Session 3225

A Novel Tool for Engineering Curriculum Development, Enhancement, and Evaluation

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Introduction

A new tool has been developed at the University of Tennessee at Martin to aid in thoroughly examining the content of the engineering curriculum. The approach incorporates a course map showing all required and elective engineering courses, including prerequisite and corequisite critical paths. Each element in the map details the content of a specific course in terms of design, computer usage, laboratory experience, written communication, and oral communication. Each of these categories is further separated into qualitative levels, i.e., beginning, intermediate, and advanced applications. The detailed content information for each course is then directly related to examples of student work, using color-coded indices. The tool is a valuable resource for development and enhancement of an engineering curriculum. It is useful not only to evaluate existing programs to support, for example, accreditation reviews, but also it is an effective tool for program assessment and continuous improvement.

Description of Course Map

The course map was developed to support our recent Accreditation Board for Engineering and Technology (ABET) Engineering Accreditation Commission (EAC) site visit[1]. The original goal was to visually portray the required courses in our engineering curriculum so that the evaluators could easily see which courses were offered, what the required prerequisites were, and when the typical student would take each course. It was decided to dedicate a complete wall within a classroom for this purpose. As the map developed, an additional wall was added to contain maps for each of the four upper-division discipline-specific elective paths in our curriculum.

The overall arrangement of the map is shown in Figure 1. The eight semesters that make up the undergraduate curriculum were arranged in eight columns, with two columns for each year of study. The rows contain the core engineering curriculum courses on top, followed by reference to engineering electives, with the required math and science courses below.

Freshman Courses	Sophomore Courses	Junior Courses	Senior Courses
Core Engineering	Core Engineering	Core Engineering	Core Engineering
		Engineering Elective	Engineering Elective
Math & Science	Math & Science	Math & Science	Math & Science

Figure 1. Arrangement of Main Curriculum Map

A separate 8½ ×11-inch sheet of paper to identify each course was attached to the wall. Colored borders were provided around each course sheet to clearly identify whether it was an engineering course (orange border) or a math/science course (green border). The courses were then interconnected to show both prerequisite and corequisite requirments. A course that was a prerequisite for a subsequent course would have a path leading from its right-hand side to the input (left-hand side) of the subsequent course. Similarly, a path entering the top of a course sheet identified a corequisite. An example illustrating a section of the map is shown in Figure 2.

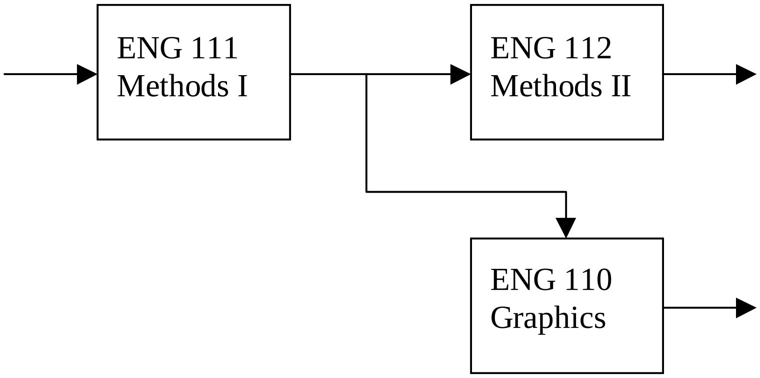


Figure 2. Illustration of Prerequisite and Corequisite Paths

Referring to Figure 2, it can be seen that Engin 111, Methods I, is a prerequisite to Methods II, and a corequisite of Graphics.

As more and more courses were added, the map rapidly became congested with the increased number of paths. Many of these paths were due to the math and science courses that are prerequisites to so many engineering courses. To alleviate this problem, the math and science prerequisites and corequisites were identified using smaller blocks near the engineering courses for which they were required. Their location in the four-year curriculum was maintained in the overall map. A photograph of the main map is shown in Figure 3.

Since the School of Engineering at UT Martin offers a Bachelor of Science in Engineering[2], our upper division students select discipline specific elective paths at the beginning of their junior year. Dashed course sheets in the main map identify these electives, which direct the viewer to specific elective maps on a separate wall. UT Martin offers elective paths in civil, electrical, industrial, and mechanical engineering. Each elective path has a number of courses that are offered, and the individual courses may have prerequisites or corequisites that are identified as in the main map. All requisites that flow from the main curriculum map are shown in smaller box format. A photograph of the elective course maps for civil and electrical engineering is shown in Figure 4. To clearly differentiate between core and elective engineering courses, the colored borders were different for each. We chose to use the school colors of orange and blue for the core and elective engineering courses respectively.

Figure 3. Photograph of Core Curriculum Map

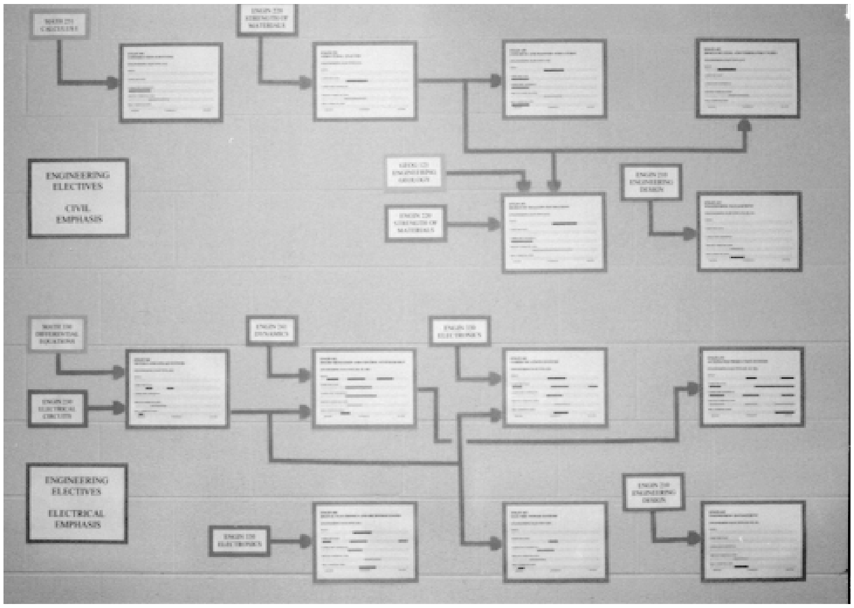
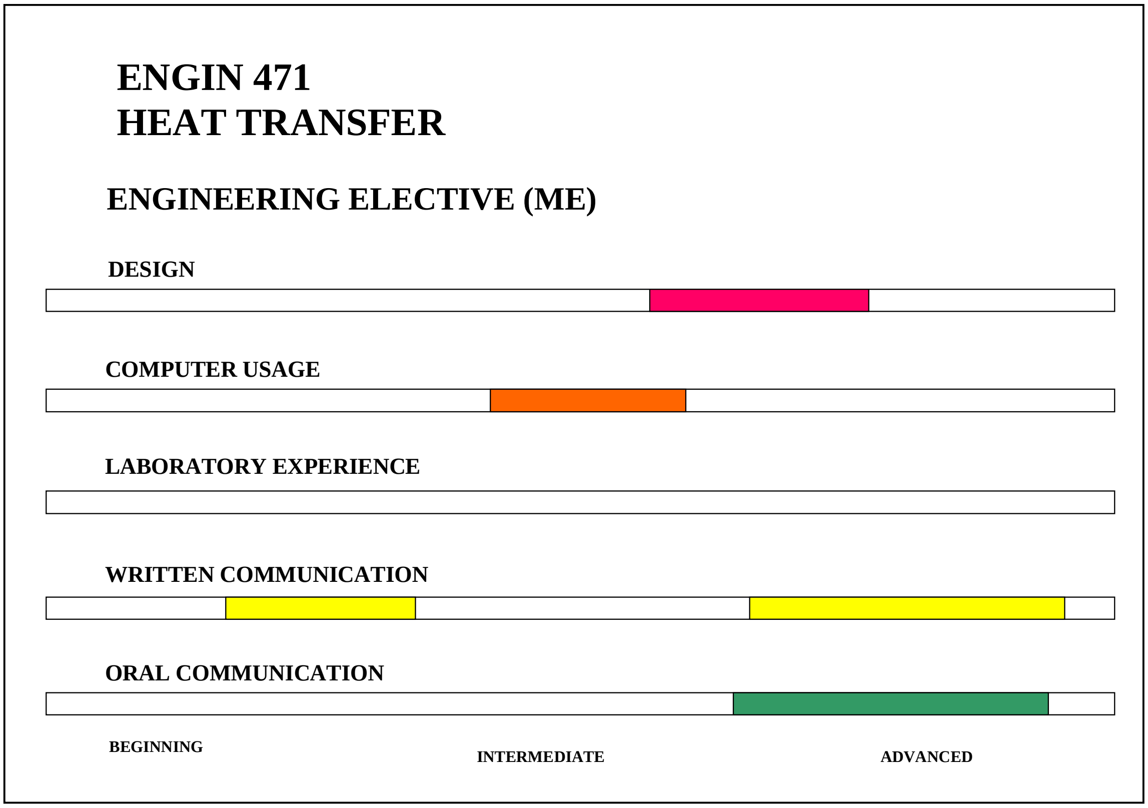


Figure 4. Photograph of Elective Map for Civil and Electrical Engineering

Description of Course Content Sheets

Each 8½ ×11-inch sheet contained in both the main and elective maps are termed Course Content Sheets. Each sheet details the course content in terms of design, computer use, laboratory experience, written communication, and oral communication. These are major skill areas which ABET and the American Society for Engineering Education (ASEE) have identified as those in which a graduating engineering student should be well qualified[3, 4.] We examined each engineering course offered in the curriculum and attempted to identify which of these five areas are specifically addressed. In developing the course content sheet format, we recognized that there are different levels of sophistication or levels of content within each of these five areas. For example, the course content sheet should reflect that using a word processor such as Microsoft Word to type a homework assignment requires a lower computer skill level than using the Simulink package within Matlab. In addition, the course content sheets should also show, at least in a qualitative sense, the amount of time or effort the student expends on a given area within each of the five content categories. An example of a course content sheet is shown in Figure 5.



ENGIN 471
HEAT TRANSFER

ENGINEERING ELECTIVE (ME)

DESIGN

COMPUTER USAGE

LABORATORY EXPERIENCE

WRITTEN COMMUNICATION

ORAL COMMUNICATION

Figure 5. Example of a Course Content Sheet

Referring to Figure 5, the catalog number and course title are at the top. Next, it is indicated that this course is an engineering elective in the area of mechanical engineering. Those courses that are required for all engineering majors would indicate “Engineering Core” in this space. Five horizontal bars are provided for the major emphasis areas of design, computer usage, laboratory experience, written communication, and oral communication. The location of a highlighted area along the horizontal axis indicates the level (beginning, intermediate, and advanced) of the activity performed in the class. The faculty determines what constitutes beginning, intermediate, and advanced levels within each emphasis area based on the specific objectives of the engineering curriculum. The horizontal width of the highlighted area at a given level indicates a qualitative measure of the amount of time or effort spent (in and out of class) by the student. For this example, it is immediately seen that the design content is relatively high level, whereas computer usage is at the intermediate level. There is no laboratory experience gained in this course. The written communication has some beginning to intermediate level work, which might involve typewritten assignments, graphing, or formatted analytical work, as well as much more advanced level work, such as a highly polished project report. Finally, there is advanced oral communication required, indicating perhaps a presentation to the class and faculty. It can be seen that the advanced communication content requires greater effort on the part of the students than the other areas. This is indicated by the width of the shaded area.

Content Levels within Each Emphasis Area

The faculty must jointly determine which tools, skills, or abilities should be included in each of the five emphasis areas, and at what level a particular skill should be placed. The breakdown used by the faculty at UT Martin is discussed for illustrative purposes. One goal in the engineering curriculum is to introduce the student to the design process as soon as possible. This can be achieved with numerical problems with a design element, as well as with introductory design projects. As the student progresses in engineering studies, he or she will be better equipped to perform more complex design problems as well as projects. Finally, a capstone design project presents the culmination of the student's educational experience. The levels within the design area used at UT Martin are listed in Table 1. The attributes increase in complexity as one reads down.

Table 1. Candidate Design Content Levels

Design Content Levels
Beginning
• Elementary and intermediate homework problems which include a design element as a predominant feature. • Design projects which emphasize the design process with some emphasis on economics, performance, etc.
Intermediate
• In depth design problems related to a specific engineering subject area, which includes problems of an open ended iterative nature. • Design projects that emphasize the design approach and require understanding of the theory being applied.
Advanced
• In depth design projects which emphasize the complete design process, from requirements to final delivery of product, including various real-life constraints (ethics, economics, safety, reliability, aesthetics, and social impact).

The software used, the level of difficulty, and the amount of original programming skill required determine the levels within the area of computer usage. The breakdown used by the UT Martin engineering faculty is shown in Table 2. In many courses, assignments will require word processing and spreadsheet usage, which are taught in the freshman design courses. As the student progresses, the use of more sophisticated programs will be required. Therefore, it is likely that computer usage in the course content sheet may have several areas within computer usage highlighted. The format of the course content sheet clearly presents this information, indicating the computer requirements for the course.

The levels of sophistication in the area of laboratory experience are shown in Table 3. It can be seen that the exposure to experiments can be at several different levels, depending on the course content – from demonstrations to explain a concept, to incorporation of laboratory techniques to develop and validate original designs or research.

The area of communication includes both written work including text oriented assignments and well formatted and developed analytical work as well as oral presentations using speech-giving techniques and professional presentation software. The levels in these two areas are given in Tables 4 and 5.

Table 2. Candidate Computer Usage Content Levels

Computer Usage Content Levels
Beginning
• Microsoft Word • Microsoft Excel • Microsoft Power Point
Intermediate
• AutoCad • SDRC I-DEAS • IT Thermodynamics, Heat Transfer Software • Math Cad • Maple/Mathematica • DaDisp • Matlab • PSPice
Advanced
• Programming (C, C++, Matlab) • Advanced programming to support data acquisition, hardware control, IEEE 4888 bus control, simulation (Simulink), etc. which require original application of software and/or hardware understanding.

Table 3. Candidate Laboratory Experience Content Levels

Laboratory Experience Content Levels
Beginning
• Structured Experiments in which entire class observes experiment under close instructor supervision • Structured experiments in which groups of students use equipment to follow test procedure which reinforces understanding of theory or concepts
Intermediate
• Less structured laboratory in which students develop approach to verify/uncover understanding of classroom concepts.
Advanced
• Students use laboratory techniques and design experiments to develop or validate a design, to extend the understanding of concepts, and to prove or disprove a hypothesis.

Table 4. Candidate Written Communication Content Levels

Written Communication Content Levels
Beginning
• Written homework assignments (word processor) • Formatted engineering analysis assignments
Intermediate
• Typed assignments using text, tables, and graphs • Formatted laboratory reports
Advanced
• Project reports • Research and design (R&D) proposals • Comprehensive project reports (analysis, text, drawings, plans, appendices, etc.)

Table 5. Candidate Oral Communication Content Levels

Oral Communication Content Levels
Beginning
• Presentation of assigned topics to instructor. • Informal presentation of assigned topics to class.
Intermediate
• Formal presentation of assigned topics to class using graphs, overheads, etc. • Formal presentation of project reports to class using presentation software.
Advanced
• Formal presentation of R&D proposals, status reports, and project reports to wider audience, e.g. faculty, practicing engineers, using presentation software

Incorporation of Curriculum Map with Student Work

The final step in making full use of the curriculum maps and course content sheets is to directly relate the work that the students are performing in a given class with the expectations or goals[5] as presented in the course content sheet. One method is to require that the students keep all work performed in their classes. At the end of the semester, representative samples of student work may then be directly correlated to the appropriate emphasis areas on the course content sheet. At UT Martin, highlighted regions for the five content areas are color-coded in red, orange, purple, yellow, and green. The student work may then easily be labeled with color-coded tabs to clearly identify samples of the appropriate emphasis areas. Ultimately, the identified student work samples become the basis for portfolio development. Thus, each step of the curriculum map contributes to student understanding of the interconnection between class work, course objectives, curriculum design and the "real life" work world.

Continuous Improvement: Application to Development, Enhancement, and Evaluation

Although the curriculum map with individual course content sheets was developed as a visualization tool to support our recent ABET accreditation site visit, it immediately proved beneficial for the program's continuous improvement process. In addition to providing a qualitative description of the location and integration of engineering design, laboratory experience, computer usage, and oral and written communications content, the map with course content sheets makes it possible to clearly view the prerequisite structure and breadth and depth in the curriculum. This in turn makes it easier to evaluate curriculum development and enhancements as part of the overall continuous improvement process.

The curriculum map has been added to the set of instruments used to measure outcomes in the multi-loop assessment process control system[6], which is vitally integral to our continuous improvement process. Guided by ABET EAC criteria, as are universities[7, 8] from across the country, the University of Tennessee at Martin and the School of Engineering faculty and staff are working with dedication to implement and refine an assessment process which will assure the highest quality undergraduate engineering education possible to meet the needs of our constituencies within the mission of the University. The assessment process under development was designed as a multi-loop control system with evaluation instruments, measurements, feedback, and control methodology allowing constant degree program and assessment process adjustment. Control decisions, i.e., modifications to the program and assessment process, are made by the Faculty for continuous improvement in satisfying objectives of the Bachelor of Science in Engineering (BSE) degree program.

Within the larger scope of the overall (summative) assessment process, ongoing success in meeting each individual BSE program objective is measured and evaluated. The closed-loop assessment process control system is multi-loop, with inner loops, middle loops, and outer loops, providing formative data. The innermost loops have the smallest time constants, i.e., are the fastest loops, with daily up to semester-long time periods and control processing by the individual faculty member. The outer loops have the longest time constants, i.e., are the slowest loops, with control/adjustment processing times in the range of six years and longer.

The curriculum map is proving to be a particularly useful instrument for measurements in the middle loops of the assessment control system. Middle loops have control/adjustment processing times in the range of a semester up to five or six years, with feedback evaluation of the effectiveness of curriculum, administration, faculty, students, facilities in meeting BSE program objectives. Assessment may involve several faculty members, committees, Industrial Advisory Board recommendations; and the control/adjustment decision is by the entire Faculty. The curriculum map with course content sheets provides qualitative measures of the amount, level (complexity/difficulty), hierarchy, and integration of engineering design, laboratory experience, computer usage and written and oral communications. Evaluation instruments, in addition to the curriculum map, may include student, graduate, and employer surveys; nationally-normed examinations; student design projects, senior research/design projects and theses, student portfolios; and ABET EAC evaluation. Control may involve curriculum changes, facilities changes, and/or personnel changes to make it possible to continue success in meeting BSE program objectives.

Use of the course content sheets on a short-term basis, particularly when used with students in the course completion method described earlier, is also of value for measurements in the innermost loops of the assessment process control system. And, the curriculum map as a visualization tool is proving useful in providing explanations and descriptions of the program for prospective and entering students as well as for administrators. The curriculum map instrument has proven to be a valuable addition to our continuous improvement process toolbox.

Conclusions

A curriculum map with individual course content sheets has been developed as a tool for visualization and examination of the curriculum in the Bachelor of Science in Engineering program at the University of Tennessee at Martin. The map and course content sheets were a success in documenting and explaining the program's curricular objectives and content for the recent accreditation site visit by an ABET EAC team.

Prerequisite structure and breadth and depth in the curriculum are made evident by the curriculum map. While providing data describing amount and complexity/difficulty level of engineering design, computer usage, laboratory experience, written and oral communications content on a course by course basis, the map also provides a clear picture of the hierarchy and integration of these elements.

In addition to supporting accreditation site visits, the curriculum map with individual course content sheets has proven a valuable instrument in the assessment process control system supporting continuous program improvement. Also, the curriculum map is proving to be a useful visualization tool in explanations and descriptions of the program for prospective and entering students, university administrators, Industrial Advisory Board members, and other constituents.

Future plans include the addition of engineering ethics on the course content sheets and the development of a computer tool to improve the utility of this approach in the development of curriculum maps for any engineering curriculum.

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