



A Classification Scheme for "Introduction to Engineering" Courses: Defining First-Year Courses Based on Descriptions, Outcomes and Assessment

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Abstract

A proliferation of first-year engineering programs exists nationwide. These are often designed from scratch and tend to be “personal courses” – designed by instructors to meet their preferred objectives. Therefore, while they may be *prerequisites* to second-year courses, first-year engineering programs are not necessarily *integrated* into an engineering curriculum. Further, since they are often designed with little consideration for best practices in introductory course design, overall outcomes and content vary widely. This leads to the issue of course developers “reinventing the wheel,” considering successful models are not adequately disseminated. The problem is further exacerbated by a lack of definition for first year models. Despite a developer knowing what they want in a course, he or she may not be able to find a course with similar outcomes with nothing more than “first year engineering” as a description.

Through an NSF sponsored study, we have developed a classification scheme for first-year engineering courses. Multiple methods of data collection were employed, including a focus group at a national engineering education conference and a survey of syllabi available on the Internet. A Delphi procedure was used to survey participants in multiple rounds toward building consensus on the classification scheme. A culminating workshop was held at a major conference in which the participants tested the scheme based on courses at their home institution. This paper presents the classification scheme and information of its development.

The anticipated impact is that the scheme will allow universities, community colleges, funding agencies, etc. to use the developed classification scheme to accurately determine specific course content when considering credit awarded for transfers, to develop introductory engineering coursework, formulate course foci, and to identify and fund efforts toward appropriate assessment gaps.

Methodology

This project involves a study and the development of a classification scheme for courses meant to introduce engineering to first-year engineering students. Such courses are typically entitled “Introduction to Engineering” or similar; yet, this course title can describe fundamentally different courses. For instance, an introduction course with weekly presentations from different departments is fundamentally different than one with an outcome to cover programming skills. With the various nuances and contrasts in the content of “Introduction to Engineering” courses between universities, these classes should be classified differently. The lack of first year models only exacerbates the problem.

Prior research in the first year of engineering has focused on an understanding of student success directly related to coursework¹, innovative curriculum design^{2,3,4,5}, and specific necessary components of the first year including a solid foundation in math⁶. Brannan and Wankat⁷ looked

at different components in the first year, including introductory courses. Little research to classify various first year engineering courses is available, although establishing a common framework seems to be a necessary step toward informing curricular reform and program development.

Development of the Scheme

Three separate methodologies were used to develop the classification scheme: analysis of syllabi, analysis of results of workshop discussion, and a culminating Delphi study. Using a multiple method approach allowed for different, iterative versions of the scheme to be created. As more information regarding course outcomes became available, gaps began to emerge. Due to the nature of the data collection, these inconsistencies were resolved and, as a result, completed a more accurate picture of first year engineering courses.

Method 1: Analysis of syllabi

In an effort to identify common concepts and student learning objectives, an Internet search of web sites from universities, colleges and programs was conducted for courses entitled “Introduction to Engineering”, “Engineering 1”, or courses with similar titles. A team of undergraduate research assistants was tasked with executing this Internet search and summarizing results in cooperation with the principal investigator during the 2012 spring semester. Researchers used common search engines to search for “introduction to engineering” and similar terms. When such a course was identified, an additional search for the course syllabus was completed. Each syllabus found was reviewed to ensure that the course was meant to apply as a common engineering course rather than a technically oriented, discipline specific course: for example, delineating between “Introduction to Engineering” and “Introduction to Electrical Engineering.” The Introduction courses may contain significant technical content (such as MATLAB programming), but must be either intended for students in multiple disciplines or have an interdisciplinary focus to be included in the analysis. Further, courses were not to be general orientation courses geared strictly toward understanding the culture of a university or a general introduction to university life – although again, these topics may appear in a course meant to introduce engineering. Finally, courses were not to be those that might introduce engineering to non-engineering majors, such as a “How Things Work” survey course.

The team identified 28 syllabi that met the criteria. Each team member was assigned to review 14 (half of the syllabi), thereby reviewing each syllabus twice. Team members listed each outcome from all of the syllabi and developed a mind-map (or concept map) by grouping similar outcomes using post-it notes on a whiteboard. In the event of similar outcomes (for example, Programming in C++ and Computer Programming), group consensus was reached to determine whether the outcomes were identical. If judged to be identical, or for cases of absolutely identical outcomes, a count was maintained.

The intent of this initial search was to develop a framework to guide formation of initial questions for and analysis of results for the upcoming Delphi study. The final scheme evolved from this concept map and served as the basis for the Delphi study results.

Method 2: Analysis of results of workshop discussion

A workshop for informal discussion of establishing the classification scheme took place at the Frontiers in Education conference in Seattle, WA in October 2012. A Catalyzing Collaborative Conversations (CCC) session was designed and organized jointly by Directors of First Year Engineering programs at Ohio Northern University and Virginia Tech. The session offered an opportunity to convene a community with a common interest in first-year engineering education and establish a set of existing and desired course outcomes for introduction courses as a group. The guided, informal discussion allowed for participants to submit their ideas; the collective ideas of the group then guided conversation toward the development or discovery of other ideas generated through the group discussion.

Approximately 24 attendees were seated in groups of 6. Each group was tasked with having a discussion around a set of guiding questions distributed at the beginning of the workshop. In order to capture results, one attendee from each group was designated to serve as a recorder. While the initial intent was to allow a fixed time for small group discussion, then to bring the groups together and have a culminating discussion among the full group, the leaders opted to allow the conversations to conclude naturally, or to continue to (and past) the scheduled end of the session.

The set of guiding questions for each group included:

- What are the objectives of the first-year engineering programs?
- Why isn't there a common set of objectives for the first year engineering courses?
- What would we consider to be the best practices for first year engineering program?
For example, should we teach Matlab/Excel rather than introducing students to the disciplines?
- If students were so successful in High School, why is there so much emphasis on success?
What do we mean by success?
- Are there any of these objectives that are hard to assess? How might we assess them?
Is there anything that we think should be a best practice that isn't because it is too difficult to assess?

In a similar fashion to the analysis of syllabi, the team of researchers created a concept map from the written comments. This prototype scheme ultimately supplemented the final version to fill in any gaps formed between the online syllabi and Delphi study.

Method 3: Delphi Study

The Delphi procedure was employed to engage a group of participants with a common interest to develop shared images based on three rounds of question development and information, with iterative feedback^{9,10,11,12}. The initial invitations to participate came from a list generated by a steering committee of faculty in first-year engineering programs, e-mail invitations to the listserv of the First-Year Program Division of ASEE, email invitations to all participants in the 2012 First-Year Engineering Experiences conference, and targeted e-mail requests sent to a variety of universities with first-year engineering programs identified through ASEE and through recent literature. Given a potentially large quantity of information from each round of online surveys

and the eventual expected duplication of responses, a target of approximately 35 participants was selected^{11,12}. Thirty seven participants submitted their interest in participating and 31 participants completed the initial round of data collection while 24 completed second and third rounds.

While the first round only consisted of the guiding questions from the workshop and prototype schemes, the second round included asking participants to examine a draft of a scheme developed from responses to the first round in addition to the first two preliminary schemes to ensure that all outcomes were captured. The advantage of the Delphi method for these first rounds is the elimination of ‘groupthink’, where participants fail to fully participate or modify their responses based on the perceived majority opinions found in a group. The second round results produced a proposed final classification scheme.

In the third round, participants received the final draft of the scheme generated by all prior work. Each participant was asked to use the scheme to analyze their courses and asked suggest improvements. As round three was completed, it appeared that consensus had been reached and only minor modification to the proposed scheme was necessary. Further edits were made after the workshop held at the 2013 FYEE conference in Pittsburgh to test the scheme. Figure 1 is the top level of the scheme which features each main outcome while Figure 2 is the scheme in its entirety.

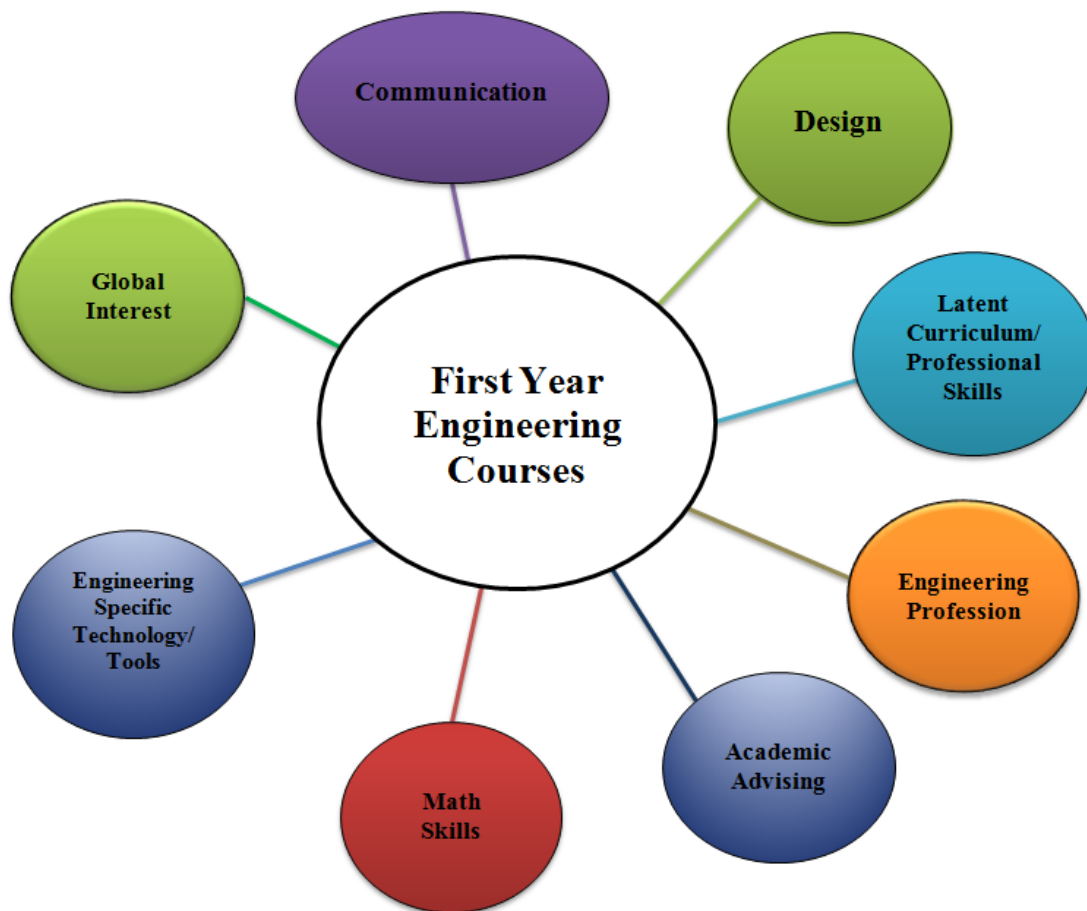


Figure 1: "Top Level" of the Final Classification Scheme

Each main division in the top level has an associated "outcome tree" with different distinct outcomes branching from it. These outcomes can cross divisions in the case of a sub-outcome falling under more than one classification. While the completed classification scheme includes the visual representation found in Figure 2, an outline format is provided in a more organized format. The purpose of the visual format is essentially to be the skeleton of the scheme, showing exactly how the outline is pieced together.

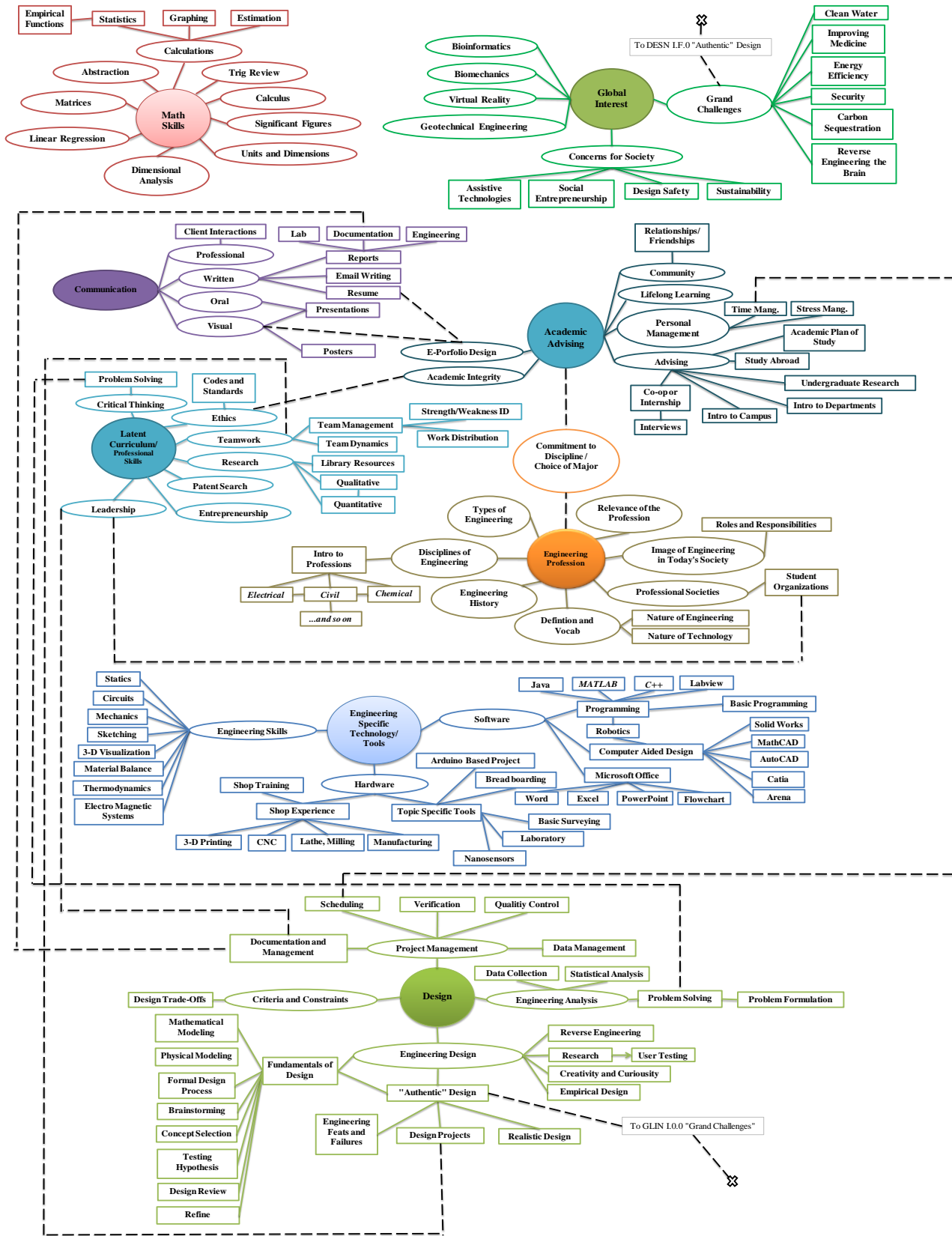


Figure 2: Visual Representation of the Classification Scheme

Using the Classification Scheme

To classify a course, participants use the check sheet (Figure 4) and check any outcome that is covered in the “Introduction” course. The scheme is meant to generate a “big picture” view of a course, so whether specific objectives are checked is left to the course developer or instructor.

The eight primary aspects of a first year engineering course are assigned with a four letter code. Following this code, main outcomes or topics are denoted with a Roman numeral. Sub-outcomes are assigned a letter, and smaller, more specific outcomes are given a number. All of these figures are separated by periods (Figure 3).

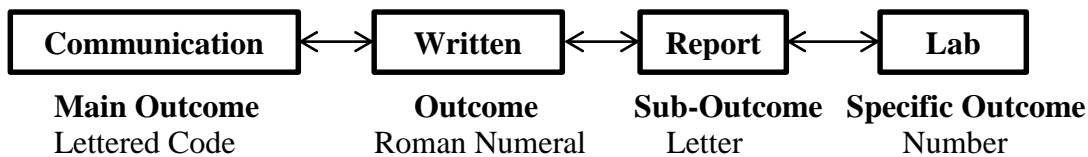


Figure 3: Specifying an Outcome Using the Scheme

For a piece in Communication such as Lab, notice its placement in the scheme: Outcome II, Sub-Outcome A, Specific 1. In terms of this classification method, this piece’s ID would be COMM II.A.1. In certain instances, it is not necessary to define Sub-Outcomes or Specific Outcomes. Therefore, in place of the absent topics, a zero takes each missing outcome’s place.

For topics that satisfy more than one outcome, the ID will be denoted with a superscript. These topics are explained in the documentation accompanying the scheme. For example, Presentations in Communication can satisfy two other outcomes, so it is written as COMM III.A.0⁴.

For depth of coverage, each instructor should estimate the amount of time spent on each aspect of first year engineering. This total does not need to add up to one hundred percent, as overlap is to be expected. For example a project to design a device linked to one fo the Grand Challenges covers multiple objectives. The percentage also does not have to correlate exactly to the “totals” column, but should most likely be related.

The scheme is intended for use to only classify one course. Users can refer to the corresponding Q&A in the Appendix (of the documentation accompanying the scheme) for any additional questions (Figure 5). This was not available at FYEE considering the developers were present to answer any questions. In fact, these questions formed the basis for the Appendix.

Outcome Checklist

Directions:

If you feel your course adequately addresses the outcome described, then mark off that outcome on the checklist. *If a covered outcome is tied to one or more other outcomes, mark those outcomes as well.* This scheme is intended to only classify one course at a time.

Covered	ID	Covered	ID	Covered	ID
---	ACAD I.0.0	---	COMM I.0.0	---	DESN I.0.0
	ACAD I.A.0		COMM I.A.0		DESN I.A.0 ⁵
---	ACAD II.0.0	---	COMM II.0.0		DESN I.A.1
	ACAD II.A.0	---	COMM II.A.0		DESN I.A.2
	ACAD II.B.0		COMM II.A.1		DESN I.A.3
	ACAD III.0.0 ¹		COMM II.A.2		DESN I.A.4
	ACAD IV.0.0 ²		COMM II.A.3		DESN I.A.5
---	ACAD V.0.0		COMM II.B.0		DESN I.A.6
	ACAD V.A.0		COMM II.C.0		DESN I.A.7
	ACAD V.B.0	---	COMM III.0.0		DESN I.A.8
	ACAD V.C.0		COMM III.A.0 ⁴		DESN I.B.0
	ACAD V.C.1	---	COMM IV.0.0		DESN I.C.0 ⁶
	ACAD V.D.0		COMM IV.A.0		DESN I.C.1
	ACAD V.E.0				DESN I.D.0

Figure 4: Beginning of Outcome Checklist

Appendix

The following questions were posed during a workshop to test the classification scheme. The workshop was held at the First-Year Engineering Experiences (FYEE) conference, Pittsburgh, PA, August 2013.

Use in "Introduction to Engineering" courses:

- How do you use the classification if institution has a First Year Program (multiple semesters)?
- How do you use the classification if institution has two required engineering courses in the first semester?
- Can you capture the whole year with the scheme?

The scheme may be used on each individual course, and results could be combined to examine an entire year. However, the intent of the scheme is to examine individual courses. For multiple semesters, use the classification scheme for each course (therefore, each semester for two-semester sequences) separately.

- Does it matter if it is a 1 credit or 3 credit course?

No – the scheme can be used for any individual course.

Figure 5: Appendix from the Classification Scheme

Results

The draft was tested by participants of a workshop at FYEE 2013, which provided valuable feedback and edits to finalize the scheme. Some participants filled out schemes for two courses, even though it was not required, which resulted in 28 completed checklists representing 24 institutions.

Participants were tasked with classifying their institution's "Introduction" course, followed by a discussion period to collect data on the ease and accuracy to which the scheme mapped the course under scrutiny, and what questions or concerns emerged as the scheme was used. Very minor changes were made in terminology, but the overall layout and usefulness of the scheme was verified. Further, its use in other courses was discussed and use within individual institutions for assessment of first-year courses was discussed.

The classification scheme was tested at two large, Midwest universities. Instructors from each section of the Introduction to Engineering course were asked to fill out the scheme, and results were analyzed for consistency between sections. Most of the items within the scheme had unanimous agreement: the topic was either part of the introduction course or it was not.

There were some items which showed some disagreement among instructors, where a few instructors would indicate a topic was covered and a few would not. The course coordinators and investigators held a conference call and discussed the likely possibility that pedagogical differences in the classroom and a different perception of the depth of coverage to indicate something was "covered" could result in these differences of opinion. For example, if an instructor uses examples in class which deal with virtual reality, they may indicate this has been covered while not part of the curriculum.

Each institution looked through the results under each of the top-level outcomes and discussed these results to decide if:

- the topic had appropriate coverage to the level intended, whether extensive coverage or no coverage (for example, thorough coverage of MATLAB, no coverage of C++, etc.)
- the topic was covered elsewhere in the curriculum (for example, if an orientation class offered an introduction to the profession)
- the topic should be covered and curricular reform was in order.

Each university is in the process of investigating necessary curricular reform as a result of this test.

Conclusion:

A classification scheme suitable to accurately classify the contents of "Introduction to Engineering" courses was developed using multiple methods, and validated through testing with multiple institutions. The scheme should prove useful for institutions as they assess the content and effectiveness of their introductory curricula, or schools dealing with transfer credits of

courses such as “Introduction to Engineering”, for funding agencies that need to classify specific characteristics of courses within proposals and as part of a general conversation on the importance of these courses for students as they transition from K-12 to engineering plans of study.

In initial use of the scheme, it was shown to be effective as a tool to investigate the first year of study, identifying areas for which curricular reform should be considered.

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