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Evaluating Student Conceptions of Technology Majors: Development of Assessment Keyword Tables

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Abstract
This paper presents the continuation of research on student conceptions related to technology majors (TMs) and careers using the Aspirations, Interests, and Confidence (AIC) survey. For four years, first-semester students at Purdue New Albany, a statewide location for the Purdue Polytechnic, were surveyed in order understand their conceptions of TMs and job titles they associate with them. Prior work reported on dominate terms used by students to describe TM and careers including: Computer Graphics Technology (CGT), Electrical Engineering Technology (EET), Mechanical Engineering Technology (MET), and Manufacturing Engineering Technology (MHET). This paper presents the results of an online survey that asked subject matter experts (SMEs) to form benchmark definitions for the aforementioned TMs. Qualitative data from the responses (i.e. structured survey text) was analyzed using NVivo® to identify themes, patterns, and dominate terminology. The data was combined with information from ABET accreditation documentation and a collaboratively edited online knowledge base to form tables of subject, action, and application keywords. These tables provide an empirical database that will enable future evaluation of collected student definitions for accuracy. By better understanding student understanding of TMs, the authors hope to provide a resource by which the educational community can improve their messaging and better communicate the role and value of technology degrees to stakeholders (i.e. students, parents, industry, etc.).

I. Introduction

Much of the research into student motivation relating to choice in science, engineering, technology, and math (STEM) majors share an underlying assumption: selection is largely based on a correct conceptual understanding of the major [1]. However, little to no evidence exists to support this assumption, particularly at the point in time when students are choosing which colleges and majors to pursue [1]. Therefore, a greater understanding of student conceptions of STEM majors would have implications in student recruitment and retention, and may also help to further our understanding of accessibility issues such as racial, socioeconomic, gender disparity, etc. In their previous work [1], the authors presented the Aspirations, Interest, and Confidence (AIC) survey, a research tool designed to investigate the aforementioned issues. The AIC collects information regarding students' conception of four technology majors (TMs): Computer Graphics Technology (CGT), Electrical Engineering Technology (EET), Mechanical Engineering Technology (MET), and Mechatronics Engineering Technology (MHET). The survey asks students to identify with a technology identity framework (e.g. technology entrepreneur, social activist, etc.), list what they expect their first job title to be upon graduation, and to write a short definition of each of the TMs, including a self-rating of their confidence in the accuracy of the provided definitions.

The AIC was distributed to all first-year students enrolled at Purdue University New Albany for the past four years: academic years (AY) 16/17 to 19/20. By using a gateway to technology course offered in the fall semester, the researchers have gathered data from students who have chosen TMs but have not yet been significantly influenced via participation in post-secondary instruction. Over this time, 112 students met the study inclusion requirements of first-semester students majoring in either CGT, EET, MET, or MHET. Previous analysis of AYs 16/17 to 18/19 showed that student choice in major is primarily related to personal curiosity in the subject matter. However, the authors have thus-far been unable to assess the accuracy, as commonly accepted by the educational community, of the student provided definitions. Thus, reporting has been limited to the commonly occurring terms or themes and confidence ratings for each given definition [1],[2].

This paper reports on the initial efforts in developing an empirically based assessment tool, which could be used in future research to rate the accuracy of given student definitions on the AIC survey. The accuracy assessment tool will be based on the formation of keywords tables: lists of terms or short phrases commonly used to describe the TMs. The tables were divided into three categories of keywords: subject (i.e. describe the specialty topics associated with TMs), action (i.e. describe the behaviors commonly demonstrated or engaged in TMs), and application (i.e. describe the hands-on or applied role associated with TMs). Robustness of the keyword tables is improved by utilizing three sources: ABET accreditation documentation, a collaboratively edited online knowledge base (i.e. Wikipedia), and data from a survey of subject matter experts (SMEs) from the post-secondary education community.

II. ABET: Keyword Table Generation

Due to its focus on accreditation, ABET defines educational programs by describing the curriculum requirements for each major. For example, the description provided in Section II: Program Criteria for Accrediting Engineering Technology Programs [3] for programs containing electrical and/or electronic(s) or other similar titles is:

> …prepare graduates to have competence in the following curricular areas:
> (a) the application of circuit analysis and design, computer programming, associated software, analog and digital electronics, and microcomputers, and engineering standards to the building, testing, operation, and maintenance of electrical/electronic(s) systems;
> (b) the application of natural sciences and mathematics at or above the level of algebra and trigonometry to the building, testing, operation, and maintenance of electrical/electronic systems;
> (c) the ability to analyze, design, and implement one or more of the following: control systems, instrumentation systems, communications systems, computer systems, or power systems;
> (d) the ability to apply project management techniques to electrical/electronic(s) systems; and
> (e) the ability to utilize differential and integral calculus, as a minimum, to characterize the performance of electrical/electronic systems.

Section II also provides descriptions for mechanical and electromechanical (closest synonym to mechatronics) related programs. However, the document does not provide a description for computer graphics. Table 1 presents keywords/phrases extracted from the ABET program criteria for EET, MET and Electromechanical (MHET). Keywords were manually coded by the authors via review of the program criteria.

TABLE 1.
KEYWORDS FROM ABET PROGRAM CRITERIA DESCRIPTIONS BY MAJOR

Keyword Categories	EET	MET	MET
Subject	Analog, Circuit, Computer (System), Communication (System), Control (System), Digital, Electrical, Electronic, Instrumentation (System), Microcomputer, Power (System)	Codes, Dynamics, Fluids, Heat, Manufacturing, Material, Measurement, Mechanics, Statics, Thermal	Analog, Circuit, Computer, Control (System), Digital, Dynamics, Electromechanical, Electronic, Fluid, Materials, Mechanics, Network, Software, Statics, Standards
Action	Analyze, Apply, Build, Characterize, Design, Implement, Maintain, Manage, Operate, Test	Apply, Calibrate, Communication, Design, Dimension, Draft, Implement, Select, Test, Tolerance	Analyze, Characterize, Design, Investigate, Manage, Operate, Troubleshoot

No application keywords were identified

III. Wikipedia: Keyword Table Generation

Wikipedia is a collaborative online encyclopedia. Community volunteer editors work on pages such that the quality and accuracy of the pages is increased by the collective opinion of the group (i.e. crowdsourcing). The Wikipedia page dedicated to EET [4] describes it as:

> Electrical/Electronics engineering technology (EET) is an engineering technology field that implements and applies the principles of electrical engineering Like electrical engineering, EET deals with the "design, application, installation, manufacturing, operation or maintenance of electrical/electronic(s) systems." However, EET is a specialized discipline that has more focus on application, theory, and applied design, and implementation, while electrical engineering may focus more of a generalized emphasis on theory and conceptual design. Electrical/Electronic engineering technology is the largest branch of engineering technology and includes a diverse range of sub-disciplines, such as applied design, electronics, embedded systems, control systems, instrumentation, telecommunications, and power systems.

Wikipedia also provides a description for MET [5], but does not provide a page for MHET or CGT (or related synonyms). Table 2 presents keywords extracted from the EET and MET pages. Keywords were manually coded by the authors via review of the pages.

TABLE 2.
KEYWORDS FROM WIKIPEDIA PAGES BY MAJOR

Keyword Categories	EET	MET
Subject	Electrical, Electronic, Embedded (System), Control (System), Instrumentation, Telecommunication, Power (System)	Machine, Product, Material, Aerospace, Automotive, Nuclear, Petroleum, Industry

Action	Install, Manufacture, Operate, Maintain, Design	Application, Design, Process, Manufacture, Lab
Application	(Focus on) Application, (Focus on) Implementation, Applied Design, Applied Principles, Lab	Less Theoretical, Applications Based

IV. Subject Matter Experts: Keyword Table Generation

The third source of keywords came from SMEs drawn from the post-secondary education community who were associated with technology majors. The original AIC survey [1] was converted from a paper survey into an online Qualtrics survey, while still utilizing a mixed method format to collect quantitative and qualitative data. The survey consisted of three sections: 1) demographic data and classification data related to academic credentials and rank, 2) TMs offered at the SME institution, and 3) self-reported definitions of CGT, EET, MET, and MHET and confidence rating for each given definition. Respondents were not required to provide definitions for each TM.

A. Methodology

The survey was distributed to SMEs in the summer of 2019. The SMEs were identified at academic institutions via programmatic accreditation data from ABET [5] [6] and the Association for Technology Management and Applied Engineering (ATMAE) accredited B.S. technology programs in the United States. Institutions from the combined data sets were then searched using www.google.com using the terms *school name* and *engineering technology* or *computer graphics* to locate a departmental website and faculty directory. The directory information was manually searched to identify SMEs using the following titles: chair, department head, and/or program coordinator. In some cases, the search was expanded to include dean if the former search terms failed to produce a SME. The survey was then distributed to the 109 SMEs via email.

The survey data was downloaded as an Excel database and formatted for analysis using NVivo, similar to the methodology in the authors' previous works [1],[2]. The data was first analyzed by filtering by confident and non-confident responses for each TM definition given. In other words, all responses were filtered to produce data sub-sets by TM, represented by respondents who reported a confidence rating of greater than or equal to four or a confidence rating of less than or equal to three on a 5-point Likert scale (1 = really not confident to 5 = really confident). This produced eight data sub-sets: CGT confident, CGT not confident, EET confident, EET not confident, MET confident MET not confident, MHET confident, and MHET not confident. The filtered data sets were further analyzed by descriptive statistics of the word count of the definitions and the dominant terms and themes used in the definitions (see Tables 5, 6, and 7). The 10 most common exact matches, stem words, or synonyms are shown. As reported in Tables 1 and 2 for ABET and Wikipedia sources respectively, the keywords are split between subject, action, and applied categories. Words contained within the name of the major (e.g. electrical, engineering, and technology) were excluded from the keyword queries.

B. Results

1) Demographics

Of the 109 SMEs surveyed, 25 (23%) provided complete responses to the online survey (see Table 3). The majority of the survey respondents were White Non-Hispanic (84%), males (80%), and between the ages of 35 and 64 (88%). Regarding professional qualifications, 100% of respondents reported having a Master's degree (40%) or Doctoral degree (60%), and 20 respondents (80%) reported having 10 or more years of experience in postsecondary education. Represented institutions are primarily located in the Midwest (32%) and Northeastern (28%). Only 4% reported having a CGT program, while 80%, 76%, and 24% reported having an EET, MET, and MHET program respectively.

TABLE 3.
SME DEMOGRAPHIC PROFILE

Demographic	**Count**
Sex	
Male	20
Female	5
Other	0
Ethnicity	
White Non-Hispanic	21
Black or African American	2
Hispanic or Latino	1
American Indian or Native	0
Asian or Pacific Islander	1
Other	0
Age	
25-34	1
35-54	9
55-64	13
65+	2
Education	
Bachelor's Degree	0
Master's Degree	10
Doctoral Degree	15
Experience[1]	
2 years or less	0
2-10 years	5
10-20 years	8
20 or more years	12
Location	
Midwest	8
Northwest	7
Southeast	3
Southwest	4
West	3
TMs Offered	
CGT	2
EET	20
MET	19
MHET	6

[1] years in post-secondary education

Table 4 summarizes given definitions by confident and not confident responders and whether a definition was provided. Not all respondents provided definitions for all TMs surveyed, and some gave confidence ratings without providing a definition. Of significance is the respondents who both provided a definition and rated their definition as confident. EET and MET both had high numbers of respondents reporting confident definitions (at 80% each), indicating widespread perceived understanding of these majors. CGT and MHET had much lower number of response rates for confident definitions (CGT = 4% and MHET = 32%), indicating that the sample SME population reports less confidence in their knowledge of these majors.

TABLE 4.
CONFIDENT AND NOT CONFIDENT RESPONDERS BY MAJOR

Major	Defined (Count)	Undefined (Count)
CGT		
Confident	1	0
Not Confident	6	5
EET		
Confident	20	0
Not Confident	1	1
MET		
Confident	20	0
Not Confident	2	1
MHET		
Confident	8	0
Not Confident	0	3

2) CGT Definition Responses

As only one respondent to the AIC survey provided a definition rated as confident, statistical analysis of the responses was not performed. The provided definition was:

> CGT majors use print, photography, video, and interactive multimedia as problem-solving tools in a variety of work settings. With solid preparation and study in each of these areas, the major is complemented by a core of business and liberal arts classes, which differentiate REDACTED's program from most others of its kind. The major also offers a combination of theory and hands-on practice, including the opportunity to work with personable faculty who are committed to ensuring each student's success.

3) EET Definition Responses

Table 5 reports the number of instances a keyword was used and the percent of responses that used that keyword within confident EET definition responses. The average length provided for EET definitions was 29 words, with a standard deviation of 18 words. The minimum definition length was four words, and the maximum definition length was 68 words.

TABLE 5.
EET KEYWORD FREQUENCIES

Keyword Categories	Keyword	Similar Keywords	Count	Responses (%)
Subject	Control	Controller, Controls	15	75
	Electronics	Electronic	11	55

	Systems	System	10	50
	Automation	NA	6	30
Action	Operate	Operate, Run, Work	14	70
	Design	Designed, Designs	10	50
Application	Skills	Proficiency, Proficient	10	50
	Hands-on	Workforce	7	35
	Apply	Applied, Applying, Practical	13	65
	Technical	NA	5	25

4) *MET Definition Responses*

Table 6 reports the number of instances a keyword was used and the percent of responses that used that keyword within confident MET definition responses. The average length provided for MET definitions was 34 words, with a standard deviation of 17 words. The minimum definition length was six words, and the maximum definition length was 69 words.

TABLE 6.
MET KEYWORD FREQUENCIES

Keyword Categories	Keyword	Similar Keywords	Count	Responses (%)
Subject	Manufacturing	Fabricate, Fabrication, Manufacture	15	75
	System	Systems	10	50
	Foundation	Fundamental, Base	9	45
Action	Design	Designing, Designers	16	80
	Make	Making, Develop	11	55
	Process	Processing, Operate	8	40
Application	Apply	Applies, Applying	16	80
	Hands-on	Workforce	8	40
	Technical	NA	5	25
	Practical	NA	5	25

5) *MHET Definition Responses*

Table 7 reports the number of instances a keyword was used and the percent of responses that used that keyword within confident MHET definition responses. The average length provided for MET definitions was 32 words, with a standard deviation of 20 words. The minimum definition length was seven words, and the maximum definition length was 66 words.

TABLE 7.
MHET KEYWORD FREQUENCIES

Keyword Categories	Keyword	Similar Keywords	Count	Responses (%)
Subject	Mechanical	NA	11	100
	Systems	System	10	91
	Electrical	NA	5	45
	Programming	NA	5	45
	Robotics	NA	4	36
	Electromechanical	NA	3	27
Action	Operation	Operate	10	91
	Design	Designing	7	64
	Integrate	Integrating, Integrate	4	36

Application	Applied	Apply	5	45

V. Inter-source Comparison of Keyword Tables

Comparison of the keyword tables between the three data sources reveals that ABET consistently uses more keywords to describe the TMs than either Wikipedia or the SMEs. For example, the ABET program criteria contains 11subject, 10 action, and zero applied keywords for EET. Wikipedia includes seven subject, seven action, and five applied keywords. From the SME population, both the top five action and subject keywords by count were contained in 25% or more of responses. All three sources also frequently utilize the modifier system when describing both the subject and action keywords. One important distinction are keywords related to *application* or *hands-on* nature of TMs. While applied keywords appear frequently in both the Wikipedia and SME data, they are not found in the ABET criteria. Similar patterns for keyword frequency and application orientation are present for MET (considering all three sources) and MHET (considering only ABET and SMEs). No CGT analysis is possible due to the lack of data from all three sources. Tables 8 synthesizes the three keywords sources into a single table by the frequency of keywords reoccurring in multiple sources and by TM.

TABLE 8.
KEYWORD SOURCE FREQUENCY BY CATEGORY

# of Sources	Subject	Action	Application
Three			
EET	Electronic	Design Operate	
MET		Design	
MHET			
Two			
EET	Communication (System) Control (System) Instrumentation (System) Power (System)	Maintain	Application of
MET	Manufacturing Material	Process Manufacture (Make)	Apply
MHET	Electromechanical Mechanics	Design Operation	
One			
EET	Analog Automation Circuit Computer (System) Digital Embedded (System) Microcomputer System	Analyze Apply Build Characterize Manage Manufacture Install Test	Applied Design Applied Principles Hands-on Implementation Lab Technical
MET	Aerospace Automotive Codes Dynamics Fluids Foundational	Calibrate Communication Dimension Draft Implement Select	Less Theoretical Hands-on Technical Practical

	Heat	Test	
	Industry	Tolerance	
	Machine		
	Measurement		
	Mechanics		
	Nuclear		
	Petroleum		
	Statics		
	Systems		
	Thermal		
MHET	Analog	Analyze	Applied
	Circuit	Characterize	
	Computer	Investigate	
	Control (System)	Manage	
	Digital	Operate	
	Dynamics	Troubleshoot	
	Electrical		
	Electronic		
	Fluid		
	Materials		
	Network		
	Programming*		
	Robotics		
	Software		
	Statics		
	Standards		
	Systems		

Words contained within the name of the major (e.g. electrical, engineering, and technology) were excluded
*Referring to the subject of learning programming.

VI. Next Steps: Keyword Power Ratings and Definition Scoring Rubric

Table 8 has significance in that it was derived from multiple creditable sources and provides an ordered dataset by which collected student definition could eventually be evaluated by. However, it cannot be used directly to evaluate or score student definitions for accuracy as is. The remaining issues are as follows:

1. How to score the use of keywords within a definition.
2. How to objectively determine definition accuracy with given score.
3. How to account for score weight between keyword categories.

To address issue one, the authors suggest a three-step process. First, keywords in Table 8 will be assigned a power rating. If repeated in three of three sources the keyword will be given a power rating of strong – 3 points (e.g. electronic and design), in two of three sources medium – 2 points (e.g. maintain and manufacturing), and in one of three sources low – 1 point (e.g. applied). Second, to score a student definition, the evaluator assigns the correct power rating (i.e. 3, 2, or 1 point) for each keyword used. This will result in three keyword power scores for each definition given: subject score, action score, and application score. Third, the keyword power scores will be used to evaluate definition accuracy using the definition accuracy rubric shown in Table 9.

To address issues two and three, the authors suggest scoring all SME provided definitions to serve as a training set. First, every definition (i.e. both confident and non-confident responses) will be assigned a subject, action, and application power score. Second, descriptive statistical analysis on the power scores will be performed and the numeric values for a-j shown in Table 9 entered.

TABLE 9.
DEFINITION ACCURACY RUBRIC

Keyword Categories	Good	Acceptable	Poor
Subject	Power Score > a	a > Power Score > b	b > Power Score
Action	Power Score > e	e > Power Score > f	f > Power Score
Application	Power Score > i	i > Power Score > j	j > Power Score

$$\textbf{Final Score} = \frac{(\text{m}*\text{Subject Score} + \text{n}*\text{Action Score}+\text{o}*\text{Application Score})}{3} * 100\%$$

VII. Conclusions

This study explored the descriptions of TMs given by ABET, Wikipedia, and SMEs from the post-secondary education community via word-frequency analysis to develop frequency tables of keywords for future evaluation of student responses to the AIC survey. The results are significant in that they provide the first step towards the development of objective evaluation tools to determine student understanding of TMs according to 1) their ability to identify specific sub-disciplines within the major, 2) their understanding of how ET is practiced, and 3) the differentiation between theoretical and applied (hands-on) learning methods. Development of such a tool will provide a new method to better understand how potential students understand TMs, information that has potential implication for recruiting and accessibility efforts. The authors have also identified that the next steps in the development of the empirically based assessment tool is the production of keyword power ratings and a definition accuracy rubric via the use of the SME data as a training set.

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