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# **AC 2012-3628: MEASURING FIRST-YEAR ENGINEERING STUDENTS' KNOWLEDGE AND INTEREST IN MATERIALS SCIENCE AND ENGINEERING**

## **Qu Jin, Purdue University, West Lafayette**

Qu Jin is a graduate student in the School of Engineering Education at Purdue University. She received a M.S. degree in biomedical engineering from Purdue University and a B.S. degree in material science and engineering from Tsinghua University in China. Her research focuses on modeling student success outcomes, which include placement, retention, academic performance, and graduation.

## **Dr. Senay Purzer, Purdue University, West Lafayette**

Senay Purzer is an Assistant Professor in the School of Engineering Education and is the Director of Assessment Research for the Institute for P-12 Engineering Research and Learning (INSPIRE) at Purdue University. Purzer has journal publications on instrument development, teacher professional development, and K-12 engineering education. Her research focuses on assessing constructs, such as innovation, information literacy, and collaborative learning.

## **Dr. P.K. Imbrie, Purdue University, West Lafayette**

P.K. Imbrie is an Associate Professor of engineering in the Department of Engineering Education at Purdue University. He holds B.S., M.S. and Ph.D. degrees in aerospace engineering from Texas A&M University. His research interests include educational research, solid mechanics, experimental mechanics, microstructural evaluation of materials, and experiment and instrument design. He has been involved with various research projects sponsored by NSF, NASA, and AFOSR, ranging from education-related issues to traditional research topics in the areas of elevated temperature constitutive modeling of monolithic super alloys and environmental effects on titanium based metal matrix composites. His current research interests include epistemologies, assessment, and modeling of student learning, student success, student team effectiveness, and global competencies; experimental mechanics; and piezospectroscopic techniques.

# Measuring First Year Engineering Students' Knowledge and Interest in Materials Science and Engineering

## Abstract

Previous studies have shown that engineering students were generally not very familiar with Materials Science and Engineering (MSE). However, career decision theories suggest that people need to be both knowledgeable and interested towards a career in order to make an informed career choice. The purpose of this study was to measure first-year engineering students' knowledge and interest in MSE, and to compare the results from students who chose MSE as their major and students who did not. Open ended questions and a Likert-scale survey were used to collect data from 919 first year engineering students. Open coding strategy was used to analyze the patterns of students' answers to open questions and to record frequencies. ANOVA as well as non-parametric statistic tests were used to identify the differences between different groups of students from the Likert-scale survey and frequencies from coding open-ended questions. Among all participants, 23 students expressed an interest in MSE as their first choice. Forty-five students identified MSE as their second choice. Sixty-eight students were randomly selected from students who did not express their interest in MSE as a control group for the qualitative content analysis. The results indicated that: 1) students who chose MSE as their 1st or 2nd choice were significantly more knowledgeable and more interested in MSE than those who did not chose MSE; and 2) first-choice students were significantly more interested in MSE than 2nd-choice students, but the difference in knowledge between 1st-choice and 2nd-choice students was not significant.

## Introduction

Many studies have focused on understanding of students' career decisions to engineering<sup>1-3</sup>. However, very few studies have looked into how students make engineering specialty decisions. Actually, the percentage of engineering students who changed their majors from one engineering specialty to another one is quite high<sup>4</sup>. For example, it has been shown by Walden and Foor that only fifty percent of the industrial engineering senior students enrolled as industrial engineering students at the beginning of their engineering study<sup>4</sup>. The other fifty percent of students switched from other engineering majors.

An important reason for this high percentage of switching in engineering is that the students are not familiar with different engineering specialties when they make the specialty decisions. Moreover, students' familiarity with different engineering specialties was very diverse. Shivy and Sullivan found that engineering students generally reported to be familiar with electrical and mechanical engineering, but not a large percentage of engineering students who did not major in materials science and engineering (MSE) reported to be familiar with MSE<sup>5</sup>. Thus, in this study we are interested in measuring students' knowledge in MSE before they enter different engineering programs, and to compare the results from students who chose MSE as their major and students who did not. The findings would inform high school career advisor, first-year engineering and MSE programs what kind of information and experiences better support students' specialty decision-making processes.

Because of engineering students' low familiarity with MSE, we decided to study MSE as the engineering specialty and focus on students' knowledge and interest towards MSE. But we hope other studies will build on this work by researching and comparing other engineering specialties.

While in many engineering programs students make their decisions when they apply to the program, in some programs students choose their specialty after their attendance of a first-year program. Such programs aim to expose their students to diverse engineering specialties through various courses. The students in this study were enrolled in a first-year program like this. However the implications from this study could also be applied to those programs without first-year programs.

## **Theories of Career Decision Making**

### *Cognitive Information Processing (CIP) Theory*

Cognitive Information Processing (CIP) theory is a theoretical framework that has been widely applied to practical career counseling<sup>6,7</sup>. In CIP theory, there are three key components for wise vocational choices: self-knowledge, occupational knowledge, and career decision making<sup>8</sup>. Self-knowledge includes individual's values, interests, skills, related personal characteristics, etc. Occupational knowledge includes knowledge of specific industries, employers, employment positions, and employer classifications. Career decision making is the process by which an individual integrates his or her self-knowledge and occupational knowledge to arrive at an occupational choice<sup>6,9</sup>. Effective information processing happens only when one has enough information of self-knowledge and occupational knowledge. During the decision making process, both cognitive and metacognitive processes are involved; generic information processing performs at the cognitive level, and knowledge of the information processing performs at the executive metacognition level<sup>9</sup>.

Lack of information about the occupation could lead to difficulties in career decision making. Gati et al. used a career indecision instrument, the Career Decision-Making Difficulties Questionnaire (CDDQ), to build a theoretical taxonomy of career decision-making difficulties<sup>10,11</sup>. Three major factors contributed to career decision making difficulties: lack of readiness, lack of information, and inconsistent information. The lack of information factor consisted of a lack of information about self, occupations, and methods of obtaining information. They found that a lack of information was a major factor impeding career decision making based on 259 Israeli samples and 304 American samples.

CIP theory emphasizes the knowledge of the occupation for one to make career decision. CIP theory also mentions the importance of interest to career decision making.

### *Social Cognitive Career Theory (SCCT)*

Among other theories, social cognitive career theory (SCCT)<sup>12,13</sup> is a robust framework frequently used to investigate career and academic behavior in both college and high school levels in sample of STEM field (engineering:<sup>1,14,15</sup>; computing:<sup>16</sup>). According to SCCT, self-efficacy affects outcome expectations; self-efficacy and outcome expectations are both precursors of interests<sup>17</sup>; and interests, self-efficacy, and outcome expectations predict choice goals jointly<sup>12</sup>. Hackett et al.<sup>18</sup> examined 197 university students majoring in engineering/science, and found that vocational interests was one of the strong predictors of academic self-efficacy, which predicted college academic achievement.

Strong interests generally indicate higher scores and prolonged persistence in STEM majors<sup>1,19-21</sup>. By examining 328 students in an introductory engineering course, Lent et al.<sup>1</sup> claimed that interests have direct impact on choice goals and actions.

SCCT also supports that interest is an effective predictor of career decisions.

## Hypothesis

Two hypotheses are proposed in this study:

Hypothesis 1. First-year engineering students who chose MSE as their first and second choice have more MSE knowledge than those who did not choose MSE.

Hypothesis 2. First-year engineering students who chose MSE as their first and second choice have greater inclinations towards MSE than those who did not choose MSE.

## Methods

### *Participants*

The participants of this study were 919 first-year engineering students who registered at a large Midwestern university during the 2009-2010 academic year. Among the participants, 202 students (22.0%) were female and 717 students (78.0%) were male. Twenty-three students (2.5%) expressed MSE as their first choice of major at the end of the first semester, while 45 students (4.9%) expressed their interest of MSE as their second choice. Sixty-eight students who did not express their interest of MSE (noted as non-MSE students) were selected randomly to match the number of first-choice and second-choice students. Not all students who did not express interest in MSE were analyzed in this study, because the sample size was too large for qualitative analysis. The number of first-choice, second-choice, and non-MSE students was 23, 45, and 68 respectively.

### *Data Collection*

All data were collected through an online system at the end of students' first semester. Students were first asked to write down their first and second preferences of major at that time. Then, students were asked to take a ten-item Likert-scale survey which was designed to measure students' self-reported degree of knowledge and interest in MSE. Last, students were asked to answer an open-ended question: *What is MSE and what do materials engineers do?*

### *Validity & Reliability of the MSE Knowledge and Interest Survey*

The Materials Science and Engineering (MSE) knowledge and interest survey (as shown in Table 1) were used to measure students' knowledge and interest towards MSE. A total of ten items were included. Students were asked to rate how strongly they agreed with these ten statements. Their choices were "Strongly Disagree," "Disagree," "Undecided," "Agree," and "Strongly Agree."

To identify factors that were measured in the knowledge and interest survey, an exploratory factor analysis (EFA) was applied using all participants (N=919). Students' answers to the survey instrument were analyzed using the factor procedure with a promax rotation in SAS 9.2<sup>22</sup>. The number of factors was determined using Kaiser-Guttman rule. This rule suggests that factors with eigenvalues greater than one should be remained<sup>23</sup>. The findings confirmed that this survey measured students' knowledge and interest of MSE as two distinct factors. Table 1 presents how each item was loaded onto these factors.

Items presented in shade measured students' confidence of their knowledge in MSE, thus these items were classified the factor of Knowledge. Similarly, items in light were labeled as factor of Interest. The internal consistency was measured using Chronbach's coefficient alpha. The Chronbach's coefficient alpha was 0.95 for Interest and 0.90 for knowledge. The internal consistency was considered high for both factors<sup>24</sup>.

Table 1. Items, loadings of the items, and Chronbach's coefficient alpha for MSE knowledge and interest survey.

	Factor Loadings	
	Factor 1 Interest ( $\alpha=0.95$ )	Factor 2 Knowledge ( $\alpha=0.90$ )
<b>MSE Knowledge and Interest Survey Items</b>		
Overall, I feel that I am knowledgeable about the field of Materials Science and Engineering.	-0.11	0.84
Overall, I have a strong interest in the field of Materials Science and Engineering.	0.88	-0.02
Overall, I feel that I am knowledgeable about the School of Materials Engineering.	-0.01	0.85
Overall, I have a strong interest in the School of Materials Engineering.	0.91	-0.00
I feel that I am knowledgeable about the coursework in the School of Materials Engineering.	0.16	0.72
I have a strong interest in the coursework for the School of Materials Engineering.	0.84	0.08
I feel that I am knowledgeable about the research opportunities in the School of Materials Engineering.	0.23	0.67
I have a strong interest in the research opportunities in the School of Materials Engineering.	0.84	0.07
I feel that I am knowledgeable about the job opportunities for graduates of the School of Materials Engineering.	0.15	0.72
I have a strong interest in the job opportunities for graduates of the School of Materials Engineering.	0.87	0.06

### Data Analysis

For the data from the *MSE Knowledge and Interest Survey*, analysis of variance (ANOVA) was conducted. To analyze the open-ended questions, we started with an open coding approach. The codes that emerged from this process were emerged based on Ohring's description of materials engineering<sup>25</sup> and our knowledge of MSE. As a result, twelve codes have emerged. Nine codes associated with knowledge of MSE (property, application, structure/scale, types of materials, composition, characterization, process, performance, and nano technology). The other three codes were related to emotions & interests, importance of MSE, and career opportunities.

The frequencies calculate using the emergent codes were statistically analyzed. Mean frequency of each code for each group of students was calculated using the total number of appearances of that code divided by the number of students. A non-parametric test, namely Mann-Whitney-Wilcoxon test, was used to test to compare groups<sup>26</sup>.

## Results

### *Data from the MSE Knowledge and Interest Survey*

The first-choice students rated their interest significantly higher than their knowledge ( $t(44) = 2.60, p < .05$ , two tails). However, students in non-MSE group rated their interest significantly lower than their knowledge ( $t(134) = 2.96, p < .01$ , two tails). For the second-choice student group, this difference was not significant ( $t(88) = .64, p = .52$ , two tails). These results are summarized in Table 2.

For knowledge, the overall ANOVA results showed a significant difference among the three groups of students ( $F(2, 133) = 8.05, p < .001$ ). Tukey's test suggested that first-choice students had significantly higher knowledge than non-MSE students, and second-choice students also had significantly higher knowledge than non-MSE students. However, the difference between first-choice and second-choice groups was not significant at the .05 level. For interest, the overall ANOVA results also showed significant differences among the three groups of students ( $F(2, 133) = 46.53, p < .0001$ ). Tukey's test results suggested that there was significant difference between any pair of the three groups of students.

*Table 2. Mean scores and standard deviations of knowledge and interest from the MSE Knowledge and Interest Survey*

	N	Knowledge		Interest	
		Mean	SD	Mean	SD
First Choice Students	23	3.57	0.76	4.16	0.78
Second Choice Students	45	3.43	0.71	3.52	0.67
Non-MSE Students	68	2.89	0.99	2.39	0.98
All Participants	919	2.83	0.90	2.44	0.98

### *Data Collected from the Open-Ended Questions*

A mixed method approach was used to test the difference of first-choice, second-choice, and non-MSE students from their answers to the open-ended questions. Nine codes were identified for knowledge: property, application, structure/scale, types of materials, composition, characterization, process, performance, and nano technology. The mean frequencies and their standard deviations of the codes represented how frequently students mentioned the codes of knowledge defined by us. It can be seen from the table that properties, application, and structure/scale of materials were three most frequently appearing codes in the answers of students.

The sum of the frequencies of the codes in Table 3 was the mean frequency of knowledge. The difference of mean frequencies of knowledge for the three groups of students was tested using Mann-Whitney-Wilcoxon test. Results were consistent with the findings from the survey: Significant differences were found between first-choice and non-MSE students ( $\chi^2(1, N = 91) = 6.82, p = .09$ ) as well as between second-choice and non-MSE students ( $\chi^2(1, N = 113) = 7.18, p = .007$ ). However, the difference between first-choice and second-choice students was not significant ( $\chi^2(1, N = 68) = .25, p = .62$ ). These results further confirmed the validity of the MSE Knowledge and Interest Survey.

Another three codes were also identified from students' answers to the open-ended questions: emotion & interest, importance, and opportunities. Table 3 summarizes the mean scores and their standard deviations of these codes. Tests of difference were not applied to these scores because of the low frequencies involved. The emotion & interest score represented students' inclinations or dislikes towards MSE. If a student expressed a strong proclivity for MSE, the student was counted as positive one. If a student exhibited aversion to MSE, the student was scored as negative one. Students with neutral opinions received zero on this scale. Importance of MSE involved importance of MSE to everyday life and importance of MSE to other engineering disciplines. Opportunities involved job opportunities and research opportunities.

*Table 3. Mean frequencies and their standard deviations of codes of knowledge from open-ended questions. The codes were sorted according to the mean frequencies of all students in the three groups.*

Code	First-Choice Students (N=23)		Second-Choice Students (N=45)		Non-MSE Students (N=68)		Three Groups (N=136)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Emotions & Interests	.17	.39	.02	.15	-.01	.40	.03	.34
Importance	.22	.42	.22	.47	.21	.41	.21	.43
Opportunity	.22	.42	.07	.25	.12	.41	.10	.34

First-choice and second-choice students had positive average scores on the emotions & interests scale. They tended to express "good" words on MSE. Students who did not choose MSE had negative average score. Some used neutral words and some even expressed their dislike towards MSE. This finding was consistent with the results from the Likert-scale survey.

It was also found that regardless of what major they chose, students were aware of the importance of MSE to people's everyday life and to other engineering majors. We also looked at the frequency of opportunity, since it is an important factor in social cognitive career theory (SCCT). First-choice students appeared to be more aware of the job and research opportunities of MSE majors than second-choice students and no-MSE students.

## Conclusions

In this study, open-ended questions and a valid and reliable survey (MSE knowledge and interest survey) was used to measure differences on knowledge and interest on MSE from first-choice, second-choice, and non-MSE students. The results from both open-ended questions and Likert-scale survey suggested that the difference on knowledge was significant between MSE-choice and non-MSE students. Not significant difference was detected between first-choice and second-choice students. The results supported the Cognitive Information Processing theory, which emphasized the importance of career knowledge to career choice. Data from the survey suggested that the difference on interest was significant between any two groups of students. The

results supported the Social Cognitive Career Theory, which summarized that interest was an important element in career choice.

The recommendation is that MSE programs should work with high school and first-year programs to provide students with enough opportunities to understand their interest and to get students to know MSE before specialty decisions.

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