the U.S. engineering workforce has two significant problems: the United States has been unable to produce a sufficient number of domestic engineers, and it has been unable to produce a sufficiently diverse engineering workforce.[2, 3]

In 2003, Gibbons reported that the demand for engineers is increasing, but the production of engineers in America is decreasing and the United States is facing an imminent shortage of scientists, technologists, engineers, and mathematicians.[2] Clark believes that one of the reasons for this shortage is that female, African American, Latino, and Native American high-school students show little interest in pursuing careers related to engineering.[4] Because these students are not aware of the benefits, opportunities, or the specifics of engineering careers, they are not taking appropriate classes in high school, and are therefore depriving themselves of many technical and scientific careers, as well as access to high salaried occupations.[5, 6]

Although it is well established in the literature that the number of degrees awarded in engineering and technology have been decreasing for over a decade, the Bureau of Labor Statistics expects a 3% to 9% growth in engineering occupations between 2002 and 2012[7, 8] These statistics suggest that the United States will be facing a shortage of engineers in the near future. If American companies cannot recruit and train domestic engineers, they will either go abroad to recruit engineers or they will move their engineering operations overseas.[1] The National Science Board's, *Science and Engineering Indicators*—2002 states:

> "The United States has long relied heavily on scientists and engineers who were born abroad, and increasingly so in the closing years of the 20th century. Many of the foreign born engineers earned their highest degrees in the U.S.; others entered the country with degrees earned abroad. This reliance rises the more advanced the degree."[1, 9]

Clearly, the United States has been unable to produce a sufficient number of domestic engineers, which is a concern for many high tech companies in the U.S. In 2001, in an interview in the New York Times, Gordon Moore, cofounder of Fairchild Semiconductor and the Intel Corporation made the following comments:

> "I have a concern that we're not training enough of the U.S. population to maintain our technical lead. Our outstanding universities, which are the envy of the world, are training half foreign-born students who are going back to where they came from. I see our tech companies taking advantage of well-trained people in other countries. But we're in danger of exporting a lot of technological advantage because we're not training enough people here."[10]

America's economy is in jeopardy because the U.S. is unable to produce and maintain a well-educated and versatile domestic engineering workforce. More effective action must be taken to nurture the intellectual development of underrepresented groups so that the pool of scientists and engineers can be expanded to include women, minorities, and persons with disabilities.[11, 12, 13]

Jordan and Nettles suggest that student participation in structured activities and time spent interacting with adults during tenth grade appear to have positive and significant effects on various educational outcomes by grade 12.[14] O'Brien and Rollefson found that participation in academic-related extracurricular activities is linked to higher academic performance and attainment.[15] As discussed in the remainder of this paper, the NCJETS program achieves these objectives through a series of academic year and summer opportunities for middle and high school students.

Overview of NCJETS Club

More than two dozen high schools in five counties in the Charlotte metropolitan area have NCJETS clubs. Each year the NCJETS program and community college partners sponsor a number of local activities and competitions. Students participate in five competitions as part of three events held on the UNC Charlotte campus during the academic year: (1) a trebuchet design competition; (2) a bridge or beam design competition (3) a written research paper/public speaking competition, (4) the national TEAM+S test; and (5) a robotics competition. In addition, an engineering/technology conference that is co-sponsored by local industries and professional organizations is included as one of the academic year events. Each of these events attracts several hundred high school students, parents and teachers, as well as industry representatives and Lee College students, faculty, staff, and administrators. Last year seven of the NCJETS teams advanced to the national competition based on their TEAM+S scores.

Two week-long resident technology camps are also held each summer on the UNC Charlotte campus. One camp targets middle school students and the other targets high school students. The purpose of both camps is to introduce students to engineering and engineering technology through fun and educational hands-on activities. Club sponsors are also invited to a day-long workshop each summer as a way to share best practices and identify opportunities for improvement.

Lee College of Engineering students, some of whom participated in NCJETS in high school, serve as mentors for some of the clubs. They meet weekly with NCJETS participants and provide guidance regarding the design competitions. The mentors also meet weekly under the auspices of a lead mentor, who serves as a student project manager and is a member of the project leadership team. The weekly mentor meetings are a valuable source of just-in-time feedback that is critical for program improvement.

NCJETS also partners with two other NSF-funded projects in the Department of Engineering Technology, *TECT: Teaching Engineering to Counselors and Teachers* (Award # ESI-0554405) and *COMETS: Career Opportunities for Meritorious Engineering Technology Scholars* (Award # DUE-0631038). The partnership is providing opportunities to incorporate a more substantial academic component into the high school camp curriculum, involve local high school teachers and counselors in its planning and delivery, and provide financial support to deserving new College of Engineering freshmen. This strategy is a win/win in that it helps all three NSF projects achieve one or more of its goals.

Phase 2 of NCJETS is focused on institutionalizing programs and processes developed in Phase 1 and also includes an educational research component. Results of two surveys administered in the first year of Phase 2 are discussed below. The purpose of the surveys was to: (1) solicit feedback from students regarding their experience in NCJETS; (2) identify factors that may contribute to their decision to pursue STEM majors; and (3) refine assessment tools and processes for use in the last two years of the program to ensure full institutionalization when NSF funding is no longer available.

Meal Ticket Survey

A brief survey was administered to NCJETS participants who participated in a design competition and conference held on the UNC Charlotte campus in March 2007. The anonymous survey consisted of 15 items that were specifically developed by the project team. The purpose of the survey was to collect preliminary quantitative and qualitative feedback given the large convenience sample for the purpose of continuous improvement of the NCJETS program. The survey was designed to answer the following research questions:

1. Is there a relationship between students' perceptions of NCJETS and their intention to major in engineering or engineering technology in college?
2. Are there differences in students' confidence in math and science abilities and perceptions of NCJETS based on gender, ethnicity, and high school grade?
3. Can gender, ethnicity, high school grade, confidence in math and science ability, and perceptions of NCJETS predict students' attitudes about engineering/engineering technology?

Data Collection

Hard-copy surveys were coded with a school identifier and were included in the conference registration packets. Club advisors distributed the survey to students and students submitted their surveys as a lunch meal ticket. It was clearly indicated to students and club sponsors that completing the survey was voluntary, that there were no negative consequences of not participating, and results would be used for continuous improvement of NCJETS. All students present did, in fact, complete the questionnaire.

The first three survey items asked students to identify their gender, high school grade, and ethnicity from a list of options provided. Students were then asked to rate their level of agreement to 10 statements using a Lickert scale (5 = Totally Agree and 1 = Totally Disagree). They also had the option of responding "Don't Know." The latter responses were included as missing values in the final data set. The last two survey items solicited written comments to the questions: "In your opinion, what one word best describes an engineer or engineering technologist?" and "What else do you want us to know about you or NCJETS?" Survey items and associated variable names are provided in Table 1. Data were imported into SPSS for analysis.

Table 1: *Meal Ticket Items Measured Using a Lickert Scale and Variable Names*

Survey Item	*Variable Name*
I have enjoyed the NCJETS club.	Enjoy
I am more interested in engineering/engineering technology as a result of participating in NCJETS.	Interest
I am good at math.	Math
I am good at science.	Science
I have a good understanding of the kind of work that engineers or engineering technologists do.	Understand
I plan to go to college.	College
I plan on majoring in engineering/engineering technology in college.	Major
I am confident that I could earn a college degree in engineering/engineering technology.	Confidence
A degree in engineering/engineering technology will allow me to make important contributions to society.	Contribute
I recommend NCJETS to other students.	Recommend

Sample

The sample included 300 students from 17 high schools, including one home school group, within the Charlotte metropolitan region: 65% of the participants were male; 72% were white; and 64% were in grades 11 and 12. It was important to know students' grade level because it was believed that juniors and seniors were more likely to have explored college and career options than younger students.

Collectively, African American, Hispanic, Multi-Racial, and Native American students comprised 17% of the survey respondents. These groups were combined into one Minority group for further analysis to ensure a sufficiently large sample size for demographic comparisons. Since Asians are not considered an underrepresented minority in engineering or engineering technology, they were combined with the Other group. As a result three demographic groups were created: Minority (n = 51), White (n = 213), and Other (n = 34). Two students who did not report their ethnicity were excluded from the groupings.

Descriptive Statistics

Interval data were screened prior to analysis. Missing values, i.e. responses of "Don't Know," accounted for $\leq$ 5% of the sample for each variable. Considering the large sample size, they were not considered problematic.

Descriptive statistics are provided in Table 2. The assumption of univariate normality was tenable for all variables except for College (*skew* = -2.95 and *kurtosis* = 8.57). Almost all of the students planned to go college: 94% percent of all respondents, 99% of females, and 86% of minority students.

Table 2: *Descriptive Statistics for Meal Survey Items Measured on a Lickert Scale*

	N	% $\geq$ Agree	Mean	Min	Max	SD	Skew	Kurtosis
Enjoy	295	94.9	4.61	3	5	.584	-1.21	.471
Interest	294	69.0	3.96	1	5	.908	-.580	.061
Math	298	78.2	4.07	1	5	.877	-.959	1.17
Science	298	77.1	4.06	1	5	.891	-.931	.986
Understand	297	71.1	3.91	1	5	.772	-.285	-.122
College	299	94.3	4.79	2	5	.580	-2.95	8.57
Major	283	44.9	3.36	1	5	1.33	-.192	-1.12
Confidence	286	64.3	3.81	1	5	1.12	-.738	-.154
Contribute	289	76.2	4.08	1	5	.913	-1.01	1.25
Recommend	290	88.3	4.47	1	5	.740	-1.31	1.46

Almost 95% of the respondents agreed or totally agreed that they enjoyed their NCJETS clubs, 88% recommend the clubs to other students, and 69% indicated that they were more interested in engineering/engineering technology as a result of their participation in NCJETS.

More than three-fourths of the students expressed confidence in their ability to do math and science. Almost two-thirds of the students were confident in their ability to earn an engineering or engineering technology degree.

Although 71% of the respondents indicated that they had a good understanding of the work that engineers and engineering technologists do and 76% believed that a degree would allow them to make important contributions to society, less than half (45%) planned to pursue a major in the fields.

Assumptions

In addition to univariate normality, other assumptions germane to univariate analysis of variance (ANOVA), multivariate analysis of variance (MANOVA), and multiple regression were tested prior to analysis. Although group sizes were unequal, each cell included a sufficient number of cases to ensure the 20 degrees of freedom (df) for error necessary to assume multivariate normality of the sampling distribution of means.[16] The only exception was College, which was collapsed into a dichotomous variable.

Homoscedasticity was verified via Levene's tests. The scatter plot of the standardized residuals versus predicted values was homoscedastic about y = 0, which provided support for the use of a linear regression model. Equality of covariance matrices was confirmed via Box's tests. When the assumption was violated, results of the MANOVA were interpreted based on Pillai's Trace coefficient.

Overall, the assumptions germane to correlation, ANOVA, MANOVA, and multiple regression were satisfied. This suggested that the r and F statistics and estimated βs were well established in the following models.

Measurement Model

An exploratory factor analysis (EFA) using Maximum Likehood Extraction (MLE) was conducted to investigate the underlying structure of latent variables. MLE is used when data are generally normally distributed.[17] An oblique Promax rotation was used to allow for correlations among factors and a cut-off of .35 was used for pattern coefficients. The Kaiser-Meyer-Olin (KMO) measure of sampling adequacy was .79 which exceeded the established cut-off of .60.[16] Eigenvalues greater than one, scree plots, and a minimum of three items were used to determine the appropriate number of factors.

Three factors were extracted and collectively they accounted for 64% of the variance in the data. However, Cronbach's alpha for the first two factors were .61 and .60. Although a cut-off of .70 is often used, $\alpha \geq .60$ is not uncommon, particularly in exploratory analyses.[18] In an effort to be conservative, especially since the reliabilities barely met the cut-off, separate variables were retained for further analysis. Five items loaded on the third factor: Interest, Understand, Major, Confidence, and Contribute. Factor loadings were well-defined as they ranged from .48 to .90. Internal consistency was acceptable (Cronbach's $\alpha = .83$). The third factor uniquely accounted for 37% of the variance in the data. It was operationalized as Attitude of the Profession and a new variable, Attitude, was created using the average ratings of the five survey items for each respondent (M = 3.86, SD = .79). The new variable was normally distributed ($skew$ = -.47 and $kurtosis$ = -.39).

Methodology

Three multivariate analyses of variances (MANOVAs) with α = .05 were conducted to determine if there was a difference in students' perceptions of NCJETS and confidence in math and science abilities based on gender, ethnicity, and grade level. Perceptions of NCJETS were measured by responses to the survey items *I have enjoyed the NCJETS clubs* (Enjoy) and *I recommend NCJETS to other students* (Recommend). Confidence in math and science abilities was measured by responses to the survey items *I am good at math* (Math) and *I am good at science* (Science). Grouping by gender, ethnicity, or grade level was the independent variable and students' responses to the four survey items comprised the combined dependent variable.

A hierarchical multiple regression analysis with α = .05 was then performed to determine if students' attitudes toward the profession (Attitude) could be predicted based on gender, ethnicity, grade level, confidence in science and math ability, enjoyment of the NCJETS club, and recommendation of NCJETS to other students. Gender, Ethnicity, and Grade Level were dummy coded with Male, White, and Senior (SR) as the references. Gender and ethnicity were entered into the model as covariates in step 1. Students' grade level and confidence in math and science ability were entered in step 2 of the analysis. Perceptions of NCJETS (Enjoy and Recommend) were entered in step 3.

Results

Bivariate correlations are provided in Table 3. Students who were confident in their ability to do math were, in general, also confident in their ability to do science (r = .40, $p \leq .01$). Students who enjoyed NCJETS tended to be more interested in engineering/technology as a result of their participation (r = .37, $p \leq .01$) and were likely to recommend NCJETS to other students (r = .44, $p \leq .01$). However, there was no relationship between students' plan to major in the professions and their recommendation of NCJETS ($p > .05$). Although the association between students' enjoyment of NCJETS (Enjoy) and Major was significant, it was too weak to be of practical significance (r = .13, $p \leq .05$).

Students' interest in the professions as a result of participating in NCJETS was moderately and significantly associated with their understanding of the kind of work that engineers and technologists do (r = .39, $p \leq .01$); belief that a degree would allow them to make important contributions to society (r = .38, $p \leq .01$); plan to major in college (r = .55, $p \leq .01$); and confidence in the ability to earn a degree (r = .44, $p \leq .01$).

There were also significant and moderate associations between students' understanding of the work of the professions and belief that a degree would allow them to make important contributions to society (r = .44, $p \leq .01$), plan to major in engineering/technology (r = .45, $p \leq .01$), and confidence in the ability to complete a degree (r = .48, $p \leq .01$).

Students' belief that a degree in the professions would allow them to make important contributions to society was also significantly related to their plan to pursue a degree (r = .50, $p \leq .01$) and confidence in the ability to complete it (r = .60, $p \leq .01$). Not surprisingly, students who planned to major in engineering/technology were much more likely to be confident in their ability to complete their degree (r = .71, $p \leq .01$).

Table 3: *Pearson Correlations for Students' Perceptions of the NCJETS Clubs, Academic Self-Efficacy, and Attitudes toward Engineering/Engineering Technology*

	Enjoy	Interest	Math	Sci	Understand	Major	Conf	Contribute
Enjoy	1							
Interest	.37**	1						
Math	.16**	.16**	1					
Science	.18**	.12*	.40**	1				
Understand	.20**	.39**	.24**	.30**	1			
Major	.13*	.55**	.16**	.11	.45**	1		
Confidence	.11	.44**	.34**	.21**	.48**	.71**	1	
Contribute	.13*	.38**	.23**	.21**	.44**	.50**	.60**	1
Recommend	.44**	.29**	.28**	.20**	.21**	.06	.15*	.32**

** p = .01
* p = .05

Descriptive statistics by grouping are reported in Table 4. The first MANOVA failed to detect a gender difference on the combined outcome (*Hotelling's Trace* = .011, F = .754, $p > .05$). The second MANOVA tested for ethnicity differences. Although there was a significant difference (*Pillai's Trace* = .055, F = 1.95, p = .05), the effect size was too small to be of practical use (partial η^2 = .027). This finding was supported by insignificant univariate tests ($ps > .0125$). The final MANOVA revealed no significant grade level differences on the combined dependent variable (*Pillai's Trace* = .069, F = 1.64, $p > .05$).

Table 4: *Sample Sizes (n), Means (M), and Standard Deviation (SD) for Variables Measuring Students' Perceptions of NCJETS and Confidence in Math and Science Ability by Gender, Ethnicity, and Grade Level*

Variable	Gender		Ethnicity			Grade Level			
	Female	Male	Minority	White	Other	9	10	11	12
n	101	182	47	205	30	47	57	71	108
Enjoy									
M	4.61	4.60	4.51	4.64	4.50	4.36	4.65	4.63	4.67
SD	.616	.565	.621	.557	.682	.735	.481	.567	.547
Recommend									
M	4.55	4.43	4.30	4.55	4.30	4.30	4.56	4.44	4.54
SD	.685	.753	.858	.682	.794	.805	.567	.841	.689
Math									
M	4.06	4.07	3.96	4.07	4.27	4.13	4.16	3.87	4.13
SD	.835	.880	.955	.849	.828	.769	.702	.955	.908
Science									
M	4.14	4.04	3.79	4.10	4.30	4.21	4.14	3.94	4.06
SD	.775	.921	1.04	.848	.596	.778	.934	.939	.823

Table 5 provides results of the three-step hierarchical regression analysis. The first step in the model controlled for gender and ethnicity. Although their contribution was significant ($F_{3,250}$ = 5.25, $p = .002$), they accounted for only 6% of the variance in Attitude. Female ($\beta = -.247$, $sr^2 = .059$, $p < .01$) was the only significant covariate. Minority and Other did not significantly contribute to the model (*ps* > .05).

Grade, Math, and Science were entered in the second step of the regression analysis. There was a 10% change in variance accounted for (ΔR^2) in Attitude which was significant ($\Delta F_{5,245} = 5.94$, $p < .01$). Female ($\beta = -.243$, $sr^2 = .056$, $p < .01$) and Math ($\beta = .233$, $sr^2 = .043$, $p < .01$) contributed significantly to the model. The value of β for Female was relatively unchanged from step 1 of the model. The unique contributions of Female and Math collectively accounted for only 10% of the variance in Attitude. None of the other predictors were significant (*ps* > .05).

Enjoy and Recommend were entered in step 3 of the model. There was a 6% change in variance accounted for (ΔR^2) in Attitude, which was a significant increase over step two ($\Delta F_{2,243} = 8.79$, $p < .01$). Female ($\beta = -.260$, $sr^2 = .064$, $p < .01$), Math ($\beta = .173$, $sr^2 = .023$, $p < .01$), Enjoy ($\beta = .167$, $sr^2 = .022$, $p = .01$), and Recommend ($\beta = .138$, $sr^2 = .014$, $p < .05$) contributed significantly to the model. Collectively the unique contributions of these four predictors contributed to 12% of the variance in Attitude. Ethnicity, Science, and grade level did not significantly contribute to the model (*ps* > .05). Overall, the model accounted for 22% of the variance in Attitude (adjusted R^2 = 19%).

Table 5: *Hierarchical Regression Analysis Predicting Students Attitudes toward the Profession Based on Gender, Ethnicity, Grade Level, and Confidence in Math and Science Ability*

Step	Variable	B	*β*	*t*	*p*	*sr*	*R*	R^2	ΔR^2	ΔF	*df*
1					.002		.243	.059	.059	5.25	3, 250
	(Constant)	4.02		56.7	.000						
	Female	-.410	-.247	-3.94	.000	-.242					
	Minority	-.080	-.039	-.607	.544	-.037					
	Other	.025	.010	.155	.877	.010					
2					.000		.401	.161	.102	5.94	5, 245
	(Constant)	2.65		9.35	.000						
	Female	-.403	-.243	-4.05	.000	-.237					
	Minority	-.018	-.009	-.143	.886	-.008					
	Other	-.053	-.021	-.349	.727	-.020					
	FR	-.131	-.061	-.955	.341	-.056					
	SO	.063	.032	.503	.615	.029					
	JR	-.030	-.016	-.247	.805	-.014					
	Math	.219	.233	3.54	.000	.207					
	Science	.120	.129	1.95	.053	.114					
3					.000		.466	.218	.057	8.79	2, 243
	(Constant)	1.27		2.92	.004						
	Female	-.431	-.260	-4.43	.000	-.252					
	Minority	.034	.016	.276	.783	.016					
	Other	.027	.010	.179	.858	.010					
	FR	-.034	-.016	-.249	.803	-.014					
	SO	.063	.032	.517	.606	.029					
	JR	-.021	-.011	-.180	.858	-.010					
	Math	.163	.173	2.64	.009	.150					
	Science	.087	.093	1.44	.152	.081					
	Enjoy	.229	.167	2.60	.010	.148					
	Recommend	.148	.138	2.08	.039	.118					

Discussion

The Meal Ticket Survey investigated the relationship between students' perceptions of NCJETS and their intention to major in engineering or engineering technology in college. It also sought to determine if there were differences in students' confidence in math and science abilities and their perceptions of NCJETS based on gender, ethnicity, and high school grade. Finally, it developed a model to predict students' attitudes about engineering and engineering technology. The survey, which was specifically developed for this project, was administered to 300 students who attended an NCJETS competition in March 2007.

Findings suggested that there was no direct relationship between students' intention to major in engineering or engineering technology and their enjoyment of NCJETS or their recommendation of the clubs to other students. However, there was an indirect relationship between NCJETS and choice of major. Students who enjoyed NCJETS tended to be more interested in the professions as a result of their participation. Their interest was significantly associated with their understanding of the work that engineers do and their belief that they could make important contributions to society, all of which were related to their plan to pursue a degree and confidence that they could complete it. It was not surprising that students who were confident in their math ability were also confident in their ability to do science.

Results of the multivariate and univariate analyses of variance failed to detect any gender, ethnicity, or grade level differences relative to students' perceptions of NCJETS and/or their confidence in their math and science abilities. These findings suggest that, on average, NCJETS is providing equal opportunities for access and participation, and that students' experiences in NCJETS are similarly independent of demographics. The findings also indicate that students who participate in NCJETS are, on average, equally confident about their math and science abilities independent of demographics.

The hierarchical linear regression model revealed that gender, students' confidence in their math ability, and perceptions of NCJETS, i.e. whether they enjoy the club and recommend it to other students, significantly contribute to their attitudes about engineering and engineering technology. Gender was a significant covariate and it individually contributed to 6% of the variance in Attitude. In comparison, the unique contributions of the other significant predictors collectively accounted for only 6% of the variance. The prediction equation indicates that males who are confident in their math ability and who have positive perceptions of NCJETS are likely to have more favorable attitudes about engineering and engineering technology than other students. Overall, the regression model accounted for almost 22% of the variance in students' attitudes about the profession.

When students were asked "In your opinion, what one word best describes an engineer or engineering technologist?" their responses overwhelmingly included smart, brilliant, intelligent, or intellectual. Many students described engineers and technologists as innovators, creators, or builders. Some students simply responded "cool" or "fun."

In summary, the Meal Ticket survey revealed the need to more comprehensively investigate other factors that may influence students' decision to pursue a STEM major such as number of years in NCJETS, highest level of degree earned by a parent or guardian, and/or exposure to engineering professionals and principles. The following survey was designed as a follow-up investigation to examine these and other factors.

End-of-Year Survey

The purpose of the end-of-year survey was to more fully investigate factors that influence students' decision to purse STEM majors in college. The survey was designed to determine if choice of college major could be predicted based on:

- Demographics such as gender, ethnicity, and grade level
- Number of years participating in NCJETS clubs
- Level of exposure to engineering principles in high school classes and practicing professionals through family and friends
- Highest level of education of parent or guardian
- Interest and attitudes in the engineering and engineering technology professions
- Enjoyment of math and science
- Perceptions regarding the rewards versus the level of effort to become an engineer or engineering technologist

Survey Design

A previously validated survey developed by the New Jersey Institute of Technology (NJIT) Center for Pre-College Programs was adapted for use in this study.[19] Forty of the original 50 items comprising the NJIT survey were included in the end-of-year NCJETS survey. Collectively, these 40 items evaluated students' attitudes about and interest in the engineering profession; career issues such as equal opportunity and leisure time; beliefs about their math, science, and other engineering-related skills such as problem-solving and creative thinking; confidence in their math, science, speaking, and writing skills; and social influences such as whether their high school teachers presented engineering principles as part of their classroom teachings, if they had friends who planned to pursue an engineering degree in college, and if they had a relative or friend who is an engineer or who is studying to be one. Twelve additional items were developed specifically by the project team. They were used to determine if students understood the difference between engineering and engineering technology, number of years they participated in NCJETS clubs, highest level of degree earned by either parent or legal guardian, and plans for college including choice of major. The last two survey items invited students to provide written comments and, if they wished to be included in a raffle drawing, to provide contact information. Table 6 provides Lickert scale survey items and associated variable names.

Table 6: *End-of-Year Survey Lickert Scale Items and Variable Names*

Survey Item	*Variable Name*
I think that engineering/engineering technology could be an interesting career.	Intcareer
Engineers/engineering technologists have little need to know about environmental issues.	Environ
I would like to study engineering/engineering technology because it could provide me with more money than most careers.	Money
Engineers/engineering technologists are creative.	Ecreative
Engineers/engineering technologists spend little time dealing with other people.	Nopeople
A career in engineering/engineering technology would leave me enough time to have family and leisure activities.	Freetime
Engineers/engineering technologists are highly respected by others.	Respect
Engineering/engineering technology requires flexibility in one's thinking.	Flexthink
Engineering/engineering technology requires good problem-solving skills.	Eprobsolv
If I become an engineer/engineering technologist, I expect that I will be given the same opportunities, pay raises, and promotions as my fellow workers.	Equality
Engineers/engineering technologists spend most of their time working with computers.	Workcomp
The rewards of becoming an engineer/engineering technologist are not worth the effort.	Notwortheff
Being an engineer/engineering technologist requires an IQ in the genius range.	Genius
I am considering studying engineering/engineering technology in college.	Considerma jor
Most of the skills learned in engineering/engineering technology would be useful in everyday life.	Usefulskill
Engineers/engineering technologists pay an important role in solve society's problems.	Society
I enjoy problems that can be solved in many different ways.	Ienjprob
I feel confident in my ability to study engineering/engineering technology in college.	Confstudy
Some of my friends are considering studying engineering/engineering technology in college.	Efriends
I am good at designing things	Design
Creative thinking is one of my strengths.	Icreative
I would rather study alone than study in a group.	Studyalone
I enjoy the subjects of math and science the most.	Ienjmathsci
I have good problem-solving skills.	Iproblsolv
I understand the difference between engineering and engineering technology.	Difference

Data Collection

The survey was conducted using *StudentVoice*™ which is web-based software used extensively on the UNC Charlotte campus to survey students, faculty, alumni, and employers.[20] NCJETS participants were invited to complete the survey during the period from May 7 through June 13, 2007. Club sponsors encouraged students to complete the survey, informed them that if they participated they could elect to be included in a raffle drawing for prizes such as a $250 gift card, and directed them to a link on the NCJETS website.[21] Once students accessed the survey, they were informed that results were confidential, would be reported in aggregate, and would be used for continuous improvement of NCJETS clubs. Although a raffle drawing served as an incentive, participation was voluntary. Students were not penalized in any way if they chose not to complete the survey.

Participants responded to each survey item by clicking on a radio button. They rated their level of agreement to Lickert items on a scale that ranged from Strongly Agree to Strongly Disagree. They also had the option of responding "No Opinion" or "Don't Know." Club sponsors reminded students to complete the survey several times throughout the six-week administration period.

At the end of the survey period, de-identified responses were downloaded from the software company server and imported into SPSS for analysis. By the end of the six-week period, 235 students had responded, which represented a 78% response rate.

Participants

Nine cases were deleted from the dataset because it was clear that students had logged into the survey but had responded to only a few questions. The final sample included 226 students from 17 high schools, including one home school, within the Charlotte metropolitan region: 57% of the respondents were male; 16% self-identified as an ethnic minority; and 62% were high school juniors and seniors. Half of the students (50%) indicated that at least one parent or legal guardian earned a four-year college degree. For 63% of the respondents, this was their first year of participation in NCJETS.

More than half (52%) of the students indicated that they had taken college-preparatory courses and 42% had taken courses for college credit. Approximately one-third of the students had taken an AP math (36%) and/or an AP science (33%) course.

Virtually all of the respondents (97%) indicated that they plan to go to college, which was consistent with results of the Meal Ticket survey. However, only 83 students (37%) had applied to college at the time of the survey. Of those who had applied, 92% had applied to and 81% had been accepted to a four-year institution. More than half (56%) of the total respondents planned to pursue a STEM major.

Descriptive Statistics

Descriptive statistics for Lickert scale items are provided in Table 7. For the sake of brevity and clarity, the term “engineering” is used to denote both engineering and engineering technology in the following discussion.

Table 7: *Descriptive Statistics for End-of-Year Survey Items Measured on a Lickert Scale*

	N	% ≥ Agree	Mean	Min	Max	SD	Skew	Kurtosis
Intcareer	226	86.3	2.87	1	4	.418	-2.30	7.12
Environ	226	11.9	1.40	1	4	.801	1.81	2.01
Money	226	42.9	2.45	1	4	.859	-.166	-.673
Ecreative	226	92.5	2.92	1	4	.351	-3.59	16.7
Nopeople	226	10.6	1.57	1	4	.927	1.47	.936
Freetime	226	46.0	2.78	1	4	.834	-.271	-.470
Respect	226	78.3	2.90	1	4	.511	-.972	3.24
Flexthink	226	93.4	2.96	1	4	.281	-2.46	17.7
Eprobsolv	226	95.1	2.96	1	4	.272	-4.24	28.5
Equality	226	78.8	2.86	1	4	.561	-1.41	3.64
Workcomp	226	36.7	2.27	1	4	.856	-.003	-.810
Notwortheff	226	10.6	1.37	1	4	.796	2.02	2.79
Genius	226	19.5	1.77	1	4	.956	.867	-.513
Considermajor	226	47.3	2.49	1	4	.967	-.317	-.917
Usefulskill	226	75.7	2.81	1	4	.571	-1.29	2.59
Society	226	84.5	2.84	1	4	.473	-2.25	5.96
Enjprob	226	82.3	2.77	1	4	.548	-2.20	4.11
Confstudy	226	63.7	2.62	1	4	.780	-.871	.125
Efriends	226	80.5	2.89	1	4	.574	-1.56	4.27
Design	226	68.1	2.62	1	4	.691	-1.19	.579
Icreative	226	77.4	2.73	1	4	.593	-1.78	2.47
Studyalone	226	38.1	2.15	1	4	.885	-.019	-1.22
Enjmathsci	226	74.3	2.69	1	4	.654	-1.50	1.55
Iproblsolv	226	78.3	2.75	1	4	.525	-1.87	2.97
Difference	226	56.2	2.71	1	4	.829	-.588	-.089

In general, NCJETS participants had favorable perceptions of the engineering profession. Almost all of the respondents (>90%) perceived engineers as creative and indicated that being an engineer requires flexible thinking and good problem solving skills. More than three-fourths felt that engineers are highly respected by others and that engineering skills are useful in everyday life. Almost 85% of the students believed engineers play an important role in solving society’s problems and 86% felt that engineering would be an interesting career.

Almost 20% of the students believed that being an engineer requires an IQ of a genius. In general, few students felt that that engineers have little need to know about environmental issues (12%), believed that engineers spend little time dealing with other people (11%), or perceived that the rewards of becoming an engineer are not worth the effort (11%). More than one-third of the respondents believed that engineers spend most of their time working with computers.

Less than half of the respondents indicated that they would like to study engineering because of the profession's lucrative salaries. Almost 79% expected equal opportunity in terms of pay raises and promotions but only 46% believed that an engineering career would leave them sufficient time for family and leisure activities.

The majority of the respondents were confident in their ability to design (68%), think creatively (77%), and problem-solve (78%). Seventy-four percent enjoyed math and science and 82% enjoyed problems that can be solved in many different ways.

More than 80% of the students had a friend who was considering studying engineering in college. Almost half of the students were themselves considering an engineering or engineering technology major and 64% were confident in their ability to study engineering. Just over half of the students indicated that they knew the difference between engineering and engineering technology.

Assumptions

Logistic regression was used to predict whether students plan to pursue a STEM major. Unlike other univariate and multivariate techniques, logistic regression allows for prediction of a discrete outcome, such as group membership, with few restrictions. Predictors do not have to be normally distributed, linearly related, or homoscedastic.[16] Error terms are not assumed to be normally distributed.[22] Any type of variable can serve as a predictor. The use of logistic regression does, however, require sufficient cell sizes. Therefore, as appropriate, variables were collapsed to ensure the assumption was met.

Measurement Model

Since some of the variables were not normally distributed, an exploratory factor analysis was conducted using principal axis factoring extraction.[17] Promax rotation was used to allow for correlations among factors. KMO = .73 indicated that the use of factor analysis was appropriate. Loadings of at least .35, eigenvalues greater than 1, scree plots, and a minimum of three items were used to identify the number of factors.

Three factors were extracted and collectively they accounted for 34% of the variance. The first factor, operationalized as Positive Attitudes of the Profession (Positive), was composed of five survey items: Ecreative, Respect, Flexthink, Eproblsolv, and Society. Factor loadings were well-defined and ranged from .41 to .67; Cronbach's α = .65. Seven items comprised the second factor defined as Interest in the Profession (Interest): Intcareer, Money, Considermajor, Ienjprob, Confidence, Design, and Icreative. Pattern matrix coefficients ranged from .35 to .62 and Cronbach's α = .68 suggested marginal reliability. The third factor was composed of five reverse scored or negatively-worded items used to operationalize students' negative perceptions of the profession. The internal consistency reliability for this factor was unacceptable (α = .48). As a result, two factors, Positive and Interest, were retained for further analysis. Together they accounted for 26% of the variance.

Methodology

The purpose of the NCJETS project is to encourage high school students to pursue STEM majors in college. Therefore, student responses on the survey were combined into two groups: (1) those who planned to pursue STEM majors and (2) those who planned to pursue a non-STEM major or who were undecided. The two groups were almost equally split: 55% (n =125) were STEM and 45% (n =100) were non-STEM. One case was excluded from the analysis due to missing values.

Grade level, ethnicity, number of years in NCJETS, and highest level of parental education were recoded as dichotomous variables to either ensure sufficiently large cell sizes or because there was a natural split in the data. Students were grouped as either freshmen/sophomores (38%) or juniors/seniors (62%), minority (16%) or non-minority (84%), one year (63%) versus more than one year (37%) of participation in NCJETS, and four-year (50%) versus less than a four-year (50%) college degree for at least one parent or legal guardian.

A hierarchical logistic regression was run using Major as the dichotomous outcome (STEM versus non-STEM). A test of the full model against a constant-only model was conducted. Gender, ethnicity, grade level, number of years in NCJETS, and highest-level of parental degree were entered as covariates. Exposure to the profession was entered into the model in step 2 as dichotomous variables, i.e. whether a student had friends who were planning to pursue an engineering major, if a student knew an engineer or someone who was studying to be one, and the frequency that high school teachers taught engineering principles. In the latter case, an ordinal scale was used: Never (0), 1-3 times (1), 4-6 times (2), 7-9 times (3), or 10 or more times (4). Four variables used to operationalize perceptions were entered in the final step of the model. These included the two new factor analytic variables, Positive and Interest, and responses to the two survey items *The rewards of becoming an engineer/engineering technologist are not worth the effort* (Notwortheff) and *I enjoy the subjects of math and science the most* (Enjmathsci).

Results

A test of the full model against a constant-only model was statistically reliable, X^2 (12, N = 225) = 21.2, $p < .05$. This indicated that the predictors reliably distinguished between STEM and non-STEM majors. However, the variance accounted for in choice of major was small, with Cox and Snell R^2 = .09 and Nagelkerke R^2 = .12. Predicted success was adequate. Although 78% of the STEM cases were correctly identified, only 50% of the non-STEM cases were predicted. Overall, the classification success rate of the model was 66%.

Table 8 shows the regression coefficients, Wald statistics, statistical significances, and odds ratios for each of the predictors in the final step of the model. Based on Wald criteria from step1, none of the covariates significantly contributed to the model ($ps > .05$). In step 2, none of predictors related to level of exposure to engineering principles in high school classes or through friends and family members were significant ($ps > .05$). The only significant predictor was

Enjmathsci ($p < .01$), which was entered in the final step of the analysis. The odds ratio indicated that students who enjoyed math and science were 2.8 times more likely to pursue a STEM major.

Table 8: *Final Block of the Three-Step Logistic Regression Predicting STEM Major*

	B	*S.E.*	*Wald*	*df*	*p*	*Exp(B)*
JRSR	.445	.298	2.23	1	.135	1.56
Female	.000	.302	.000	1	.999	1.00
Minority	.569	.418	1.85	1	.174	1.77
NCJETSYr1	-.476	.317	2.26	1	.133	.621
Parent4YrDeg	.171	.292	.345	1	.557	1.19
ENETFriends	-.274	.386	.505	1	.477	.760
HSTeachENET	.022	.116	.035	1	.852	1.02
KnowENET	-.156	.323	.233	1	.629	.855
Positive	.351	.629	.312	1	.577	1.42
Interest	.515	.387	1.77	1	.184	1.67
Notwortheff	-.461	.491	.879	1	.348	.631
Enjmathsci	1.05	.350	8.89	1	.003	2.84
Constant	-2.76	1.90	2.12	1	.145	.063

Discussion

Although almost two-thirds of the students were in their first year of NCJETS, they nonetheless had favorable impressions of the engineering profession. Most believed that engineering skills are useful in everyday life and that engineers play an important role in solving society's problems. They also perceived engineers as highly respected by others and they indicated engineering would be an interesting career. More than half of the respondents planned to pursue a STEM major and almost half planned to major in engineering or engineering technology. The majority of the students expressed confidence in their ability to study engineering/engineering technology in college.

At the time of the survey, approximately one-third of the students had not yet taken trigonometry or pre-calculus. Less than half of the students had taken calculus and just over half had taken physics. This is not surprising given that 38% of the participants were in the ninth and tenth grades.

Although exposure to engineering principles in high school classes and through family and friends was a not a significant predictor in the model, it is clear that students are getting information about the profession beyond NCJETS. Most of the students indicated that their teachers had talked to them about engineering or engineering technology. More than half of them had discussed the profession with their parents. Unfortunately, only one-fourth of the students indicated that they had engaged in similar discussions with their high school counselors. The latter suggests that more can and should be done to educate and engage high school counselors. An NSF-sponsored sister project at UNC Charlotte, *Teaching Engineering to Counselors and Teachers (TECT),* was developed to strengthen the way in which high school teachers and counselors approach the integration of engineering-based materials into their courses and counseling.

Based on the sample of students who participated in this study, the only factor that appears to predict choice of a STEM major in college is their enjoyment of math and science in high school. Admittedly, these results are somewhat surprising given the abundance of empirical and theoretical literature related to the recruitment and retention of underrepresented minority and first-generation college students in STEM fields and the influence of students' attitudes about engineering on their persistence in the major.[23,24] Results of the logistic regression suggest that students who enjoy math and science are 2.8 times more likely to pursue a STEM major than other students, independent of gender, ethnicity, grade level, level of parental education, and number of years in NCJETS. This suggests that more should be done to engage all students who enjoy math and science in activities similar to NCJETS. It also suggests that high school math and science teachers need to be educated about engineering so that they can introduce engineering principles and information about the profession into their classes as a way to encourage students to pursue the major.

Limitations

There are several threats to validity that compromise results of these studies. Students were not randomly selected to participate. NCJETS participants likely possess characteristics that predispose them to greater self-confidence in science and math ability and positive attitudes about engineering and engineering technology, particularly since the majority of NCJETS participants were introduced to the profession through the influence of family and/or friends. Survey items were either adapted from a previously validated instrument and/or were specifically developed for the study. Only students who had internet access could participate in the web-based survey. There was no way to verify that those who had completed the survey on-line were actually NCJETS participants. Finally, the under-representation of female and minority students is problematic in any engineering-related study.

Conclusion

Results of the surveys suggest that NCJETS is favorably contributing to students' interests in and attitudes about engineering and engineering technology. However, project personnel need to find more effective ways to promote the benefits and opportunities of a career in engineering or engineering technology to students, parents, teachers, and guidance counselors. Specifically, students must understand the breadth and depth of work involved in the professions and the many contributions that engineers and technologists make in terms of their impact on society. Students who are confident in their math and science skills should be aggressively recruited to participate in NCJETS as they are almost three times more likely to pursue a STEM major than other students.

The comprehensive and integrated nature of the NCJETS, TECT, and COMETS projects at UNC Charlotte address many concerns associated with high school students' decision to pursue STEM majors. Collectively, the projects provide a mechanism whereby students, teachers, and counselors may become involved with the hands-on and theoretical aspects of engineering and engineering technology. NCJETS and TECT actively engage critical stakeholders and are continually evolutionary based on their feedback.

Best practices and lessons learned will be incorporated into the expansion of program concepts. New rural and inner city middle and high schools are currently being added to the program. Innovative facets of the high school model are being adapted for middle school student, parent, teacher, and counselor involvement. The expansion and solidification of the professional and industry alliance is of utmost importance to provide students maximum exposure to the virtually limitless opportunities available, and to ensure sustainability of the projects and institutionalization of project beyond NSF funding.

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