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Application of and Preliminary Results from Implementing the First-Year Introduction to Engineering Course Classification Scheme: Course Foci and Outcome Frequency

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Application of and Preliminary Results from Implementing the *First-Year Introduction to Engineering Course Classification Scheme*: Course Foci and Outcome Frequency

Introduction

First-year programs nationwide typically feature an introductory curriculum featuring a semester or yearlong "Introduction to Engineering" course or sequence. Examining a number of these courses shows that the content can vary significantly. For example, one course could focus on MATLAB programming while another course could emphasize technical communication. Most courses are a combination of these topics to varying degrees; therefore, an NSF-sponsored project to classify these courses was conducted which resulted in the *First-Year Introduction to Engineering Course Classification Scheme*.[1] This taxonomy allows programs or instructors to quantify the content of their course(s) using the scheme. As a result, the scheme has proven useful in comparing between institutions or between sections of a course within one program.

The taxonomy was tested during a workshop at the First Year Engineering Experience (FYEE) Conference in 2013. Participants of the study included first year instructors who were responsible for using the classification scheme in order to classify the first year course that they had previously taught.

This paper will detail results of analyzing courses with a preliminary catalog of course objectives found in these Introduction courses. This analysis is a step toward an eventual goal of determining a method to make meaningful comparisons between courses or sections. Moreover, descriptors of courses such as "design heavy" that can be determined using the scheme, operationally defined as course foci, are also desirable.

Background

The Classification Scheme

The *First-Year Introduction to Engineering Course Classification Scheme* is a taxonomy that was developed to allow an instructor to describe his or her course using a common tool. Among other uses, the scheme is an ideal tool for accurately awarding credit to transfer students.[2] The scheme outlines a finite list of outcomes that are commonly found in a first year engineering course that are organized using a coding system. The process in which one utilizes the taxonomy to describe a course will be called "classifying a course."

Courses are intended to be classified individually; however, programs that divide the first year experience into multiple interdisciplinary courses (e.g. Intro to Engineering 1 & 2) can combine the results of each classified course in order to gain a full description of the program. To classify a course, users of the scheme will 'check' each outcome covered in the section or course, leaving those that are not covered unchecked. Each of the outcomes are sorted under eight primary aspects (main outcomes) that are denoted by a four-letter code; an outcome that falls under a main outcome is assigned a Roman numeral. Sub-outcomes related to an outcome are given a letter. Finally, specific outcomes are given a number.[1] This relationship is illustrated in Figure 1.

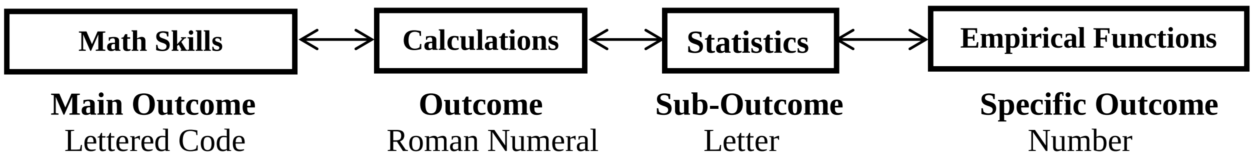

Figure 1: Specifying an Outcome Using the Scheme

To illustrate, Calculations, which is under Math Skills, is denoted as follows:

Main Outcome MATH, Outcome IX, Sub-Outcome A, Specific Outcome 1.

In terms of this classification method, this piece's ID would be MATH IX.A.1. If there is no need for Sub-Outcomes or Specific Outcomes, then a zero is used as a placeholder to preserve structure. For example, "Types of Engineering" is outcome IV under the main outcome Engineering Profession. "Types of Engineering" has no Sub-Outcomes or Specific Outcomes; therefore, this outcome is given the code ENPR.IV.0.0.[1]

In some cases, topics may satisfy more than one outcome. In such an event, then the ID will be given a superscript and the outcome itself is referred to as a *tied outcome*. For instance, "Academic Integrity" (ACAD.IV.0.0) was identified as being related to "Ethics" during the development of the taxonomy (PROF II.0.0); therefore, these two outcomes are *tied*. The criteria for marking the additional outcome is found in the "Additional Information" section on the check sheet. In the case of "Academic Integrity" and "Ethics," the ethics behind dishonesty in the workplace must addressed in addition to the ethics of academic integrity in order for both to be marked.[1] Tied outcomes are, in many cases, suggested relationships in order to encourage the complete and accurate classification of a first year engineering course.

Current Revisions

The version of the classification scheme used in this study was a July 30th, 2013 revision, just prior to the workshop in which data was collected. After this study, slight revisions were made to improve the classification scheme. Few major changes were made; in fact, none changes fundamentally changed the scheme.[2] These changes were as follows:

(1) Grand Challenges (GRCH) was renamed as Global Interest (GLIN) and outcomes were reorganized to better suit the renaming. It was deemed unnecessary to explicitly list each of the Grand Challenges individually. During the data analysis, it became clear that if coverage of the Grand Challenges was included, they were typically taken as a unit. Topics related to the National Academy of Engineering's Grand Challenges were collapsed under one outcome, namely "Grand Challenges" (GLIN I.0.0).

(2) Latent Curriculum/Soft Skills (SOFT) was appropriately renamed as Professional Skills / Latent Curriculum (PROF) due to the negative perception of the term “soft skills.” None of the outcomes in the category were changed.

(3) Academic Advising (ACAD) was renamed as Academic Success (still designated ACAD) to better describe the topics this main outcome contains.

(4) “Modeling” (formerly DESN I.A.1) was further broken down into “Mathematical Modeling” (DESN I.A.1) and “Physical Modeling” (DESN I.A.2) due to questions on what constituted “modeling” as an outcome.

(5) “Entrepreneurship” (PROF VII.0.0) was added under the main outcome, Professional Skills / Latent Curriculum.

(6) “Sustainability” (GLIN II.D.0) was added under the main outcome, Global Interest.

(7) “Design” (ESTT.II.C.0) was renamed as “Computer Aided Design” (ESTT.II.C.0) for clarification within the Engineering Specific Tech/Tools category.

To summarize, the eight main outcomes are as follows: Communication (COMM), Engineering Profession (ENPR), Math Skills and Applications (MATH), Design (DESN), Global Interest (GLIN), Professional Skills / Latent Curriculum (PROF), Academic Success (ACAD), and Engineering Specific Technology/Tools (ESTT). From here on, only the new terms will be used.

Initial Use of the Classification Scheme

The *Classification Scheme for First Year Engineering Courses* has served as a catalyst for discussion on revision to existing curricula in the first year in a few American institutions. One Midwest university in particular reported on a self-study exercise in which each section of the course was classified. The intent was to use the classification scheme as a tool to pinpoint potential gaps among sections of a common course.[3] This exercise was performed for six different courses that were part of two main tracks: a standard introductory sequence and an honors sequence. Professors and teaching assistants were instructed to classify their section of “Introduction to Engineering” and found widespread agreement in most areas within most to all sections, but also identified some discrepancies in topics that were only covered in a subset of sections. A simple three-color coding system was implemented to gauge the degree of agreement between evaluators. Green denoted that the items were addressed in all sections of one or more courses, yellow denoted items that were inconsistently marked, and red indicated that the item was not addressed in the course sequence.[3] The collection of codes for the sub-outcomes for each main outcome (Figure 2) was accompanied by a summary of the findings and recommendations for changes to the current first year curriculum.

		[redacted]	[redacted]	[redacted]
Comunication	Yes, Maybe, No	# of 3	# of 4	# of 4
Professional				
Client Interactions	M [redacted]	0	0	2
Written				
Reports				
Lab	Y [redacted]	0	4	4
Documentation	Y [redacted]	0	3	4
Engineering	Y [redacted]	0	1	4
Email Writing	N	1	0	0
Resume	Y [redacted]	3	0	0
Oral and Visual				
Presentations	Y [redacted]	0	3	3
Visual		B		
Posters	Y [redacted]	0	0	3

Figure 2: Color Coding Based on Application of the Scheme for Communication[3]
[Note: specific course numbers were intentionally blurred]

In a debriefing conference call with the investigators and course coordinators, one point of interest was noted – the meaning and value of a "covered" mark (or "checked" objective) in the scheme.[2] It is possible that pedagogical differences in the classroom and the subjective nature of depth of coverage with respect to the binary "covered or not covered" system utilized by the scheme could contribute to variability. Including a more standardized measure of what constitutes "coverage" of an outcome is expected to contribute toward remedying this issue and reducing unintended variability between sections.[2]

Framework of Study

The methodology employed in this study is a combination of two different analyses, described as *by course* and *by outcome analysis*. An analogy can be drawn: consider *by course* analysis as a top down summary of one particular course's coverage while *by outcome* as a bottom up approach that involves examining each outcome individually. For both analyses, a sample of 28 classified courses from 24 different institutions were used from an NSF sponsored workshop at the FYEE Conference in Pittsburgh in 2013.

By Course Analysis

Content of a first year engineering course is often conveyed by means of a syllabus (often common among sections of a course) or listing in the university catalogue; however, a more standardized, complete means of displaying a course's content would be useful when making comparisons to Introduction to Engineering courses at other universities. This idea of displaying results of a classified course is an issue of data presentation and finding the best method of interpreting the results.

The data produced by a classified course is multivariate, so a plot that enables the presentation of such data is expected to be useful. While a few methods of displaying this kind of data exist, Chambers et al. discussed star plots (or radar charts) in particular as a method of presenting these types of multivariate observations.[4] By construction, the number of variables is arbitrary where for each observation, a ray of some length is plotted along the corresponding variable's axis. To ensure there is value in the shape generated by connecting the endpoints of the observations, a meaningful order must be assigned.[5] Further, some sense of scaling must be determined in order to compare coverage between the eight main outcomes.

Upon determining the order of the variables and correct scaling, the proper use of a star plot helps us to answer three prevailing questions: (1) Which variables are dominant for a given observation? (2) Is there a natural clustering of observations? and (3) Are there any observations that are also outliers? [6]

(1) *Which variables are dominant for a given observation?*
This question is related to what the investigators operationally define as *course foci*. Foci are defined to be areas in which content is heavily centered, thus foci would emerge as dominant variables in the radar chart. Although course foci were not originally envisioned during the development of the scheme, an implied result of classifying a course could be the ability to determine the foci of a classified course. Much of the work to describe course foci visually and mathematically is to formalize the descriptive power that foci contain.

(2) *Is there a natural clustering of observations?*
Drawing inspiration from the dominant variables, courses with similar *course foci* could be clustered and given appropriate names for organizational purposes. Given a large enough sample, the number of *types* of engineering courses could be determined.

(3) *Are there any observations that are also outliers?*
As a result of finding clusters, one could easily determine where any new observation, a classified course, could find its proper *type*.

By Outcome Analysis

While *by course analysis* is satisfactory for providing a general overview of a given first year engineering course, the raw data used to produce the radar charts is useful as well. A picture of the data is not as clear, but examination of the frequency in which particular outcomes are marked enables refinement and validation of the current construction of the taxonomy. Currently, the classification scheme is designed to mark outcomes using a binary system. For example, if "e-Portfolios" is covered in "Engineering 1," then that outcome receives a checkmark (or a 1). On the other hand, if "e-Portfolios" is not covered, then the outcome is not checked (or is given a 0). As mentioned from the applications of the scheme, plans to incorporate depth of coverage are currently in place. This would likely be accomplished by means of a scale to indicate how deeply each topic is covered or a box for the user to indicate what percentage of the course is dedicated to a specific topic.

While the binary system does not imply any depth of coverage, it does suggest that the user of the scheme perceived the existence of *enough* coverage for an outcome. In the context of *by outcome analysis*, determining the frequency in which the various outcomes are marked collectively in the sample was of particular interest. Courses classified multiple times do not introduce a confounding variable as it has been shown that variance in course content does exist not only between universities, but between sections offered at the universities as well.[3] In this sample, instructors from the same university classified different courses, so the variable associated with overlap is not an issue.

After the 28 courses in this study were classified, the total number of times a particular outcome was marked was recorded on a separate document. Once each outcome was scored, the five number summary (minimum, first quartile, median, third quartile, and maximum) was calculated for each of the eight main outcomes. Each outcome was color-coded with respect to the quartile that the value belonged to in the data set. The system used in the coding process is described in Table 1:

Table 1: Coding Method

Value = Minimum	Red
Minimum < Value ≤ Q1	Orange
Q1 < Value ≤ Median	Yellow
Median < Value ≤ Q3	Light Green
Q3 < Value ≤ Maximum	Dark Green

The dark green outcomes were the most reported as covered in an "Introduction to Engineering" course based on this data pool while the red outcomes were the least addressed. From here, a generic "Introduction to Engineering" course for this sample could be constructed using the dark green outcomes as the guiding content.

Data Analysis

We will begin with *by course analysis* and discuss methods of presenting the data, then move on to *by outcome analysis* in order to examine the frequency in which individual outcomes were marked.

By Course Analysis

Appendix A contains the raw data used in this analysis. While the raw scores are useful for comparisons, the number of outcomes in each of the eight main outcomes are not equal. Because of this variation in the number of course outcomes per main outcome, a simple conversion was used in order to simplify comparisons by avoiding the exclusive use of decimals (1):

$$\text{Adjusted Score} = 10\left(\frac{\text{raw score}}{\text{number of outcomes}}\right) \quad (1)$$

The scaling allows for slightly better visual comparisons between courses through shapes and size. Note that optimal ordering and proper scaling of the main outcomes remains under investigation and the order as presented in this paper serves as a basis for comparison only. Figure 3 provides one example of how courses can be compared visually. For Sample 1, most of the content is directed toward COMM, DESN, ENPR, and ESTT. Sample 2 is spiking toward ENPR, DESN, and ESTT. Finally, Sample 3 is heavily weighted in GLIN, PROF, COMM, and DESN. By simple inference, it is clear that Sample 1 and Sample 2 appear distinct from Sample 3 in many instances; yet, it appears as though the samples do share common amounts of coverage. For example, Sample 1 and Sample 3 share coverage in COMM and DESN. The measurement of the degree of similarity is only visual at this stage of development.

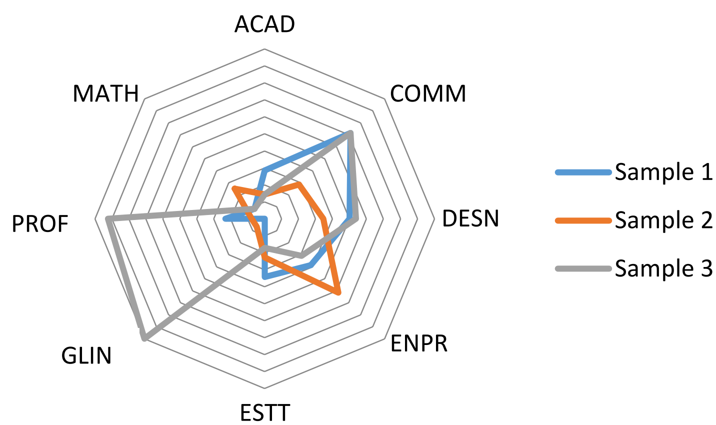

Figure 3: Radial Plot Comparison of Three Sampled Courses

One method that can guide comparisons is the calculation of the quartiles for each main outcome. After determining the quantities of interest (Minimum, Q1, Median, Q3, and Maximum), the results can be plotted using the same technique (Figure 4). Note that the minimum is zero for each main outcome, so the corresponding quartile is not visible in the radar plot in Figure 4 and Figure 5.

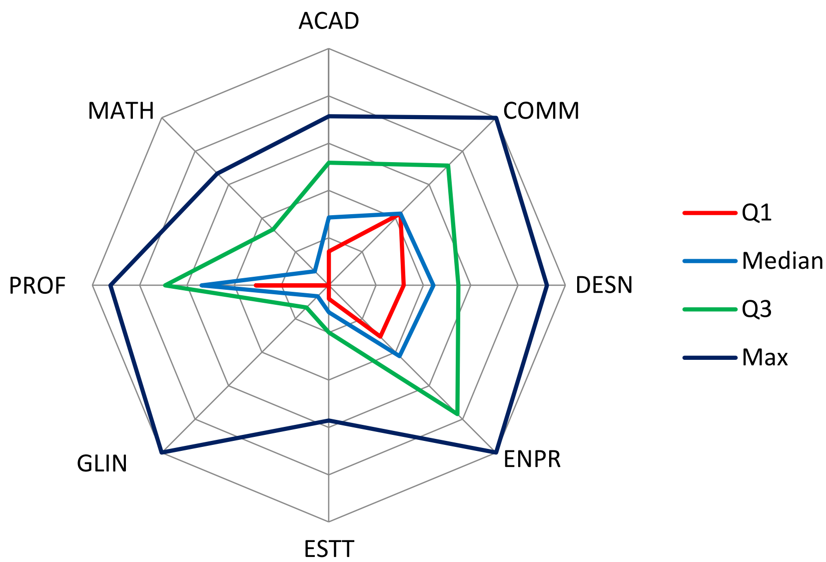

Figure 4: Plot of Quartiles

Using this technique, a sample course can be incorporated into the radar plot in Figure 4 and be directly compared to the quartiles. Take Figure 5 for example; one sample course from the workshop is plotted along with the boundaries defined by the quartiles.

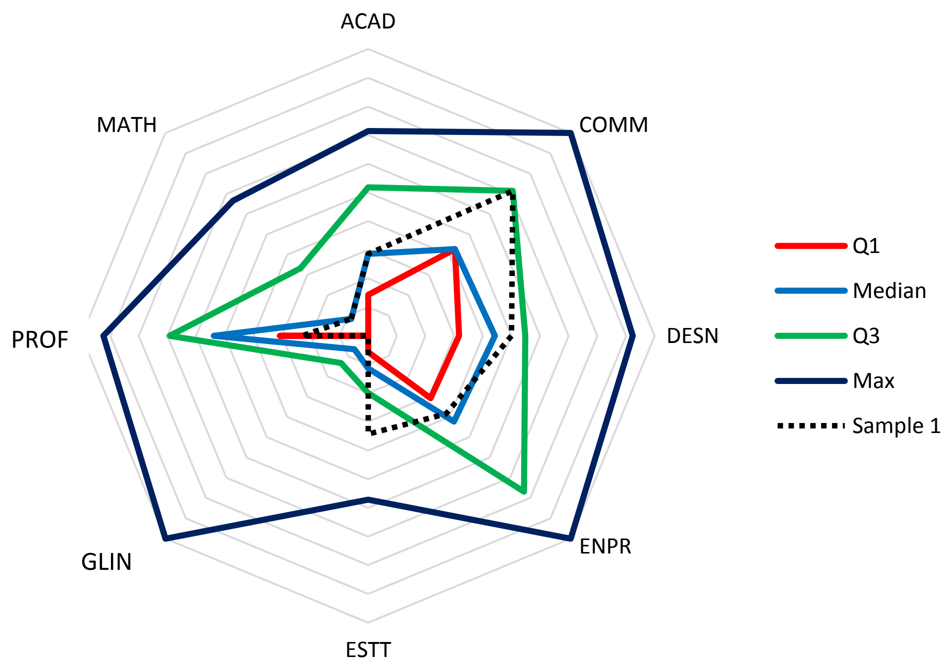

Figure 5: Comparison of a Sample Course to the Quartiles

While the method is considered sound, the five number summary is only as powerful as the data set that generates it. Thus, this current comparison is only comparing the preliminary data set of 28 unique classified courses. This application shows promise since a brief quartile comparison with the existing data can be easily generated. Since the quartiles are defined by the boundaries in the plot, the position of the observations for the main outcomes can be described in terms of the boundaries. Table 2 contains the intervals where the adjusted score for each main outcome lies relative to the quartiles.

Table 2: Main Outcomes and Their Relative Position to the Boundaries

Main Outcome	Relation to Quartiles
ACAD	At Median
COMM	*Q3*
DESN	> Median, < Q3
ENPR	> Q1, < Median
ESTT	> Q3, < Max
GLIN	At Min
PROF	> Min, <Q1
MATH	At Median

This process can be considered a pilot test toward a process to answer the questions of "what constitutes a high/low [Outcome] score" and "how many distinct course models might be identified." A much larger sample size, with consideration to include a representative variety of introduction courses, could be used to better define the outcome boundaries and allow for more accurate comparisons between courses and quartiles. Further, cluster analysis may provide a method of culling common course types by examining frequent shapes and abstracting them for further comparisons.

By Outcome Analysis

Since there are eight main outcomes, each collection of outcomes will be examined separately. Note that outcomes that serve as headings (those at the top level) are not included since these are not intended to be marked.

The data will be presented in a table that is divided into 5 columns where each heading is one element of the five numbers summary (minimum, first quartile, median, third quartile, and maximum) with the appropriate value for the dataset in parentheses next to the word. The outcomes will be listed by name with the amount of times the outcome was marked in parentheses in order under the interval in which the outcome belongs.

The full list of outcomes can be found in Appendix B.

Academic Success [ACAD]

Table 3: Frequency Table for Academic Success

Minimum (1)	Q1 (5)	Median (8.5)	Q3 (14)	Maximum (21)
Personal Management (1)	Interviews (2)	Stress Management (6)	Time Management (10)	Intro to Departments (15)
	Study Abroad (5)	Intro to Campus (7)	Co-op or Internship (10)	Relationships and Friendships (17)
	E-Portfolio Design (5)		Plan of Study (12)	Academic Integrity (21)
	Choice of Major (5)		Lifelong Learning (14)	

The outcomes marked in Academic Success seemingly revolved around a theme of developing one's self in the context of the university (Table 3). Paradoxically, "Personal Management" was only marked once despite the fact that two specific outcomes associated with it, "Stress Management" and "Time Management," were marked 6 and 10 times respectively. "Choice of Major" was not marked as frequently, likely due to the way in which majors are selected or emphasized in first year engineering courses. "Academic Integrity" and "Relationships and Friendships" were marked an unusually high amount of times. This may be a result of including outcomes associated with the latent curriculum as it is inherent to the course; for example, a user classifying his or her course could arrive at the "Academic Integrity" outcome and think, "Of course we promote academic integrity!" and mark the outcome for the sake of including it. The same argument can be made for the "Lifelong Learning" outcome. Ideally, the scheme would be filled out by checking outcomes that are explicitly covered in the course.

Communication [COMM]

Table 4: Frequency Table for Communication

Minimum (6)	Q1 (9.25)	Median (12.5)	Q3 (16.5)	Maximum (21)
Client Interactions (6)	Posters (7)	Resume (10)	Email Writing (16)	Engineering Report (18)
		Lab Report (12)		Presentations (21)
		Documentation (13)		

Table 4 outlines the marked outcomes for Communication. Oral communication appears to be the dominant outcome in this sample of classified courses with "Presentations" being marked 21 times. Unsurprisingly, the outcome "Engineering Report" was marked almost as frequently as "Presentations," suggesting that technical communication is prevalent. "Email Writing" was reported to be in the sample's courses frequently as well. This could be attributed to the occurrence discussed in Academic Advising concerning marking outcomes that are engrained in the curriculum and not explicitly mentioned.

Design [DESN]

Table 5: Frequency Table for Design

Minimum (4)	Q1 (9)	Median (12)	Q3 (18)	Maximum (24)
Reverse Engineering (4)	Authentic Design (6)	Modeling (10)	Documentation and Management (13)	Creativity and Curiosity (19)
	User Testing (7)	Realistic Design (11)	Design Review (14)	Refine (20)
	Testing Hypothesis (8)	Data Collection and Statistical Analysis (11)	Scheduling (16)	Concept Selection (21)
	Empirical Design (9)	Problem Formulation (11)	Design Projects (17)	Design Trade-offs (21)
	Research (9)	Problem Solving (12)	Fundamentals of Design (17)	Brainstorming (24)
	Engineering Feats and Failures (9)		Formal Design Process (18)	Data Management (24)

The outcomes marked under Design in the sample followed a predictable pattern as shown in Table 5. Elements of the design process are concentrated in the Maximum interval. Another instance of outcomes possibly marked for the sake of being marked is "Creativity and Curiosity." Likewise, "Problem Solving" could fall into the same category, but was not marked as frequently as one might expect.

"Modeling" was also marked less than hypothesized, but this can be attributed to the misunderstanding of what was meant by the outcome itself. As mentioned, "Modeling" has been split into two distinct outcomes, "Physical Modeling" and "Mathematical Modeling." Perhaps this alteration will provide more accurate markings than what was found in the 2013 draft of the classification scheme.

Engineering Profession [ENGR]

Table 6: Frequency Table for Engineering Profession

Minimum (7)	Q1 (10)	Median (13)	Q3 (14)	Maximum (19)
Commitment to Discipline (7)	Engineering History (8)	Images of Engineering in Today's Society (12)	Roles and Responsibilities (14)	Relevance of the Profession (19)
	Definition and Vocabulary (10)	Professional Societies (13)	Nature of Engineering (14)	Types of Engineering (18)
	Nature of Technology (10)	Student Organizations (13)	Intro to Professions (14)	Disciplines of Engineering (16)

Similar to the set of outcomes under Design, the frequency in which the outcomes in Engineering Profession were marked followed a somewhat predictable pattern as shown in Table 6. Outcomes associated with the clarification and introduction of the various disciplines of engineering occupied the upper two intervals, Q3 and Maximum. Other topics such as “Engineering History” and “Nature of Technology” were not reported as often.

Engineering Specific Tech / Tools [ESTT]

Table 7: Frequency Table for Engineering Specific Tech / Tools

Minimum (0)	Q1 (1)	Median (3.5)	Q3 (5)	Maximum (16)
Java (0)	C++ (1)	Electromagnetic Systems (2)	Solid Works (4)	3-D Visualization (6)
MathCAD (0)	Labview (1)	Material Balance (2)	Flowchart (4)	Shop Experience (7)
Arena (0)	CAD/AutoCAD (1)	Thermodynamics (3)	Shop Training (4)	Circuits (9)
Lathe, Milling (0)	Catia (1)	Laboratory (3)	Bread boarding (4)	MATLAB (11)
3-D Printing (0)	Nanosensors (1)		Arduino Based Project (4)	Excel (13)
CNC (0)			Robotics (5)	Word (15)
Manufacturing (0)			Statics (5)	PowerPoint (16)
Basic Surveying (0)			Mechanics (5)	
			Basic Programming (5)	
			Sketching (5)	

Table 7 displays the frequency of marked outcomes in Engineering Specific Tech/Tools. This is one example of a set of outcomes where it would be impractical and likely impossible to mark every outcome. For example, under the “Programming” outcome, it would be unusual for a course to include multiple programming languages rather than exploring one language in depth.

Outcomes associated with Microsoft Office were marked frequently, likely due to the prevalence of writing engineering reports and presentations – as expected. Likewise, the outcomes such as “3-D Visualization” and “Circuits” under “Engineering Skills” exist in the Q3 and Maximum intervals. Another set of outcomes to note were those related to “Computer Based Design” as well as “Programming.” In the sample, outcomes under “Computer Based Design” were rarely marked with “Arena” and “MathCAD” never being covered. The “Programming” set of outcomes were far more spread out in terms of coverage. “MATLAB” was reportedly the platform more commonly used in first year engineering within the sample while “Java” was not marked at all.

Topics associated with hands-on tools in the machine shop were not marked frequently, but students are reportedly visiting the shop (Shop Experience) and are being trained to some extent while there (Shop Training). In addition, the outcomes under “Topic Specific Tools” were not covered as well with the exception of “Arduino Based Project” and “Breadboarding.”

Global Interest [GLIN]

Table 8: Frequency Table for Global Interest

Minimum (2)	Q1 (3)	Median (4)	Q3 (5.5)	Maximum (16)
Geotechnical Engineering (2)	Virtual Reality (3)	Biomechanics (4)	Assistive Technologies (5)	Social Entrepreneurship (6)
Sustainability*	Bioinformatics (3)	Design Safety (4)		Concerns for Society (11)
				Grand Challenges (16)

Sustainability was added after the draft used during data collection, so it would not have been marked in this round of data collection.

When considering the rearranging of the main outcome, "Grand Challenges" became the most frequently marked (Table 8). The remaining topics that were not seized by the "Grand Challenges" merger did not change in placement.

In addition to "Grand Challenges," the "Concerns for Society" outcome and associated sub-outcomes were frequently marked. The other outcomes not associated with either "Grand Challenges" or "Concerns for Society," were assorted topics within the general interest of the engineering community: namely, "Geotechnical Engineering," "Virtual Reality," "Bioinformatics," and "Biomechanics." The four outcomes described were marked infrequently in the sample, which is not a surprising result.

Math Skills and Applications [MATH]

Table 9: Frequency Table for Math Skills and Applications

Minimum (1)	Q1 (3)	Median (5)	Q3 (7)	Maximum (14)
Calculus (1)	Abstraction (2)	Linear Regression (4)	Estimation (6)	Significant Figures (8)
	Trig Review (3)	Matrices (5)	Graphing (7)	Units and Dimensions (14)
	Empirical Functions (3)	Statistics (5)	Dimensional Analysis (7)	

The marked outcomes in Math Skills and Applications did provide an unexpected trend (Table 9). The outcomes, "Significant Figures" and "Units and Dimensions," were most frequently marked in the sample. While it appears as though other topics in mathematics ("Trig Review," "Matrices," "Statistics") exist within the 28 engineering courses, the presence commanded by these outcomes was not nearly as strong. The lack of the outcome, "Calculus," is understandable considering the students enrolled in the course are likely participating in a Calculus based course at the same time. Similarly, the outcome "Trig Review" may be covered in a Physics course. Statistics topics such as "Linear Regression" and "Empirical Functions" can be covered in a Statistics for Engineers course offered at the university.

The emphasis on the outcome "Units and Dimensions" could be attributed to topics that are naturally included in the course. In a similar relationship, one possible explanation for the popularity of "Significant Figures," "Estimation," "Graphing," and "Dimensional Analysis" could be related to "Engineering Reports" and general activity in the classroom as well.

Professional Skills / Latent Curriculum [PROF]

Table 10: Frequency Table for Professional Skills / Latent Curriculum

Minimum (2)	Q1 (10)	Median (13)	Q3 (20)	Maximum (22)
Patent Search (2)	Qualitative (5)	Leadership (12)	Critical Thinking (19)	Work Distribution (21)
	Quantitative (6)	Strength / Weakness ID (13)	Problem Solving (20)	Team Management (22)
	Research (10)		Codes and Standards (20)	
	Library Resources (10)		Team Dynamics (20)	

In terms of outcomes within Professional Skills / Latent Curriculum, the distribution was not surprising. The three most popular outcomes were related to students working as teams: "Team Dynamics," "Team Management," and "Work Distribution." Another popular outcome was related to Ethics, namely "Codes and Standards." It is worth noting that Ethics is a topic that, somewhat surprisingly, failed to show up in online syllabi, but emerged in conversation during the development of the scheme.[8] The typical outcomes followed suit, such as "Problem Solving" and "Critical Thinking."

Outcomes that were not marked as frequently were almost exclusively related to the "Research" outcome, with the exception of "Patent Search." The lack of these outcomes in the sample are expected in first year engineering, especially qualitative research. In addition, it would depend on what the first year instructors are deeming suitable classroom activities that constitute qualitative and quantitative research. Perhaps the outcomes, "Qualitative" and "Quantitative," need to be better defined in the Classification Scheme itself in order to gather markings that are more accurate.

Results

As presented with the data analysis, *by course analysis* will be discussed first, then *by outcome analysis* will follow.

By Course Analysis

Two remaining issues complicate rigorous analysis: (1) establishing a meaningful ordering of outcomes around the radar chart and (2) properly scaling main outcomes to contend with the differences in total outcomes such that the meaningful order is supported.

Visual exploratory analysis by examining shapes of courses has been successful. Most importantly, relationships between courses can easily be seen when plotted used a radar chart.

For example in Figure 6, two of the courses from the sample, namely course 2 and 28, had relatively similar shapes when plotted in the same chart. The distinct similarity that is visible in the figure is the spike toward ENPR, the implied scaling in ACAD and COMM, and the scaling toward GLIN. The courses seem to have a difference in coverage (emphasis) in PROF.

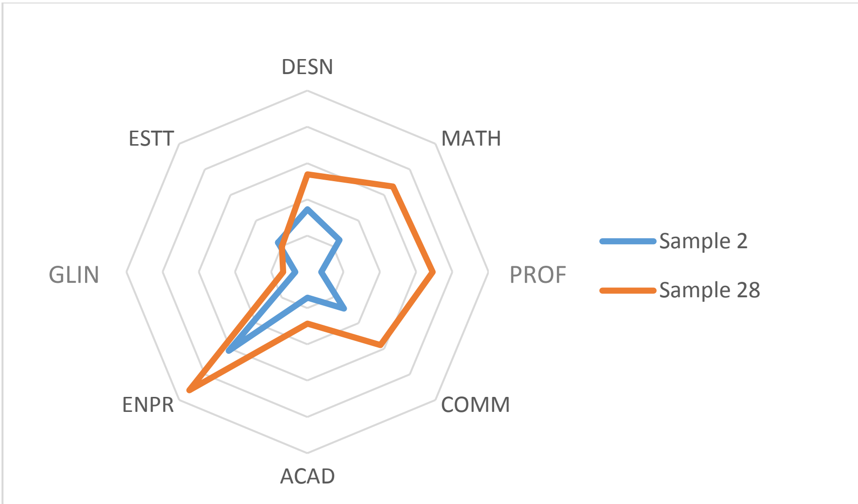

Figure 6: Sample 2 and 28 Plotted in the Same Radar Chart

Due to the small sample, other similarities are difficult to find. More investigation needs to be done on a larger collection of data to establish claims of similarity between courses. The same argument can be made for finding clusters of courses and determining course foci, the dominating combination of variables.

By Outcome Analysis

Examining individual outcomes proved to be more successful on a sample of this size. Much of what was found followed general expectations of what might be expected in a first year engineering course; however, one main outcome did provide an unusual trend. The Math Skills and Applications main outcome presented a perplexing skew toward more basic skills that one would expect to be covered in a Physics course, such as significant figures and basic units. Although, due to the limited data set, more information would be useful to determine why the outcomes were marked. This could be due to the lack of a "level of coverage" to guide users to make informed decisions on what constitutes an outcome as covered.

To summarize the sample, the following inferences in Figure 7 can be made about popular outcomes from the 28 first year engineering courses within the initial data set.

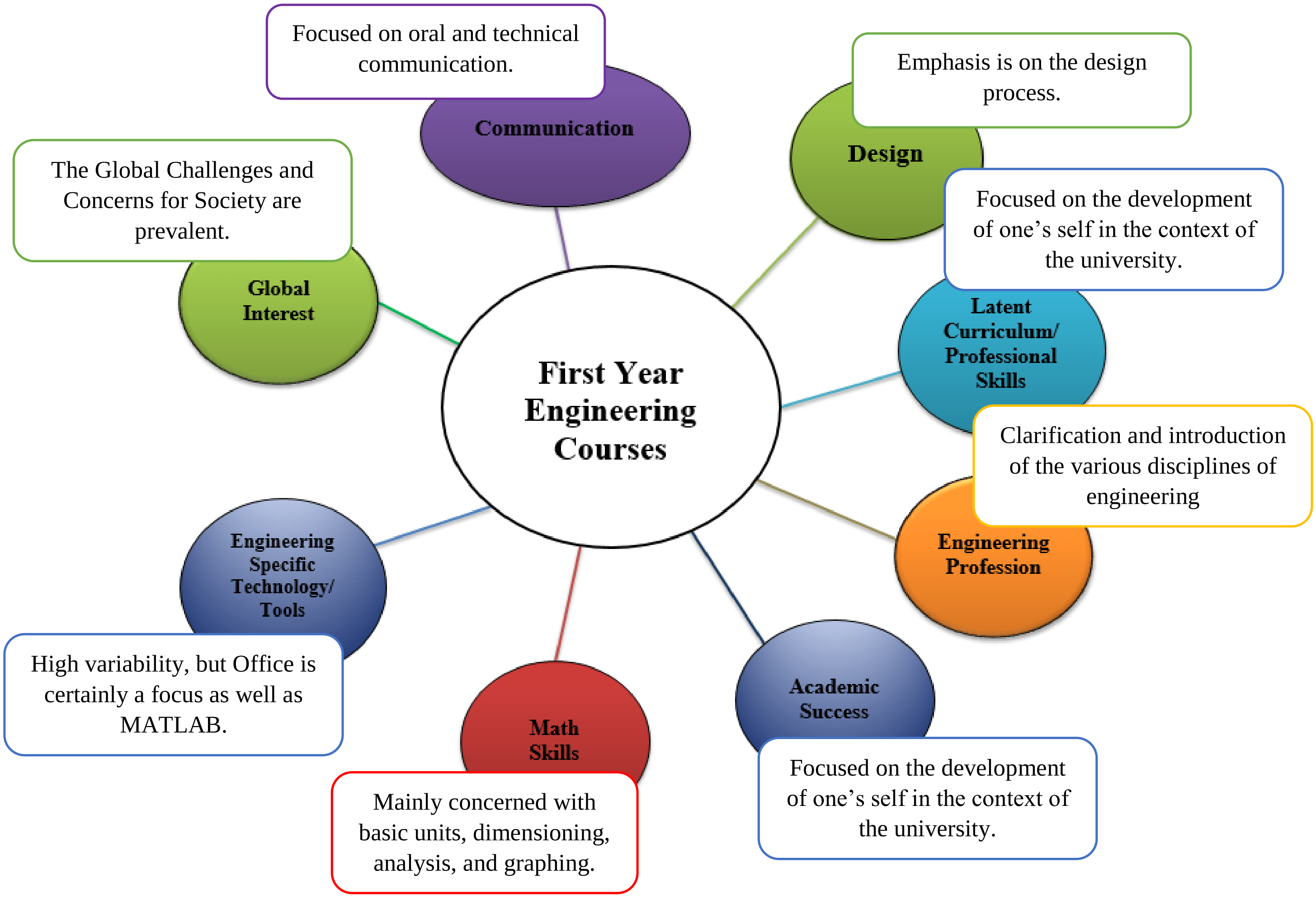

Figure 7: Summary of Sample from FYEE Workshop[2]

More general and powerful conclusions should be possible with a larger sample size, but the summary presented is only applicable for this data set.

Implications and Limitations

General implications from this effort are limited due to the preliminary nature of this research; however, the results from this effort have given rise to areas that will require further study.

One perceived limitation of the scheme is the method of data collection; that is, the classification for some course is self-reported. In its current form, the scheme serves as a taxonomy, or list of objectives. Through this testing, the importance of further classifying courses or sections through expanding beyond a binary yes/no decision and developing a separate model became more apparent. In terms of the taxonomy, variation between instructors is not necessarily bad unless the variation is large or learning objectives pertaining to certain topics are not being addressed. In fact, variation among instructors of different sections may provide valuable information to those assessing a program.

Moreover, plotting a course within the context of a radar chart enables general top down comparisons to be made, which was termed *by course analysis*. Examining *by outcome analysis*, can reveal trends in engineering courses by examining individual outcomes with a large enough sample; yet, there is a need to introduce more rigorous analysis techniques in order to draw firm conclusions. This rigor is particularly important when attempting to determine course foci and cluster courses to uncover trends.

Since modifications have been made to the taxonomy, it is a necessity to collect new data and analyze the classified courses appropriately. It is hoped that establishing the final version of the scheme and further data collection will enable more meaningful analysis, which will yield results that are more powerful.

Future Directions

Beyond collecting more data, two particular avenues of research that the application of the scheme could assist in addressing are the determination of course foci and identifying assessment gaps in the curriculum. Methodology for determining course foci will likely involve examining the frequency of marked outcomes and radar charts for the courses themselves. For assessment gaps, conducting an exercise in classifying each section can assist in identifying topics that are not adequately being addressed.

Further, the content of these first year courses is often a combination of the instructor's preferences, learning outcomes dictated by the program, and accreditation outcomes. As a result, these courses tend to occupy their own sphere of content and loosely relate to later classes – perhaps even to other "Introduction to Engineering" courses at different universities.

Although the classification scheme was created with this application in mind, investigation into precise relationships between different engineering courses remains. While preliminary attempts at comparisons illustrate fundamental differences, determining a more precise means of describe such differences remain. In order to better understand the way in which each piece of the courses corresponded with each other, a mathematical model can be developed in order to study the relationships between first year engineering courses.

Finally, issues with finding a more meaningful order of the main outcomes around the radar chart and better scaling main outcomes to account for differences in total outcomes to complement the ordering need to be resolved.

Conclusions

The *First-Year Introduction to Engineering Course Classification Scheme* is a tool that was created using mixed methods and was validated through testing with multiple institutions. The scheme has proven to be useful for institutions as they conduct workshops to assess the content and foci of their introductory curricula. In addition, schools with desire to accurately award transfer credits for courses such as "Introduction to Engineering" will be enabled to make decisions that are more informed. Funding agencies that need to identify specific characteristics of courses within proposals will now have a tool designed to do so. The scheme can also be a method of guiding K-12 Engineering Education pedagogy as schools prepare to authentically tie to engineering standards in their respective states.

Preliminary efforts have been presented, referred to as *by course* and *by outcome analysis*, and provide an initial interpretation of the results of classifying a course. Currently, these methods as well as a mathematical model of the classification scheme are in development in order to answer fundamental questions related to the taxonomy. For instance, how many types of engineering courses exist? How do we determine what a course's foci are? As result of answering these questions, perhaps more profound curiosities will emerge. For the classification scheme, further applications and analyses will cement the taxonomy as a fundamental tool for first year engineering as a whole.

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Appendix A: Classified Courses from NSF Sponsored Workshop at FYEE 2013

Sample	ACAD	COMM	DESN	ENPR	ESTT	GLIN	PROF	MATH
1	4	5	13	5	12	0	3	1
2	2	2	9	8	8	1	1	3
3	2	5	14	4	6	15	12	1
4	2	3	11	0	5	0	5	7
5	10	7	6	5	1	1	8	0
6	8	3	14	13	2	1	10	6
7	5	3	12	8	4	0	4	0
8	2	3	10	0	3	0	1	1
9	10	2	1	5	0	2	2	0
10	8	7	24	12	2	15	7	1
11	3	3	9	6	3	0	4	1
12	4	5	20	2	1	1	11	0
13	0	6	10	1	4	2	6	2
14	7	6	13	7	2	2	9	4
15	3	3	10	5	6	0	4	5
16	3	3	20	5	20	0	8	3
17	3	4	12	4	7	1	7	4
18	5	2	5	9	1	1	9	0
19	10	6	19	10	6	2	9	3
20	9	3	9	10	1	0	7	0
21	10	2	15	13	2	0	10	0
22	1	3	4	4	7	2	6	4
23	0	0	0	0	4	0	0	0
24	5	4	18	11	11	6	8	2
25	1	1	0	0	4	0	1	0
26	4	5	18	11	4	5	9	1
27	6	3	14	8	7	7	12	8
28	4	4	14	12	7	2	9	8

The table above displays data collected from the NSF-sponsored workshop held at the FYEE 2013 conference. Each row is a course that was classified by a first year instructor and each column is one of the eight main outcomes found in the classification scheme. The value in each cell, referred to as the raw score, corresponds to the number of outcomes under the main outcome that were marked by the user.

Appendix B: Complete Table of Outcomes from the Classification Scheme at FYEE 2013

Communication (COMM)

- I. Professional
  - A. Client Interactions
- II. Written
  - A. Reports
    - 1. Lab
    - 2. Documentation
    - 3. Engineering
  - B. Email Writing
  - C. Résumé
- III. Oral and Visual
  - **A. Presentations (COMM IV.A.0 / ESTT II.D.3)**
- IV. Visual
  - A. Posters

Engineering Profession (ENPR)

- I. Relevance of the Profession
- II. Images of Engineering in Today's Society
  - A. Roles and Responsibility
- III. Professional Societies
  - **A. Student Organizations (PROF VI.0.0)**
- IV. Types of Engineering
- V. Engineering History
- VI. Definition and Vocabulary
  - A. Nature of Engineering
  - B. Nature of Technology
- VII. Disciplines of Engineering
  - A. Intro to Professions
- **VIII. Commitment to Discipline (ACAD VII.0.0)**

Design (DESN)

- I. Engineering Design
  - **A. Fundamentals of Design (DESN I.F.3)**
    - 1. Mathematical Modeling
    - 2. Physical Modeling
    - 3. Formal Design Process
    - 4. Brainstorming
    - 5. Concept Selection
    - 6. Testing Hypothesis
    - 7. Design Review
    - 8. Refine
  - B. Reverse Engineering
  - **C. Research (PROF IV.0.0)**
    - 1. User testing
  - D. Creativity and Curiosity
  - E. Empirical Design
  - F. Authentic Design
    - 1. Engineering Feats and Failures
    - **2. Design Projects (PROF III.0.0)**
    - **3. Realistic Design (DESN I.A.0)**
- II. Engineering Analysis
  - A. Data Collection and Statistical Analysis
- **III. Problem Solving (PROF I.A.0)**
  - A. Problem Formulation
- IV. Criteria and Constraints
  - A. Design Trade-offs
- V. Project Management
  - **A. Documentation and Management (PROF VI.0.0 / COM II.A.2)**
  - **B. Scheduling(ACAD II.A.0)**
  - C. Verification
  - D. Quality Control
    - E. Data Management

Global Interest (GLIN)

- **I. Grand Challenges (DESN I.F.0)**
- II. Concern for Society
  - A. Assistive Technologies
  - B. Social Entrepreneurship
  - C. Design Safety
  - D. Sustainability
- III. Biomechanics
- IV. Bioinformatics
- V. Virtual Reality
- VI. Geotechnical Engineering

Academic Success (ACAD)

- I. Community
  - A. Relationships and Friendships
- II. Personal Management
  - A. Time Management
  - B. Stress Management
- **III. E-Portfolio Design (COMM II.C.0)**
- **IV. Academic Integrity (PROF II.0.0)**
- V. Advising
  - A. Plan of Study
  - B. Study Abroad
  - C. Co-op or Internship
    - 1. Interviews
  - D. Intro to Campus
  - E. Intro to Departments
  - F. Undergraduate Research
- VI. Lifelong Learning
- **VII. Commitment to Discipline (ENPR VIII.0.0)**

Math Skills (MATH)

- I. Trig Review
- II. Calculus
- III. Significant Figures
- IV. Units and Dimensions
- V. Dimensional Analysis
- VI. Linear Regression
- VII. Matrices
- VIII. Abstraction
- IX. Calculations
  - A. Statistics
    - 1. Empirical Functions
  - B. Graphing
  - C. Estimation

Professional Skills (PROF)

- I. Critical Thinking
  - **A. Problem Solving (DESN III.0.0)**
- II. Ethics
  - B. Codes and Standards
- III. Teamwork
  - C. Team Management
    - 1. Work Distribution
    - 2. Strength / Weakness ID
  - D. Team Dynamics
- IV. Research
  - E. Library Resources
  - F. Quantitative
  - G. Qualitative
- V. Patent Search
- VI. Leadership
- VII. Entrepreneurship

ENGR Tech/Tools (ESTT)

- I. Engineering Skills
  - A. Electromagnetic Systems
  - B. Circuits
  - C. Statics
  - D. Mechanics
  - E. 3-D Visualization
  - F. Material Balance
  - G. Thermodynamics
  - H. Sketching
- II. Software
  - A. Programming*
  - B. Programming and Design*
  - C. Computer Aided Design*
  - D. Microsoft Office*
- III. Hardware
  - A. Shop Experience*
  - B. Topic Specific Tools
    - 1. Bread boarding
    - 2. Arduino Based Project
    - 3. Basic Surveying
    - 4. Laboratory
    - 5. Nanosensors

Outcomes indexed under this outcome were omitted to conserve space. Please review the complete version of the scheme for the complete list.

Note than an outcome in **bold** designates that it and one or more outcomes can be marked off if certain requirements are met. These outcomes were defined to be *tied outcomes* in the paper. The classification scheme defines the non-trivial relationship between the outcomes so the user understands what would constitute an appropriate marking.