

2006-142: THE PARALLEL CURRICULUM MODEL: UNDERSTANDING ENGINEERING EDUCATIONAL INNOVATIONS TO OPTIMIZE STUDENT LEARNING

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The Parallel Curriculum Model:

Understanding Engineering Education Innovations to Optimize Student Learning

Past ASEE conferences have presented great ideas for teaching engineering. However, all these innovations lack a way to see how they affect the overall education of engineering students. Traditionalists are left wondering if the new ideas are diluting students' understanding of core engineering and scientific principles. Innovators walk a thin line between educating their students and simply training their students in the simulated "real life" design situations.

Just as innovation in engineering needs well-specified parameters to define the problem and evaluate the results, educational innovations require the same. The Parallel Curriculum Model (PCM) provides a comprehensive format for designing curriculum around key components such as content, assessment, teaching strategies, learning activities, products, resources, and ascending levels of intellectual demand. The most salient feature of PCM rests in the multiple curricular configurations that result from the use of four interrelated and parallel designs for organizing curriculum: Core, Practice, Connections, and Identity. The four parallels offer opportunities to optimize student learning through the creation of a curriculum that is more meaningful, powerful, and engaging in the education of confident and competent engineering professionals. Projects presented at past ASEE conferences are innovative because they address specific parallels, thus fleshing out a student's overall education. The PCM not only offers a way to see education as a whole, so as to identify the gaps, but also a way to assess and evaluate the effects of innovation on a student's entire engineering education.

PCM addresses many topics outlined by the Educational Research and Methods Division (ERM) including active and cooperative learning, integrated and non-traditional curricula, life-long learning, new learning models and applications, and the art and science of teaching. This paper explains PCM and how it relates to engineering education, analyzes selected ASEE presentations in relationship to the four parallels, and illustrates how PCM integrates key curriculum components and the four interrelated parallels to create innovative curricular designs in engineering education.

1 Introduction

1.1 Motivation

Recent presentations at ASEE conferences showcase innovative courses and projects in engineering programs across the country. These presentations are inspirational for those interested in revising or enhancing their individual courses, departmental curriculum, or engineering program.

The motivations for such innovations are multifaceted including the desires to introduce students to the world of engineering and to inspire those students who choose engineering to “stick with it.” There is also a desire to ensure that graduating students are well prepared for the professional challenges, technical and otherwise. More pragmatically, there is a desire to meet ABET standards which are required for each engineering program’s accreditation.

Each institution faces a different set of challenges even if they share the same objectives to turn out qualified, capable, and influential engineers who will move the world to a better future. The challenges faced by a predominantly technical institution are different from those faced by a largely liberal arts setting. These in turn are very different from the challenges faced by 2-year engineering preparation programs in community colleges or colleges with dual degree programs such as the College of St. Catherine.

1.2 ABET and Curriculum Revision

Engineering Criteria 2000 and ABET’s criteria for accreditation challenge faculty in engineering education to create quality programs that “satisfies the needs of constituencies in a dynamic and competitive environment.”^{1, p. 1} Many of the general criteria for basic level programs require the educational experience to expand from one being focused on book knowledge learning and “canned” experiments to one that also emphasizes authentic real-world applications of this knowledge.

Some institutions might believe that satisfying ABET criteria means requiring students to take more courses (e.g., communication, ethics, public speaking, psychology) in an already intensive curriculum. Others might believe that students need to have projects in more courses, which causes concern because little time is left for instruction of core knowledge and concepts. Others might believe that students need to engage in interdisciplinary projects more often or for longer periods of time. This might cause concern for engineering professors either because these projects might “take away” time from required instruction or because the projects are open-ended and unpredictable in nature which makes the task difficult to schedule and assess.

To avoid throwing the “baby out with the bathwater,” engineering educators need a framework or model to ensure that revisions to projects, courses, curriculum or programs both satisfy the ABET objectives and educate (rather than train) students. A good model would provide the educator with a way to assess success, tune instructional activities, and stay focused on the main objectives. It would allow the educator to prioritize objectives for the projects within a course or courses within a curriculum, thus being better able to handle “perturbations” to the system such as students who may be unfamiliar with certain previously assumed areas (e.g. students who have never taken apart an engine), special interests of the students (e.g. rock-climbing or prosthetics), relevant current events (e.g. World Trade Center collapse or the centennial celebration of the school) or newly acquired resources (e.g. clickers for Jeopardy-like questions or film/photos from Hurricane Katrina recovery efforts).

1.3 The Parallel Curriculum Model and Paper Overview

This paper proposes that the Parallel Curriculum Model (PCM) is a flexible and comprehensive model for designing a streamlined, manageable, and assessable curriculum that allows instructors to honor their content expertise while serving a diverse student population. By separating knowledge of a professional into four main curriculums or parallels, the PCM helps frame the

instructional strategies so instructors can select the most appropriate ones for the objectives. By aligning the knowledge, skills, and dispositions of the engineering professional across four main curriculums or parallels, PCM helps the instructor to identify and select essential curricular components to design and plan a comprehensive curriculum.

Section 2 grounds the Parallel Curriculum Model in the educational literature. It shows how PCM has evolved from the “shoulders of giants” in the fields of intelligence, knowledge, learning, thinking skills, curriculum development, and gifted education.

Section 3 demonstrates how PCM can be used to evaluate and revise courses or projects within courses. The PCM analysis process is concretely illustrated using innovative engineering education projects presented at past ASEE presentations. The analysis also helps address particular concerns the presenters had on how effective their process and products were.

Section 4 briefly shows how PCM can be used to frame curriculum for programs by showing how PCM is used to delineate the role partner liberal arts institutions have in educating engineering students. This paper then concludes in Section 5.

2 The Parallel Curriculum Model

2.1 Systems, Models and Strategies

The “real world” needs engineers who possess the knowledge, skills and dispositions in their disciplines to meet the complex and dynamic changes found in the fast-paced world. ABET criteria is an attempt by the engineering profession to characterize the requirements of an engineering professional who will be a valuable contributor to the “real world.” This defines the engineering educational system in the United States today.

Different educational institutions rise to meet this challenge. Some follow a purely technical philosophy, others come from a liberal arts approach. Others have a mixture of the two such as traditionally liberal arts institutions with engineering schools or liberal arts colleges that have dual degree programs with technical institutions. Others such as community colleges serve to bridge students to technical institutions, academically and/or economically. All of these different systems are legitimate, effective ways to educate students to become engineering professionals.

Each institution has departments and programs that develop curriculum and courses. Within the courses, several instructional strategies (Figure 2.1) can be used to improve student learning. These strategies have been employed with great success at numerous institutions. ASEE presentations highlight these strategies and their effectiveness on a set of students.

However, as more comprehensive strategies such as projects are used, the question becomes: Are the system criteria (ABET and otherwise) being satisfied—and to what degree? Moreover, what degree is appropriate in which projects within a course? What degree is appropriate in which courses within a curriculum? How does this relate to the students’ current intellectual level?

What is missing is a model—a framework—to categorize the criteria into manageable areas. This is something required by all educational systems for professionals. As professions realize how complex the “real world” is, they continually “add on” more specific criterion in an attempt to

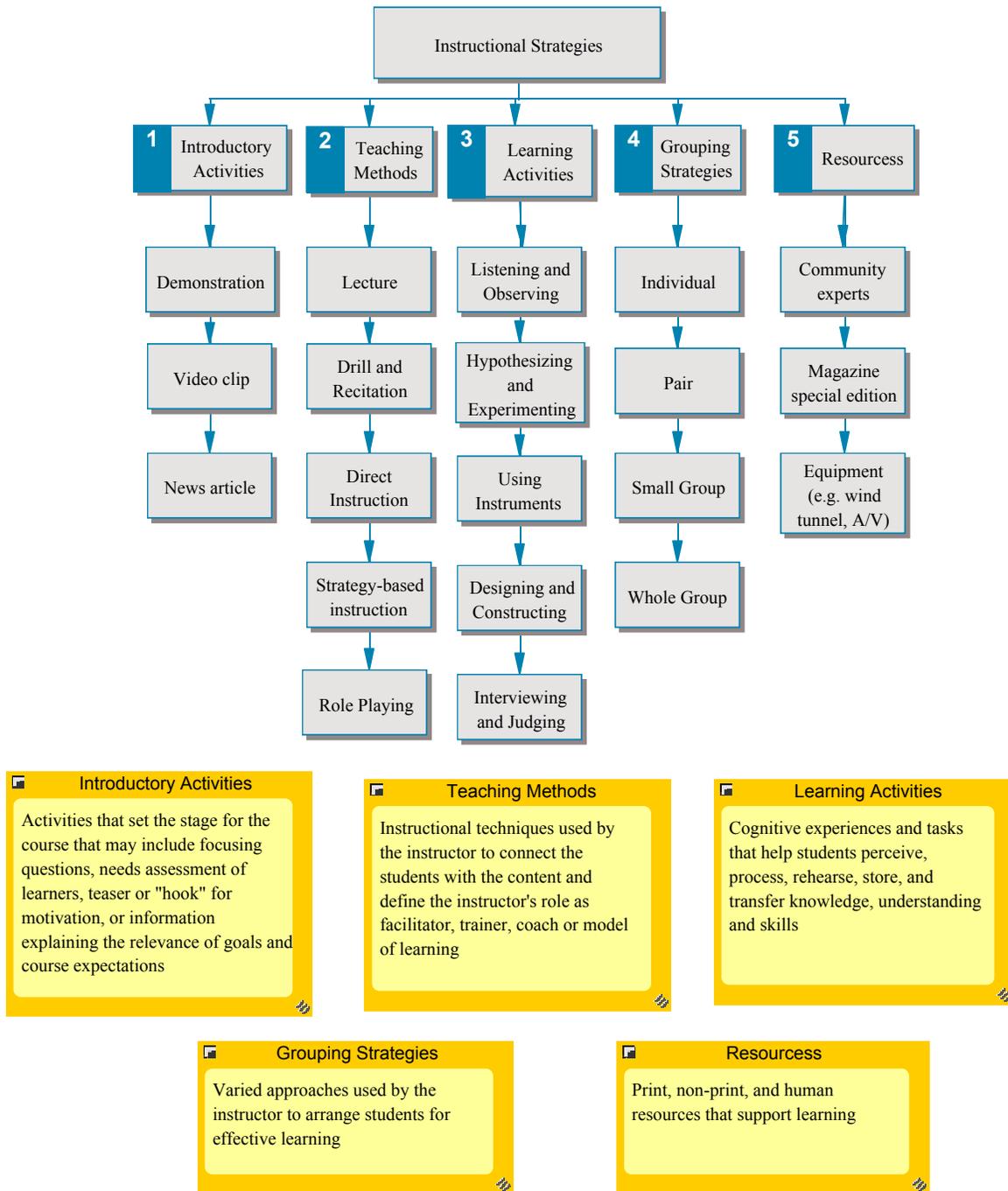


Figure 2.1: Instructional Strategies

encompass the requirements. For example, educational professionals struggle with over 100 individual criteria that must be satisfied. The engineering profession also struggles with the dilemma on how to effectively satisfy requirements that seem to continually increase in number.²² The Parallel Curriculum Model provides such a framework.

2.2 PCM's Origins and Implications

The foundational theories contributing to the development of The Parallel Curriculum Model (PCM)²⁰ span multiple disciplines including philosophy, psychology, and educational pedagogy. The works of individuals in the disciplines provide the basis for understandings associated with

intelligence, knowledge, learning, thinking skills development, and curriculum development. Selected examples include

- Howard Gardner's Multiple Intelligences theory,⁶
- Robert Sternberg's Triarchic Theory of Intelligence,¹⁸
- William James' levels of knowing,⁷
- Alfred North Whitehead's levels of involvement with knowledge,²⁶
- Lev Vygotsky's zone of proximal development,²⁵
- Jean Piaget's Theory of Intellectual Development,¹²
- Edward de Bono's lateral thinking,⁴
- Bloom's Taxonomy of Cognitive Development,²
- Robert Marzano's Dimensions of Thinking,⁹
- Ralph Tyler's principles of curriculum and instruction,²³
- Philip Phenix's *Realms of Meaning*,¹¹
- Hilda Taba's teaching strategies,¹⁹ and
- Jerome Bruner's structure of a discipline.^{8,i}

The PCM divides knowledge of a professional into four distinct curriculums:

- **Curriculum of Core:** This encompasses core knowledge within the discipline.
- **Curriculum of Practice:** This involves the application of knowledge using the tools and methods of the scholar, researcher, and practitioner.
- **Curriculum of Connections:** This covers the numerous relationships and connections that exist across topics, disciplines, events, time, and cultures.
- **Curriculum of Identity:** This develops the intrapersonal qualities and affinities within and across disciplines.^{3, slide 17}

PCM itself does not advocate any individual learning strategy or curriculum order. For example, it acknowledges the role of Connection in mastering a field, but does not advocate that all engineering students must engage in a year of interdisciplinary work. That is one strategy to incorporate the Curriculum of Connections, but it is not the only one and may not be the most effective one for a given institution's system.

PCM provides a *language* to describe how educational objectives, instructional strategies, and assessment relate back to the overarching criteria required by a system. For example, the traditional engineering program can be described and analyzed as follows:

The Core and Practice curriculums are taught in the first years with science, math and computer science requirements. Engineering Core and Practice are introduced in the sophomore year through introductory courses and laboratories. Design classes and co-ops, which students attend in the last years, provide environments that require the curriculums of Connections and Identity but these curricula may not be explicitly taught. Capstone projects are used to assess how students integrate all of these curriculums.

With such an analysis, it is easy to articulate why the traditional program has failed to serve at-risk populations such as women: By concentrating the Core and Practice up front, this program may discourage or misrepresent the discipline for those, particularly women, who need some sense of Connection to society and Identity to the field.⁵

Recent innovative efforts in engineering education can be understood using the PCM language:
By including low-level engineering design in the first year, the programs are trying to pull in engineering Practice to help students Connect their first year Core science and math courses to engineering. Through these efforts, it is hoped that students start to identify themselves as engineers earlier, and thus stay with the engineering program.

The PCM recognizes the value and contribution of each of the parallels to a professional's knowledge base and keeps the curriculum designer focused on all of them when determining objectives. It honors the Core knowledge of instructors but also provides strategies on how to systematically expand into the other areas. Using the PCM as a guide, the designer is allowed to flexibly organize content, teaching, and learning by focusing on a single parallel or by combining parallels in different proportions.

Using the PCM to design curriculum results in a high-quality curriculum that accomplishes several educational ideals:

- **Organization of content around the multiple aspects of knowledge:** Any professional requires different types of knowledge. A “book smart” student does not necessarily make the best engineer, but neither does the student who randomly tinkers. The PCM provides a framework for the curriculum designer to “see” the composition of the engineering professional's knowledge set.
- **Flexibility in selecting curriculum components:** There is no one “perfect” teaching method, learning activity or product for any given content. The ideal items depend on a number of factors including the background and abilities of the students, the expertise and character of the instructor, the attitude and philosophy of the department and institution, and the resources available. For maximum transfer of knowledge, understanding, and skills, it is necessary that a designer can select from the wide range of components known. The PCM allows the curriculum designer to effectively select the most *appropriate* curriculum components for each parallel. Different components may be selected for different parallels. This frees the designer's imagination to explore different activities as needed. However, by having four distinct parallels, the designer is provided touchstones so that the big picture of the whole course is not lost.
- **Respect for the unique characteristics of the learner:** By knowing the primary parallel of a course, the instructor can better modify activities “on the fly” if students enter above or below expected levels. If a group of students are weak on computer skills that were assumed, the instructor could release some of the activities and products focused on secondary parallels (e.g. oral presentation refinements) to teach these skills and not sacrifice the objectives for the primary parallel (e.g. the analysis of mechanical systems).
- **Systematic extension from knowledge-based education to include development of process skills:** Education of an engineer is much more than training. Just as the engineers of the past created the wonders and catastrophes of space travel and nuclear bombs, our engineering students will be the shapers of the future, so we want them to be able to think, design, question and challenge. Their education must not only include facts and philosophical abstractions; it must also foster concrete and abstract thinking. The education must be designed to provide them with the opportunity to develop in these areas.³

2.3 The Parallels of PCM

This section explains each parallel in detail and puts them into an engineering perspective: First, ABET requirements are aligned along these parallels and then specific examples of how a typical mechanical engineering program addresses them are provided.

2.3.1 CORE Parallel

The Core or Basic Curriculum parallel allows instructors to capitalize on their content expertise by structuring and identifying the framework of knowledge, understanding, and skills associated with the discipline or subject area. Key attributes of the Core Curriculum include:

- coherence in its organization,
- focus and organization to achieve essential outcomes,
- promotion of understanding over rote learning,
- taught in a meaningful context,
- requires students to grapple with ideas and questions using critical and creative thinking,
- is engaging and satisfying to learners, and
- results in evidence of worthwhile student production.^{20, p. 21}

Several of ABET's criteria require this foundational curriculum. For example,

- in Criterion 3 (Program Outcomes and Assessment), a) an ability to apply knowledge of mathematics, science, and engineering;
- in Criterion 4 (Professional Component), a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline, and b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study; and
- in Criterion 8 (Program Criteria), Program criteria provide the specificity needed for interpretation of the basic level criteria as applicable to a given discipline.^{1, pp. 1-3}

In a mechanical engineering program, the core material includes the basic concepts required. Courses such as physics, chemistry and mathematics are usually required of students in the first year because they represent the core material required for future engineering courses. In the second year and first semester of junior year, the introductory engineering courses such as thermodynamics, statics, dynamics, materials, fluids, and control systems, set the knowledge foundation required by more advanced mechanical engineering areas.

2.3.2 PRACTICE Parallel

Building from the Core Curriculum, the Curriculum of Practice moves knowledge to the application of facts, concepts, principles, skills, and methods. The overall goal of this parallel provides students with opportunities to develop expertise in the chosen discipline. Essential features include opportunities to:

- understand the nature of the discipline in a real world application manner,
- understand the impact of this discipline on other disciplines and other disciplines on this discipline,
- understand and use the discipline as a means of looking at and making sense of the world,
- value and engage in the intellectual struggle of the discipline,
- function as a producer in the discipline, and
- function as a scholar in the discipline.^{20, p. 29}

ABET Criteria 3 and 4 show that the curriculum of Practice is just as important in an engineer's education as the Core curriculum. Subitems in Criterion 3 list many Practice standards:

- b) an ability to design and conduct experiments, as well as to analyze and interpret data;
- c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
- e) an ability to identify, formulate, and solve engineering problems;
- g) an ability to communicate effectively; and
- k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.¹

Additionally, in Criterion 4, a discussion is made about the need to bridge students' understanding from knowledge to practice:

The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.¹

Additionally, the criterion ends with the following summary statement about the student's final requirements in the engineering major: "Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints."^{1, p. 3} Both of these ABET criteria underline the importance of the Practice curriculum in engineering education.

By graduation, mechanical engineering students are expected to have substantial experience with the engineering design process, technical drawing/solid modeling, oral presentations, and technical writing. Some programs require courses explicitly focused on these topics while others design courses that exercise students in these areas. A senior engineering student is expected to define the problem concretely, gather information, brainstorm, build prototypes to evaluate the possible solutions, and effectively propose a reasonable solution that satisfies requirements.

2.3.3 CONNECTIONS Parallel

The Curriculum of Connections provides an extension from the Core Curriculum and requires instructors to design courses that allow students to discover and learn from the interconnectedness of knowledge.^{20, p.23} Connection curriculum allows students to apply concepts, principles, and skills:

- across disciplines;
- across time and time periods;
- across locations;
- across cultures;
- through varied perspectives;
- as impacted by various conditions including social, economic, technological, political; and

- by examining links between concepts and development of the discipline.^{20, p. 25}

By requiring students to become aware of engineers' impacts on society, to be skilled in working in teams, to communicate orally and in writing, and to behave ethically, ABET is pushing the traditional engineering curriculum to include the curriculum of Connections. Criterion 3 lists many examples of how ABET requires the curriculum of Connection to be more consciously integrated into the curriculum. Note how some overlap with other parallels:

- c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
- d) an ability to function on multi-disciplinary teams;
- g) an ability to communicate effectively;
- h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; and
- j) a knowledge of contemporary issues^{1, p. 2}

Mechanical engineering programs incorporate connections through the topics they pick for design problems and projects. For example, working with a paraplegic to create an adaptive technology exercises items c), g), h), and j). Building a Baja vehicle for competition is usually done by a team of engineering students. This expands the experience to include item d) and challenge item g) in different ways.

2.3.4 IDENTITY Parallel

The Curriculum of Identity capitalizes on the cognitive and affective development of learners by developing their interests, expertise, strengths, values, and characteristics. In the early days of university education, students were assigned a preceptor or personal advisor. They would meet regularly with this mentor and discuss various intellectual topics. The advisor took an active role in helping plan the students' future and invariably would know if any student were losing interest or verve in the work. A good preceptor would be able to work with students, through various activities and discussions, to help them see themselves as future participants in the field. Theoretically, this is the role of the modern advisor in today's colleges.

Attributes of the Curriculum of Identity allow students to:

- reflect on their skills and interests as they relate to the discipline,
- develop awareness of their modes of working as they relate to the modes of the operation characteristic of the discipline,
- reflect on the impact of the discipline in the world and of self in the discipline,
- think about the impact of the discipline on the lives of others in the wider world,
- examine the ethics and philosophy characteristics of the discipline and their implications,
- project themselves into the discipline,
- develop self in the context of the discipline and through interaction with the subject matter, and
- develop a sense of pride and humility related to both the self and the discipline.^{20, p. 37}

Elements in ABET Criterion 3 take on this curriculum:

- f) an understanding of professional and ethical responsibility; and

- i) a recognition of the need for, and an ability to engage in life-long learning.^{1, p. 2}

Although it is not always explicitly addressed, most engineering programs hope that students see themselves as engineers by graduation. Recent programs include opportunities for students to explore the different engineering areas. These start to address the Curriculum of Identity. They not only challenge students to determine how engineering complements their own personal interests, they try to excite and support students so they enter their careers as confident, contributing engineers.

Service learning and social action activities can also develop the Curriculum of Identity if the particulars of the action arise from the students' choices. It is imperative that the activity's design, action plan development, implementation, and execution is entirely motivated by the students. Some schools are able to support students who are free to select their own capstone topic or independent project. These are excellent ways to address the Curriculum of Identity.

Incorporating the Identity curriculum more fully into a formal curriculum setting (i.e., courses that are graded) is difficult. As indicated above, the products and instructional activities must come largely from the students. With more diversity (a desirable aspect), it is increasingly inappropriate to assume that students see themselves in the same way. Assessments of Identity are not easily quantifiable, and doing so sometimes diminishes the authenticity of the results. They can be qualified, however, if experts are engaged in the process. For example, practicing engineers could help evaluate the students in mock performance reviews. However, design, coordination, execution, and evaluation of these activities are time-intensive and require individual attention to be the most effective.

It takes immense creativity, organization, and patience for any instructor to conduct a graded course focused on the Identity curriculum. Independent studies are the best ways so far, but often are not possible until the end of the students' tenure in school.

At-risk populations may benefit from some early attention to Identity aspects. Support programs address this need by matching first year engineers with role models, either peers (Big Brother/Big Sister model) or professionals (E-mentoring or on-site mentoring programs). Interestingly, these programs are usually not part of the formal curriculum of a college. They are instead, normally part of the co-curricular (formerly "extra-curricular") activities that are conducted through student life departments, dorms, or campus student organizations. Ways to integrate Identity early and often into the engineering curriculum, formally or informally, might help retain students in engineering.

2.4 PCM in the Curriculum Design Process

The PCM provides a strategy to select ABET requirements that are appropriate to the course. Separated into four distinct parts of an entire curriculum, the requirements can be addressed as separate parallels without losing sight of the big picture of the students' engineering education. The PCM framework splits the different types of content covered in a course, allowing the designer to select the most effective curriculum components for the unit, students, and instructor expertise. For example, teaching the Core material with lecture and recitation may be appropriate, but the Practice elements are better done in role-playing or small group activities.

When designing a course, the designer would identify the primary parallel, then the secondary one. The objectives would then be set up for each individual parallel (Figure 2.2). Assessments *of* learning and *for* learning would then be designed. The other curricular components would then be specified for each parallel. This approach provides greater assurance that everything done and assessed ties directly to the objectives and ultimately the standards.

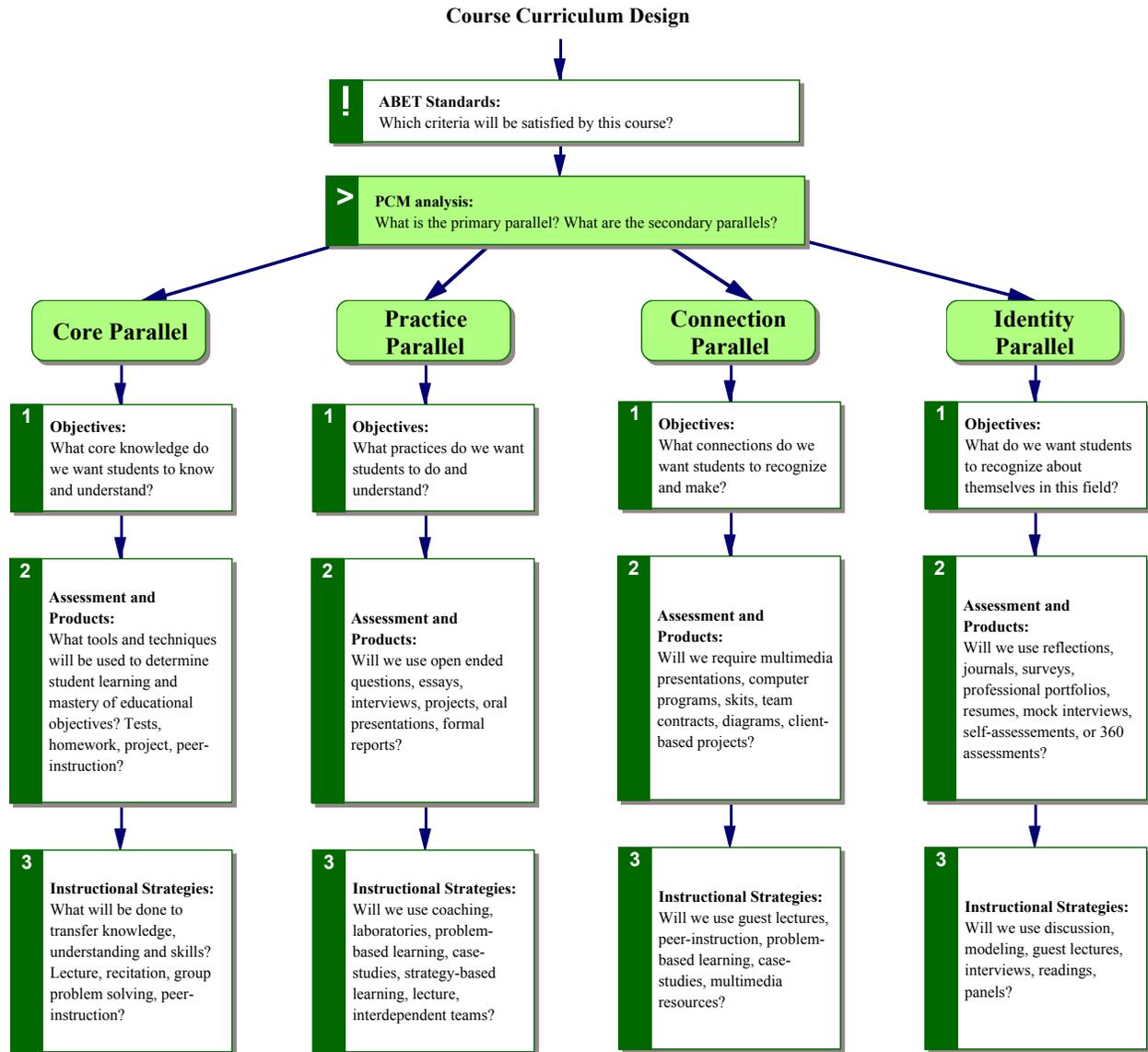


Figure 2.2: Possible Curriculum Design Process with PCM

A note about assessment: Assessments “of” learning vs. “for” learning

A whole paper could be written about using PCM to design assessments. In this paper, we will focus mainly on how PCM can be used to develop and revise curriculum. However, to truly appreciate how PCM frames the entire curriculum design process, some mention must be made about assessment and how PCM can help design assessments *for* student learning.

Assessments *of* learning are used to document student achievement or mastery of standards at a given point in time. Traditionally, exams, quizzes and homework problems were used for this purpose. It is ideal when these assessments indicate achievement of standards. Most instructors are adept in creating these assessment tools. However, with more complex assessment products such as projects, the question becomes: What has the student learned by doing this project? Assessments *for* learning provide feedback to inform the instructional activities and student learning. The instructional activities are the ways that an instructor can modify or influence the system (students). Assessments for learning target student achievement toward standards throughout the learning process by focusing on assessing their current knowledge, reasoning, performance skills, products and dispositions.¹⁷ They can include the use of portfolios, performances, products, student self-evaluations, observations, checklists and rubrics. Additionally, they can include practices such as giving feedback on drafts or having students present their progress in phase reviews.

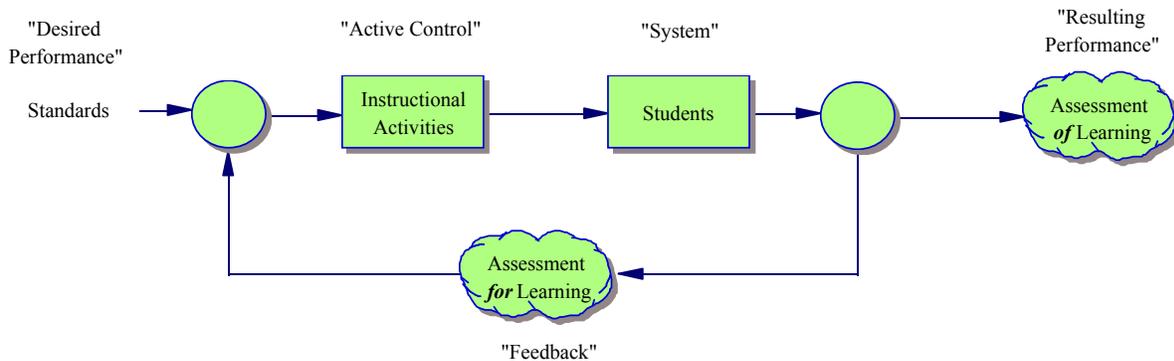


Figure 2.3: Classic Active Feedback Control Diagram

Together these two assessment types complete a sophisticated control system, with students at the center. Figure 2.3 uses a classical control block diagram to illustrate how these types of assessments work together with standards and instructional activities to educate students. Conscious development of each of these types is imperative for optimal effectiveness. For example, projects present rich assessments *of* students' learning. However, they can be a nightmare (for both faculty and students) if they do not correlate clearly with the objectives and are not supported by the instructional strategies. Assessments *for* learning give students and instructors feedback on how well the student is learning so adjustments to the instruction can be made.

PCM helps focus the assessment tools and products. For example, with the use of design reviews, the instructor may elect to provide written or verbal descriptive feedback as opposed to a checklist of elements presented in the review. By identifying the use of descriptive feedback as the assessment strategy, the instructor must identify the essential elements for evaluation. As all teachers know, there is always room for improvement, so the temptation is often to give *all* the comments that come to mind. This can create frustration for the students who are unaware of how to prioritize these suggestions – or may not realize which are requirements and which are suggestions. The PCM framework can help focus reviewers comments by first addressing the

objectives of the primary parallel. If students are “sailing through” those challenges, focus can be directed on the secondary parallels.

Conversely, there are times when instructors see that most or all of the teams are not progressing well. Sometimes students focus on the wrong problems, forget that they have to deliver something that works, or are distracted because other educational objectives (such as teamwork) appear to be hindering their progress. The PCM provides a way for instructors to remember the primary objectives and thus determine how to modify future instructional activities to support or challenge the students appropriately in focused areas. For example, if it seems that the team members still don’t understand the material required to solve the problem, focus can be made on ensuring they learn the concepts and skills required. If, however, individuals on a team actually are knowledgeable in the Core requirements but are failing to coordinate their efforts well (due to communication, fervent individualism, etc.), then feedback would focus on strategies to improve teamwork.

3 The Parallel Curriculum Model and Project/Course Innovations

The Parallel Curriculum Model (PCM) can be used to understand the innovative nature of projects and courses. Additionally, it can underline how the curriculum can be improved or, more importantly, how it may fail in the future if the assumptions they make become invalid. This section uses PCM to analyze four different ASEE projects presented in 2004-05.ⁱⁱ

3.1 Methodology

In each innovative example, the PCM was used following the guidelines in Section 2.4:

1. **Content:** Each paper was read to determine the content requirements of the course. This course content was determined from the paper content, the authors’ knowledge of engineering education, and ABET requirements.
2. **Other curricular components:** Since this is a reverse-engineering analysis, the other curricular components (assessment and instructional activities) were identified first. In design, these would be selected in response to the objectives of each parallel. It is useful to think of curricular components in tiers.
 - a. *Primary Curricular Components:* These are the “starting line up” components. In design, they are identified early on and lesson plans are used to outline their preparation, expectations, execution and debriefing. In this analysis, they included what types of introductory activities, teaching strategies, learning activities, assessment, and products were used.
 - b. *Secondary Curricular Components:* These are the “pinch hitters.” In this analysis, they were used throughout the term to tweak, tune or amplify the standing curricular components. These included grouping strategies, resources, and any formative changes that occurred as the course progressed.
 - c. *Lesson Plans:* Technically, lesson plans include not only the syllabus, schedule of lessons or activities, but also a layout of the particular primary and secondary curricular components for each lesson. Since these were not included in most of the papers, little is done in this analysis regarding them. However, if information about these, it is considered in the analysis of the overall effectiveness.
3. **PCM Analysis:** When doing a PCM analysis, it is important to identify the primary and secondary parallels. When designing curriculum, this is done just after the content is

determined. In this reverse-engineering exercise, it follows the identification of the curricular components:

- a. *Primary Parallel*: Key phrases regarding the project particulars were underlined and classified along one of the parallels. Then the paper was looked at as a whole: The primary parallel was determined by the most frequently occurring parallel.
- b. *Secondary Parallel(s)*: The secondary parallels were then identified and their relationships to the other parallels were determined.

These curricular design components were then considered as a whole, using the PCM. In design, each curricular component seeks to motivate, instruct, or assess students in the content areas. By using the PCM “lens,” the relationships of curricular components to the parallels underlined how the course educated students, what may be missing from the curriculum to meet its goals, and where an institution could go from this point.

In each innovative example, a summary of the project is provided, highlighting background information on the institution, students, and class. The key innovation is then summarized before the PCM analysis is conducted. The curricular components are outlined with respect to the PCM, and each section ends with a discussion about different directions each project can progress.

3.2 Physics for the Modern Warrior

The first paper analyzed was written by Michael P. Shannon and Lance K. Calvert, *Physics for the Modern Warrior: Bringing Innovation to Physics Instruction at the United States Military Academy* (2004).

3.2.1 Background

This paper, from the United States Military Academy at West Point, summarizes how their required calculus-based physics course was reworked to be more directly relevant to their students. All students at West Point, regardless of their major, are required to take this two-semester course. The military institution believes that it is important for their graduates “to understand how these [technological] devices work and the methods needed to prevent an enemy from using them against our forces.”^{16, p. 1} Because each graduate will be assigned a company of soldiers to command, the problems presented are typical of those they would need to solve in the various phases of a military operation.

The key innovation is that the traditional order of physics concepts was changed to accommodate this unifying theme of a military call to action.

3.2.2 PCM Analysis

The content of this course covers the material required of a two-semester freshman physics course. This is well defined in the academic community and in standard engineering curriculum requirements. Although the order is changed, the authors are clear that all the material was covered. The physics content aligns with ABET criteria 3 and 4.

A variety of curricular components were used: The “Call to Action” of a nuclear attack was the introductory activity that motivated the entire course. The “model-coach-fade” method transitioned teaching strategies (modeling, coaching) to learning activities (coaching, fading) so students became more active in the learning process. Secondary curricular methods were also used such as small groups in the coaching and fading as well as the military briefings on

weapons. The institution also leveraged its unique resources by bringing in actual weapons students would encounter in the field. Figure 3.1 summarizes these activities in the PCM framework.

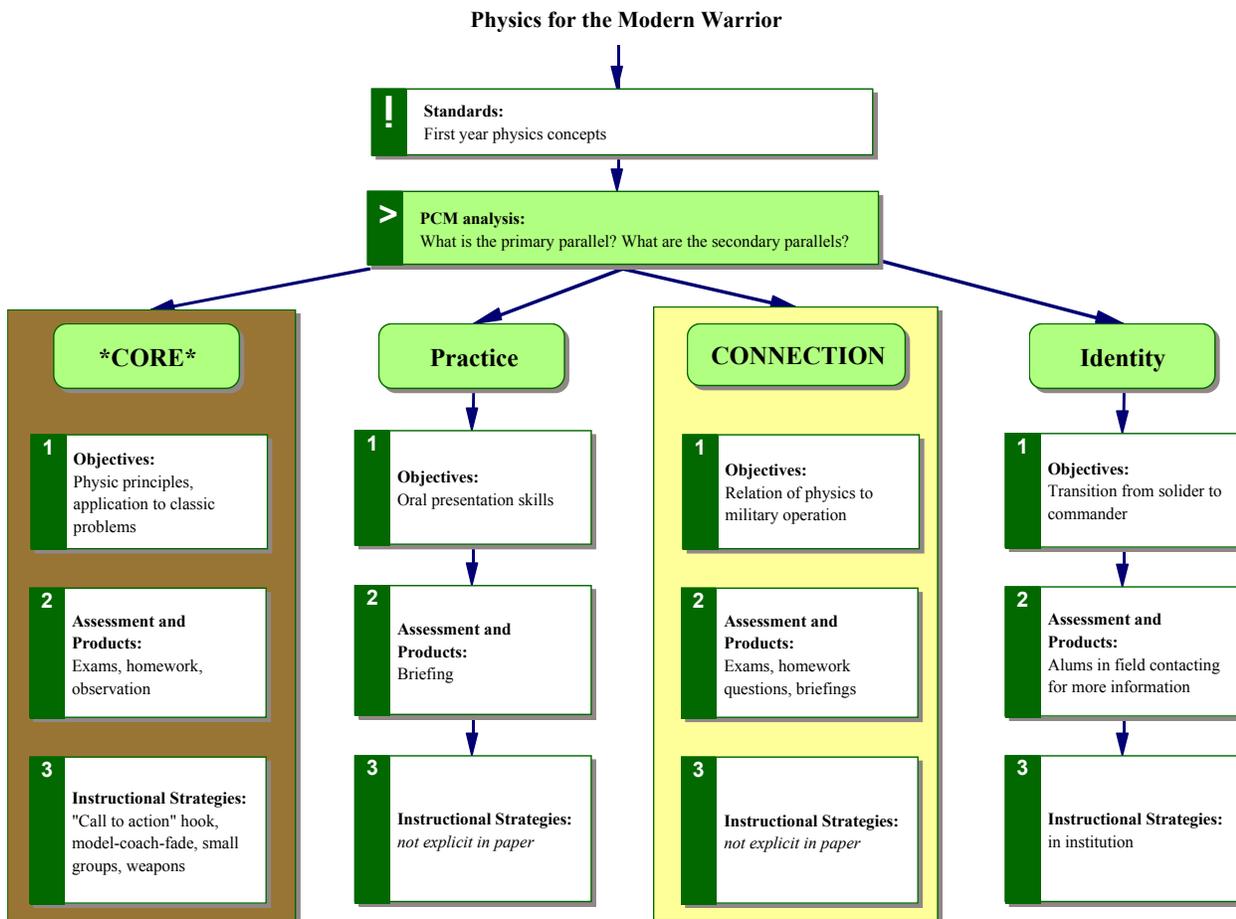


Figure 3.1: PCM Analysis of *Physics for the Modern Warrior*

The primary parallel was the Curriculum of the Core. Students must exit the class with the core physics principles under their belts. The entire project was designed to help all students, engineering majors and otherwise, learn as much of the material as possible.

The secondary parallel was the Curriculum of Connection because there was a strong desire to connect the physics lessons to a military operation. This “not only gives structure to the course, but also provides a means for the department to connect the many physics topics to the military applications that these young men and women will be exposed to in their Army career.”^{16, p. 5} The Connection parallel was the second thing on instructors’ minds when determining teaching strategies and learning activities. All assessment questions were focused on “Army-relevant problems”^{16, p. 8} and the traditional order of units was abandoned.

The Curriculum of Practice was a minor parallel. Students were required to demonstrate their abilities to operate as they would in the profession: Teams of students were required to “present military application briefings of 7-10 minutes at various points throughout the program that highlight military hardware with a focus on how the systems are employed and how the physics they have just studied is applied.”^{16, p. 7} No explicit instruction regarding the methods of how to prepare and present briefings was indicated in the paper, thus it was a minor objective. Hopefully, other courses instructed students on this Practice since it was used for assessment.

The Curriculum of Identity was a subversive parallel. Language referring to this was rare to non-existent in the paper. However, the designers assumed a shared military identity of the students. Since this is a military institution, this assumption was most likely a good one. Interestingly, although this parallel was minor in the instruction, it played a key role. It *leveraged* the students’ identity of being “soldiers” and, through the instruction focused on the other parallels, *transitioned* them to being “commanders”. This physics course, in a way, was changed to serve the military institution’s Curriculum of Identity.

3.2.3 What modifications could be made using PCM?

The presenters utilized their strong content expertise when designing this course. The content of the course was well defined, making it easy to identify the primary and secondary parallels. Furthermore, the project focused on a clear introductory activity and utilized teaching and learning strategies that were practiced by all 16 department instructors across 64 course sections.

Based only on the paper, the holes were in the minor parallels. Regarding the Identity curriculum, this course design would fail with students who did not see themselves as soldiers and those who did not want to be commanders in the future. Regarding the Practice curriculum, disparity in student performance might occur if the students were not explicitly instructed on the Practice of giving military application briefings. However, if students were given ample instruction in other courses, this would not be a problem. It is important to consider the curricular components in a single course as well as the curricular components of a program as a whole.

In their talk, the presenters cautioned about how transferable this program was to other schools. They realized that they discovered something interesting while reworking their course in this manner but were unable to state specifically how this could be done elsewhere.

The PCM analysis, however, points out clearly what the innovation is and outlines how this *could* be transferred to other institutions. Although the content is Core-focused, the innovation arises from the Connection and a shared Identity. If an institution can articulate a shared Identity of its students, this method could be utilized elsewhere, with some modifications.

For example, the College of St. Catherine (CSC) is a school founded on a tradition of social justice. It has a curriculum that encourages students to use their education for social action and philanthropy. If this strategy were used at CSC, the “Call to Action” could be changed to a “Call for Help,” in response to a natural disaster such as Hurricane Katrina.

This shared identity could also be construed on a departmental-level, rather than college-level: For an aerospace engineering program, this strategy could be used with a “Challenge: to Fly!” Each of these “frameworks” leverages a sense of identity that the students in the program are

most likely to share. This awakens the excitement and imagination of the students to learn the Core concepts required to meet the challenge presented.

In a physics course, the curriculum could transition students to a more general Identity. After students are “hooked” by the unifying theme, the basic physics concepts could be connected back to the technology in their everyday lives. By completing this Connection back to a personal Identity, students value the Core material taught, even if they change their majors.

3.3 Introducing First-year Students to Engineering, Economics, and Social Responsibility

The second paper analyzed was written by Margot A. S. Vigeant, James W. Baish, Daniel Cavenagh, Richard J. Kozick, Stoian Petrescu, Richard Zaccone, Ronald D. Ziemian, *Introducing first-year students to engineering, economics, and social responsibility: ADA compliance as a first project* (2004).

3.3.1 Background

This paper described a first-year engineering course at Bucknell University, a liberal arts college in Pennsylvania. This team-taught course is required of all students intending to major in engineering (approximately 200). Its objectives were to both introduce students to typical engineering practices and to expose students to the different engineering majors available at the university. A month-long project was used. It had students propose modifications to help the university comply with the Americans with Disabilities Act (ADA). The faculty hoped to achieve ABET-based engineering goals, expand the quantitative aspects of the project, motivate students, and heighten the students’ sensitivity to disability issues.

The key innovation of this project lies in having first-year students use typical engineering practices when solving a real university problem.

3.3.2 PCM Analysis

While the course tried to expose students to the various engineering disciplines available at the institution, the content of this course was primarily dictated by the authors’ desire to meet the ABET criteria 3a, c, d, e, f, g, h, and k.¹

The curricular components included lectures, laboratories, lab discussions, and a month-long project that required a presentation and report. Figure 3.2 summarizes the course components in a PCM framework.

From the start, the designers had the Curriculum of Practice on their minds. Curricular components such as specific lab assignments and lectures were focused on these practices. The assessment products (project presentation and report) were also typical practices expected of professional engineers.

A secondary parallel of this project was the Curriculum of Connections. This was supported by the “reality factor” of the project. By connecting students to the real world needs of disabled people (a guest lecturer who is a wheelchair user and lawyer), the students realized that their work as engineers will affect others in tangible ways. By having students report findings to the actual decision-making body (University’s ADA Committee), they also realized the role engineers play in the compliance process.

The Curriculum of Identity may have been a secondary parallel based on the stated goals. While explicit lectures were given about the different engineering majors available, there is an indirect hope that students' interest in engineering will emerge from the project. By having students *do* engineering, it was hoped that the students *see* themselves as engineers. There was also a hope to heighten individual sensitivity to disabled issues. This assumed that students were motivated by the (positive) social impact they may have on those in need.

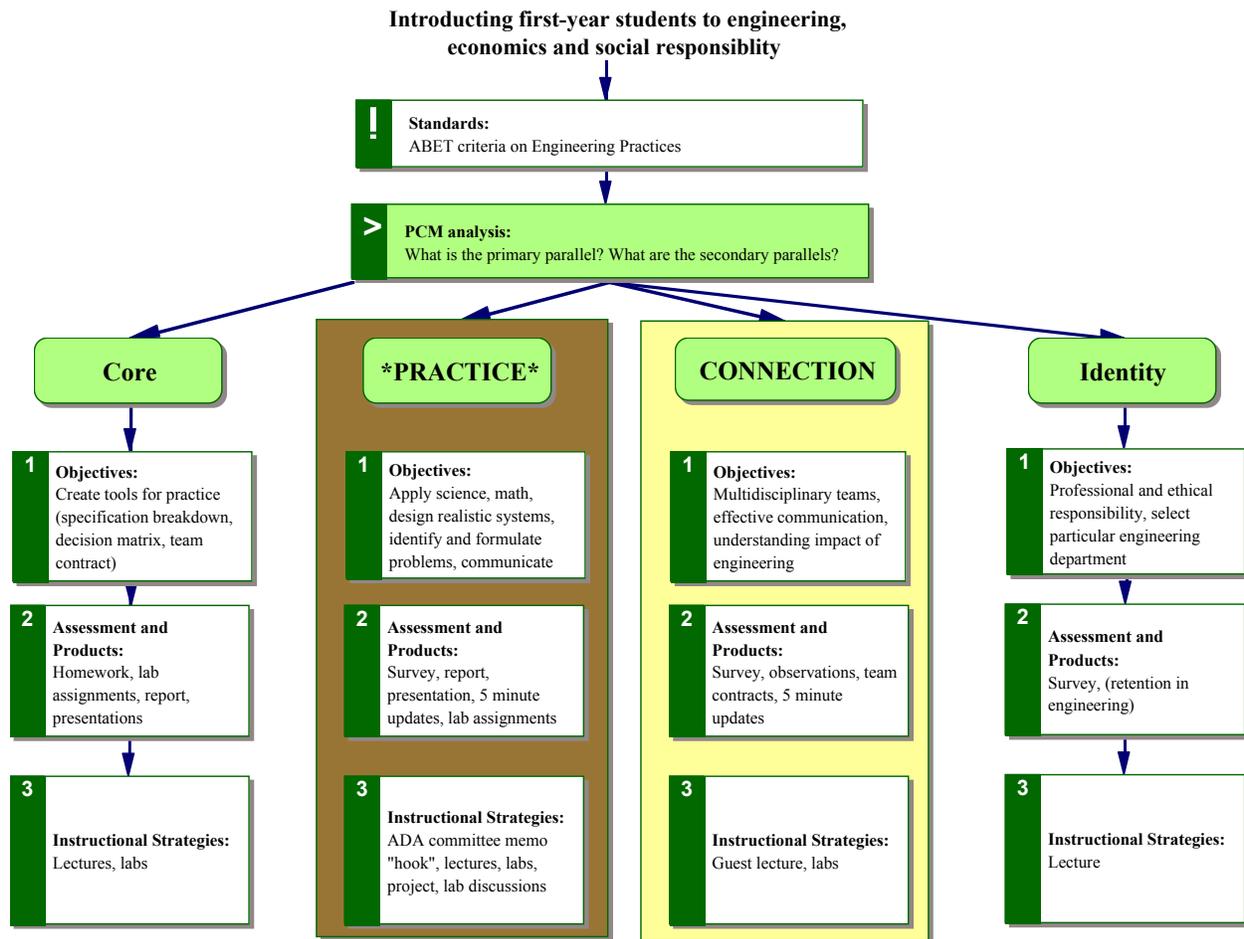


Figure 3.2: PCM Analysis of *Introducing First Year Students to Engineering, Economics and Social Responsibility*

The Core Curriculum objectives were a bit blurred. It is helpful to consider Core in this class in two ways. First, there is the Core material, such as the science and math that were needed to complete the project. Second, there is the Core of typical engineering practices: how to generate typical tools such as a requirements breakdown, decision matrices, and team contracts.

Little instruction was indicated regarding the first kind of Core material: It was probably assumed that students already knew the physics necessary for angle and force computations, the possible materials available and their properties, and the mathematics required for calculations. Regarding the second kind of core, some instruction was given on how to create these tools, how to “use oral/written communication” and how to “use graphical communication.”^{24, p. 3} It was assumed that students could either get all that was required from the lectures provided *or* that

they had taken or were taking courses in technical writing, technical drawing, and public speaking.

3.3.3 *What modifications could be made using PCM?*

In the PCM framework, some holes in the design exist based on the paper's description. Analyzing the instructional content using PCM reveals that the actual objectives are somewhat blurred: 1) to introduce different fields (Identity), 2) introduce technical and professional practices (Practice, requires Core), and 3) have students solve a long-term, ill-defined problem (Practice, requires Core and Connection, hope to develop Identity).

Having too many parallels in mind could result in a less focused curriculum. It is understandable why student evaluations indicated confusion: "several [students] pointed out that they would have appreciated a higher degree of organization and clarity from the project and the professors."²⁴, p. 8 The authors attributed this to the pilot nature of the project. While this may have been a primary reason, the PCM analysis reveals that specific curricular modifications could optimize the student learning.

In a sense, by doing less this course could achieve more. By focusing on the Curriculum of Practice and pulling in the secondary parallels when convenient would result in more streamlined student learning. Some ways this could be done include:

- ***Highlight the Practice content by explicitly introducing the project and its objectives early on in the term:*** For example, the project could be introduced at the beginning of the term, instead of at the end. The objectives of having students practice *being* engineers would be stated up front. If this course is meant to create an engineering context for core science and math material taken simultaneously, assessment tools would determine if students can give explicit examples of how the material in other courses would be needed to solve this problem.
- ***Highlight the value of Practice mastery by explicitly introducing the timeline and milestones early on in the project:*** For example, prompt the students with "How are you going to get this done in time?" The answer, of course, is that engineers have common practices that make "impossible" tasks achievable. These Practices include project management, teamwork, and the engineering design process. Now the stage is set for students to learn aspects of these. After each lesson, remind students how the lesson helps the overall project completion.
- ***Detail the degree students are expected to master Practices by giving a clear indication of rewards that students will get if they challenge themselves further:*** Students need to know what the basic requirements are, so that they can stay focused as they sift through the many other variables that may affect product outcome (team issues, limited graphical or written communication skills). This is especially important to eliminate disparity issues. For example, the authors indicated that they were impressed with some of the students' graphical abilities. If impressive graphics were given greater consideration by instructors, then in a sense, favoritism was shown to teams that had members with more visual knowledge and skills than others. It is important to explain how they will be considered (or not considered), especially if these skills were not part of the course instruction but were developed and leveraged by students who had previous experience.
- ***Expand Practices curriculum by creating explicit connection with the client:*** A key error engineers make in industry is to stay isolated from their clients or potential users. In

an attempt to protect wheelchair users from unwanted attention from inquisitive engineering students, the instructors forbade the students from talking with wheelchair users during the design process. This is actually encouraging a poor Practice. It is important for engineering students to interact as much as possible with the end users. This could be done within the curriculum. For example, a wheelchair “client” could be assigned to each team. This person would give students feedback on their designs and questions. “Reasonable burden” is something that only the client can comment on. This also helps students develop the human interaction required when they talk with clients who are directly affected by their work.

- ***Since Identity is a goal of the course, integrate awareness about different engineering disciplines into the context of the project:*** For example, at the end of the term, faculty could have a roundtable discussion or lecture, explaining the role that their individual discipline would have in the project. This would provide a context for students to “see” what their interests were in the project (Identity) and how that matches up with the different disciplines. For example, those interested in the details of ramp design might find civil engineering appealing. Those interested in finding out about the different materials that could be used might be more interested in chemical or mechanical engineering. Those interested in improving wheelchair capabilities might find mechanical or electrical engineering more appropriate.

First-year courses like this are important at many engineering institutions. It is important to make sure the course is a good experience for as many students as possible. The PCM analysis can help instructors streamline this critical course to optimize the student learning.

3.4 If She Weighs the Same as a Duck, Then She’s a Witch

The third paper analyzed was written by Stephen Ressler and Joseph P. Hanus, *If She Weighs the Same as a Duck, Then She’s a Witch: Using a Classic Monty Python Movie to Stimulate Transfer of Learning in Engineering Mechanics* (2004).

3.4.1 Background

This paper described a project in the engineering mechanics (statics and dynamics) introductory course at the U.S. Military Academy at West Point. The course included sophomore and junior-level students who were both engineers and non-engineers (science, humanities and social science students). It was one of the first engineering courses the students take.

This project, assigned near the end of the term as a “culminating course project,” intended to have students practice transferring their knowledge to new situations and to motivate them to continue in engineering. The students were required to watch *Monty Python and the Holy Grail* and select a non-trivial situation to analyze using engineering mechanics methods. The results of this analysis were then presented in a written report, complete with model sketches, assumptions made, computations required, and a discussion of the results and their significance.

The key innovation of this project is having students find an engineering situation in a non-engineering context, specifically in a popular film.

3.4.2 PCM Analysis

The content of the entire course was the standard engineering mechanics required of novice engineering students. This paper detailed a single project in the course. The project’s goal was to

have students transfer their learning to a new or unfamiliar situation. In particular, it had the following objectives:

- provide students with an opportunity to apply a major course concept to solve a problem in an unfamiliar context,
- allow students to choose from a broad range of possible problems to solve, and
- provide an enjoyable problem-solving experience as a culminating course project. ^{14, p. 2}

The course itself was not described in this paper. Regarding this project, the instructional strategies seemed minimal. The focus was largely on the student learning activity of creating the product. Students were given the assignment as a list of tasks to do: View the movie, select a scene, perform an engineering analysis, and prepare a written report. The analysis requirements were detailed in four parts:

1. Conceptual model of object or device from that scene, represented as a sketch or diagram.
2. Reasonable assumptions of the relevant engineering properties (e.g. weights, dimensions, coefficients of friction, types of support).
3. Computations to determine some aspect of the object's performance.
4. Explanation of the results and their significance. ^{14, p. 2}

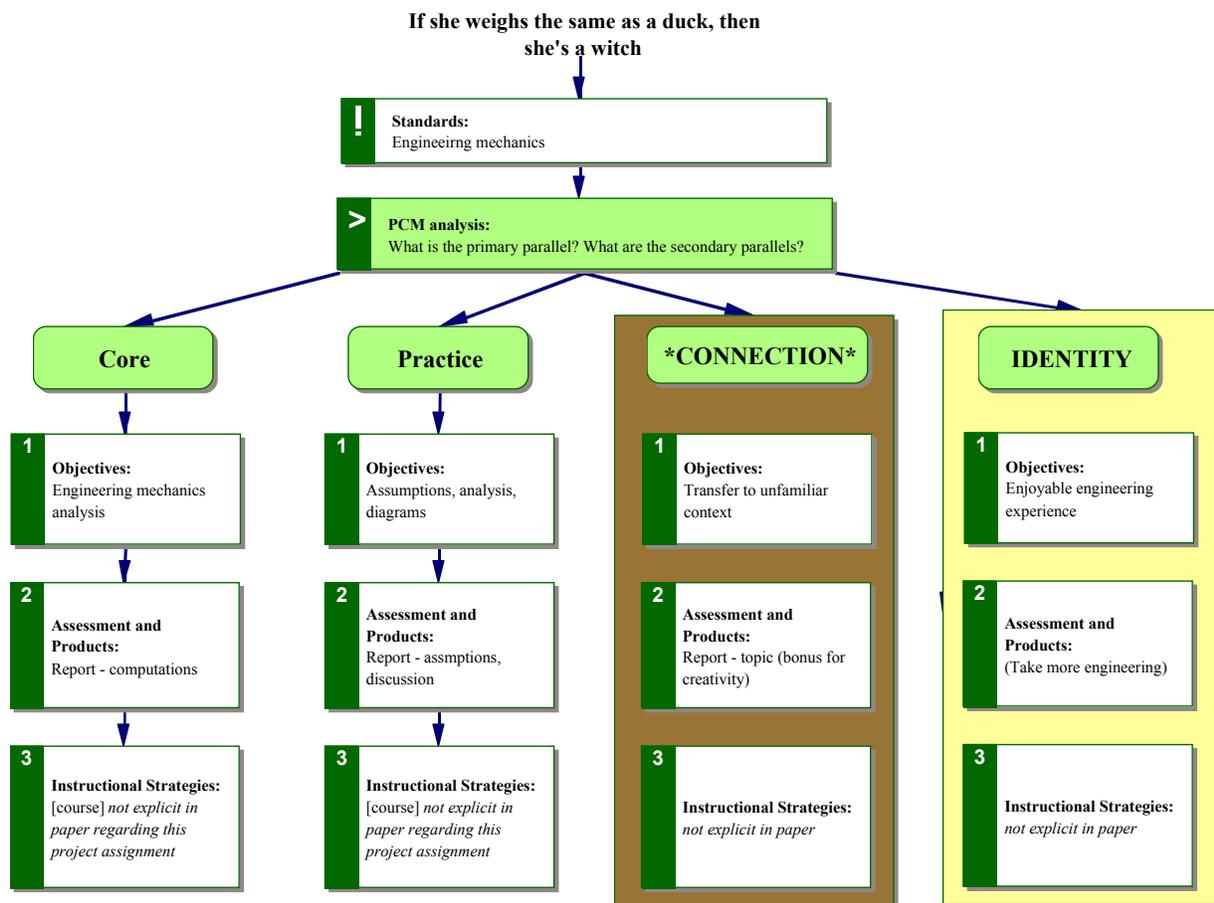


Figure 3.3: PCM Analysis of *If She Weighs the Same as a Duck, then She's a Witch*

Student products were assessed based primarily on the quality of the analysis, with some consideration of the report quality. Creativity was rewarded with bonus points as a way to encourage students to take a risk. This particular 2-week project was a cumulative one, assigned at the end of the term, and was worth 3% of the students' total course grade. Figure 3.3 shows the curricular components for this project in a PCM framework.

Since the goal was to have students use their knowledge in a new context, the primary parallel was the Curriculum of Connection. As the authors state: "In a context that one would normally not associate with engineering, the students have successfully identified situations to which their classroom instruction in engineering mechanics can be applied."¹⁴, p. 2

The Curriculum of Identity was a secondary parallel. The authors hoped that students would enjoy the exercise and thus continue their studies in engineering. Allowing the students to have some choice in what to analyze also addressed the Curriculum of Identity.

The Curriculums of Core and Practice were implicitly important for students to succeed since the majority of the assessment focuses on the quality of the engineering analysis. This required Core concepts from the engineering mechanics lessons and the Practices required to make "ball park" estimations.

3.4.3 What modifications could be made using PCM?

This was a great example of project-based learning. The designers leveraged their instructional expertise by giving a clear focused assignment to challenge the students to transfer their learning to a seemingly non-engineering context. However, the PCM analysis reveals that though the objectives were Connection and Identity in nature, the assessment was exclusively focused on Core and Practice. More could be done to achieve the Connection and Identity objectives by modifying the curricular components of this project:

- ***Make Connection aspects of the project "worth more"***: The goal of the project involves the Connection parallel, but the assessment focuses on the Curriculums of the Core and Practice. This makes sense for a capstone to the course, but the Connection objectives are rewarded only as bonus points. Moreover, the light weighting of the project in the overall course (3%) may encourage less impressive efforts in the future. As the project becomes a standard way to evaluate students, over-drawn students may find that the creativity and detail expected for the project may not be worth the payback in terms of their grade. If the light grade weight was adopted to counter the experimental nature of this project, it should be reconsidered in the future if this project will be a way to evaluate the Connection content of the course.
- ***Incorporate Connection instruction when introducing this project or pepper it throughout the Core instruction***: If it was desired for students to develop their ability to connect their material to other situations, Connection instruction is required. This could be done in a number of ways: Instructors could model how to find various obvious and hidden examples in the film, other films, or other situations while the core concepts are being taught. Discussion or readings could cover why using an engineering "eye" in non-engineering areas is valuable or important. Experts or students in non-engineering areas could be invited to present problems they wrestle, and mechanics students could suggest

engineering analysis approaches that could help provide insight into the problem or potential solutions.

- **Expand the Connections:** Guide students in questioning the film in more than an engineering-only manner. This creates a larger context for students, requiring them to leverage their knowledge from other classes, their past experiences, and perhaps their own interests. During the talk, the authors indicated that they were searching for new films. This is a good idea for a variety of reasons. First, there was an operating assumption that “many students were already quite familiar with the film.”^{14, p. 2} This assumption may prove detrimental for students with different backgrounds and experiences. For example, if students have not watched the film before, they may need two viewings in order to sift the plot (and enjoyment of the film) from the assignment. Furthermore, if students have difficulties understanding the British accent, the context for the problems may be missed. Other assumptions about the medieval setting could also influence student performance: for example, what materials were available, what tools were used then, or what cultural considerations (such as the persecution of witches) may “get in the way” of students being able to distill the essential components of the problem. During the talk, movies with Jackie Chan were suggested. A way to expand the Connections instruction would be to have students experience some simple martial arts or gymnastics routines. This would give all students a shared Connection experience and help them determine other factors to consider in their analysis.

Expanding the Connection *instruction* required for this project would help achieve solid learning in this area and complement the Curriculums of the Core and Practice. Additionally, explicitly helping students connect their new-found knowledge to other situations could help students advance on several parts of ABET Criterion 3.

3.5 Exploring Intrinsically Motivated Learning by Engineering Students

The last paper analyzed was written by Briar E. Schumacher, Donald F. Elger, Jon A. Leydens, *Exploring Intrinsically Motivated Learning by Engineering Students* (2005).

3.5.1 Background

This paper described a study done with eight undergraduate mechanical engineering students at the University of Idaho. These students ranged from freshmen to seniors. The purpose was to find out what students were interested in, particularly an area they apply to many aspects of their lives. After this was identified, the researchers probed how students improved themselves in this chosen area. Although this was not conducted in a particular class or regarding an engineering subject, this paper started to probe the engineering students for what motivates them in areas of interest and how this motivation-interest synergy propels them forward to become experts in these and other areas.

The key innovation in this project was that it started with the students’ own sense of identity, including their interests and values.

3.5.2 PCM Analysis

The interviews were conducted more as facilitations rather than question-answer sessions to illicit revealing responses from students: The interview started with “Help the student identify a topic in which they have intrinsic motivation.” This was followed by “Help the student identify

and reflect on the factors that enhanced their learning in the topic that they chose.” Finally, it ended with “Help the student prioritize the factors that helped their learning.”^{15, p. 3}

In the findings, the authors stated that beginners required a small amount of foundation (Core) and frequent participation (Practice). These two factors will increase motivation in a beginner. More advanced or experienced students, however, tended to have the opposite requirements. They tended to want “more foundation before engaging in participation.”^{15, p. 6} This assumes that the students have an inherent interest in pursuing this area/activity and wanted to do well.

Interestingly, the findings of this study were directly opposite of the traditional engineering curriculum which submerges students in Core material and some Practice in the first few years. In the latter years, as juniors and seniors, students heavily engaged in Practice by working on large-scale projects and internships. Traditionally, this had been because the students don’t “know enough” engineering in the first few years.

The results of this study underlined the innovative nature of the previous three projects since they each pushed more Practice into the first and second year Core curriculum. Although “professional results” are not possible in these first year experiences, the successes of these projects are supported by this paper’s findings: “A person learning engineering wants and needs to do engineering.”^{15, p. 6}

Apparently, incorporating more Practice early in the curriculum promises to buoy motivations of students who know they want to be engineers – or those who discover they like engineering. Students may have difficulties with more Practice if they enter the field because of misconceptions or external pressures such as parental or economic pressures. However, it may be better for these students to find out earlier rather than later that engineering is more than just a simple application of Core material. This study provided insight on how to develop the Curriculum of Identity with the Core and Practice curriculums.

3.5.3 What modifications could be made using PCM?

The findings of this study are valuable for curricular development. Starting with students’ sense of Identity is extremely valuable. The study found that at least 7 out of the 8 students were intrinsically motivated by topics that could be used or highlighted in the engineering Core, Practice or Connection curriculums.

A PCM-savvy instructor could leverage individual interests in an engineering course to motivate these students. For example, by paying explicit attention to some of the Core mathematics required for engineers, the instructor can demonstrate how mathematical calculations or reasoning is used in engineering courses. This would pique the student with interest in math. By incorporating Practices such as teamwork and documentation, the instructor could engage the students with interests in Boy Scouts/ leadership and documentation/ report writing. By selecting projects or discussion topics that Connect engineering with other fields, the instructor could leverage the students interested in rock climbing, Frisbee, and downhill skiing.

In order to carry these ideas of Identity forward, curricular components could be modified: Introductory activities can be used to find out students’ interests beforehand as well as ways to probe students about how they learn more in these areas. Teaching strategies can underline how

engineering enhances performance in their interest activities. Learning activities and products can challenge students to Connect engineering knowledge with their interest areas. Students with similar interests, for example, could be grouped to work on a project. Alternatively, students with complementary interests across the parallels could also be grouped together. For example, students with an interest in documentation (Practice) can be matched with students with area specialties (Core) and those with interests in the particular application (Connection). By creating opportunities for authentic participation of the student in the courses, the students can be more intrinsically motivated in learning the Core, Practice, and Connection topics.

| Step | 1: Warrior | 2: ADA | 3: Duck | 4: Motivation |
|--|--|--|--|---|
| 1. Content <ul style="list-style-type: none"> Standards Within program | First year physics curriculum standard; Introduces core physics for students, regardless of major | ABET criterion 3; Introduces engineering practices to engineering students regardless of specialty | Transfer of learning to new or unfamiliar contexts | Study starts by finding out about activities students are interested in and how they learn more in these areas |
| 2. PCM Analysis <ul style="list-style-type: none"> Primary parallel Secondary parallel(s) | CORE Uses Connection (military operation), and some Practice (assessment) to transform Identity (soldier to commander) | PRACTICE Wants Connection (with client, society) to create Identity (see self as engineer by doing, chose engineering disciplines) and utilize Core (relation with science & math prerequisites) | CONNECTION Wants Identity (motivation, excitement) but assesses Core and Practice (engineering analysis and report) | IDENTITY Hope is to increase student motivation in learning Core and Practice material; Connection is not directly addressed but may be implied |
| 3. Assessment & Instructional Activities <ul style="list-style-type: none"> Primary curricular components Secondary curricular components <i>Lesson Plans were skipped in analysis</i> | Intro activity (Call to Action), Teaching strategies (model, coach), Learning activities (coach, fade, small groups), Assessment & Products (tests, homework, military briefings) Grouping (small group), Resources (weapons, faculty expertise for briefing evaluations) | Intro activity (project), Teaching strategies (project-/problem-based learning, lecture, guest lectures, lab), Learning activities (listening, discussion, doing, calculating), Assessment & Products (lab assignments, project presentation & report) Grouping (teams), Resources (human experts, wheelchairs) | Intro activity (film), Teaching strategies (project-based learning), Learning activities (observing, calculating), Assessment & Products (report) Grouping strategies (2-person teams), Resources (A/V, film) | Curricular components with the Identity focus can be used to identify the individual interests of a class so as to inform how teaching strategies, learning activities, and products can be adjusted to capitalize on the areas that intrinsically motivate the students Students could be grouped by interest or across interests |
| Final Curriculum Analysis with PCM guidelines | | | | |
| | Leverages content expertise; content focused; assumes practice instruction elsewhere; could carry to other institutions | Leverages instructional expertise; content too broad; streamline curricular components along primary parallel | Leverages instructional expertise in problem formulation; missing instruction to develop connection; streamline curricular components along primary parallel | Requires instructor's time to determine students' interests; choose flexible instructional topics, activities, and projects to connect with those interests |

Figure 3.4: Summary of PCM Analyses

3.6 Summary of Findings

The findings are summarized in Figure 3.4. From this, we can see that the Core-based innovation is the most consistent and streamlined. This is not surprising since Core is where most instructors

start. Those venturing into the other curriculums challenge themselves by venturing into unfamiliar territory; bumps are to be expected.

Bumps come about when curricular components do not clearly support the content objectives. The PCM analysis helps underline where this deviation occurs and that clarity helps suggest ways to realign them. The PCM also indicates how curricular components can be streamlined to optimize student learning for the desired content areas.

4 PCM and Engineering Preparation Curriculum

PCM analysis can also be used in designing a program's curriculum. For example, the College of St. Catherine, a liberal arts college for women, does not have an engineering program itself. Instead, it partners with other institutions like the University of Minnesota. The traditional dual degree program has engineering students take their liberal arts requirements and the supporting science, math and computer science courses at the college. Then, in the fourth year, students transfer to the partner institution to complete their engineering education.

Based on the analysis in Section 2.2, this is a recipe for disaster, especially for women students. To succeed with our students, it is important to introduce engineering early. Since women also are unaware of how engineering connects to other disciplines and society, we need to provide opportunities for students to learn about these parallels.

As a liberal arts institution without an engineering department, we can't provide a complete engineering education. However, we can expand our role from just Core instruction to include some of the other parallels. Efforts are now being made to fill out the engineering preparation program using the PCM as a guiding framework:

- **Core** – Science, math, and computer science are still being taught. This is practical since these courses are available at the college, and they are required of all engineering programs. We are cooperating with the University of St. Thomas, a partner in the Associated Colleges of the Twin Cities, to introduce some Core engineering classes earlier. This helps students learn what the engineering discipline is earlier which usually piques their sense of Identity. We have a 5-year plan to tie in some hands-on fundamentals such as CAD and shop skills with our Associates degree programs. Having these tools available will also allow Baccalaureate students to have an opportunity to learn some of these skills while at the College.
- **Practice** – We have been teaching an engineering course for non-majors since 2003 that emphasize engineering Practices. At this time, one of our partner schools accepts this for their introduction to engineering. We are negotiating with the other partners to determine how this or a combination of other courses may satisfy some of their introduction to engineering courses. We also have informal opportunities such as “Taste of Engineering” which are open to all students.¹⁰
- **Connection** – We are developing a “Case Study” demonstration, similar to one done with our Health Professions, to demonstrate to students how engineering and other STEM majors combine to approach interesting cases. This activity has been extremely successful in encouraging students to consider other areas of health rather than just nursing. The purpose of the STEM case study would be to inform students, especially those on pre-med track, to see other ways their math and science abilities can be used.

Many of our talented STEM students initially enter college with the idea of going into medical school.

- **Identity** – We have been having field trips, shadowing programs and luncheons with the research and industrial facilities in the Twin Cities. These have had some success. We plan on incorporating some kind of engineering representation at the annual science seminar series to expose more students to what they can do as engineers.

5 Conclusions

This paper proposes that the Parallel Curriculum Model (PCM) is a flexible and comprehensive model that can be used to design engineering curriculum. It can be used on several levels: projects within a course, individual courses, programs in a department, or even engineering curriculum within an institution.

This paper covered how PCM could be used to design, analyze and improve individual courses. It explained the relationship of the four curriculums (Core, Practice, Connection and Identity) in an engineer's education and used them to analyze projects presented at past ASEE conferences.

The PCM is a useful model for engineering education because it

- clearly correlates with the “big ideas” described by the ABET standards.
- divides these ideas into *manageable* areas or parallels.
- provides guidelines for curricular design that complements a creative designer's mindset.
- allows separate components to be selected for individual parallels. This optimizes student learning in a streamlined design while still:
 - addressing diverse student needs;
 - honoring the instructor's content expertise;
 - allowing curricular components such as objectives, assessment and instructional activities to align with individual parallels;
 - leveraging available resources; and
 - keeping the course on task regarding the primary parallel.
- provides a language to describe or improve educational innovations.

The ideas of the PCM clearly explain why past innovations such as first year engineering courses, service learning, project-based learning, team projects, and co-curricular support programs are so successful in retaining and educating engineering students. Analyzing existing courses from a PCM framework can help explain and improve them.

This paper discussed how PCM could be used to design, analyze, and optimize innovative projects and courses. It illustrated how departments can apply it to revise program of study. It can also be used by institutions for systematic change such as how the engineering curriculum integrates across engineering disciplines, how the engineering school connects with the larger institution's general education requirements, and how students' formal curriculum integrates with their co-curricular (extra-curricular) activities.

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ⁱ A more detailed discussion of the contributing theories is presented in *The Parallel Curriculum: A Design to Develop High Potential and Challenge High Potential Learners*,²⁰ and *The Parallel Curriculum in the Classroom Book 1: Essays for Application Across the Content Areas K-12*.²¹

ⁱⁱ *Disclaimer:* These papers were selected from presentations that were attended by the authors during the last two years. They focus on introductory courses that mechanical engineers would take in their first or second years rather than more advanced courses that upper-level students would focus on. The institutions represented include public, private, and military, all which differ slightly in resources. Each project emphasized one of the parallels, but also pulled from the other parallels to create a more complete lesson, touching the students in multiple ways.