# Work in Progress: Signature Pedagogies in Engineering - Surface Structure

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The American Society for Engineering Education (ASEE) has a long history of making recommendations for improving engineering education, ranging from providing more contact with real engineering projects[1] to making engineering programs more engaging, relevant and welcoming[2]. A clear understanding of current practice in engineering education is critical to this process of improvement. Engineering, like other disciplines, has unique ways of thinking and knowing (habits of mind) and particular practices of teaching and learning[3]. These unique practices, called 'signature pedagogies', organize how future engineers are educated in the profession.[4] Lucas, Hanson and Claxton[5] propose that the predominant pedagogy of engineering does not align with true engineering habits of mind (EHoM). This work in progress aims to define the surface characteristics of engineering education pedagogy by analyzing topics presented at recent ASEE international conferences. The results of this study will inform a larger study which looks at potential disconnects between the way we teach engineering (signature pedagogy of engineering) and how engineers actually function in the discipline (EHoM).

## Rationale

Earning an engineering degree is a first critical step in becoming a professional engineer. An ABET accredited bachelor's degree requires only 48 credit hours of study in engineering topics[6]. Typically, one credit hour is equivalent to 15 contact hours with an additional 30 - 45 hours of out of classroom work expected of the students. Thus, the students are expected to 'learn' engineering with somewhere between 2100 and 2900 hours of study. Comparing this to employment, this amounts to only one to one-and-a-half years of full-time work. Upon receipt of a degree, a graduate is eligible earn the title of Engineer in Training. The status of Professional Engineer requires passing an exam after an additional 4 years of practice under a licensed engineer.[7]

Findings from the seminal Carnegie Foundation report *Educating Engineers*[8] indicate that engineering education is holding on to an approach to knowledge acquisition that is consistent with practice which the profession has long left behind. The authors of this report concluded that the primary goal of the engineering degree is the acquisition of technical knowledge, followed distantly by preparing the graduate for professional practice. This tradition of putting theory before practice in order to comprehensively cover technical knowledge allows little opportunity for a deep learning that mirrors professional practice. "What is needed for more effective engineering learning are ways of teaching that better connect the component parts of engineering work"[8(p174)]. Sheppard et al. identify five key insights for rethinking the education of engineers: "Engineering work is inherently interactive and complex; Formulating problems and solving problems are interdependent activities; Engineering has many publics, Engineering incorporates many domains beyond the technical; Engineers affect the world."[8(p175)] However, pockets of innovation suggest that transformation of engineering education is underway. In order to measure this transformation, it is important to benchmark the current practice, or 'signature pedagogy', of engineering.

## Signature Pedagogies

A signature pedagogy "organize[s] the fundamental ways in which future practitioners are educated for their new professions"[4(p52)]. According to Shulman, signature pedagogies have three structural dimensions – surface (operational acts of teaching and learning), deep (assumptions about how best to impart knowledge) and explicit (moral dimension that comprises a set of believes about professional attitudes, values and dispositions). Signature pedagogies in professional disciplines also have three temporal patterns: an initial pedagogy that frames and prefigures professional preparation, capstone apprenticeships and a sequenced and balanced portfolio[4]. Engineering, with its mix of analysis courses, laboratories and design studios, is characterized by the latter. Shulman also notes that a signature pedagogy can also be illustrated by what it is missing.

While there is an extensive body of research in the field of engineering education, a concise definition of the signature pedagogy of engineering has yet to be articulated. Historically, the most common form of teaching in engineering is the lecture, augmented with laboratories[9]. To paint a fuller picture of the signature pedagogy of engineering, it is instructive to look at instruction techniques being discussed at recent ASEE conferences. This study is limited to the surface structural dimension.

## Method

This study uses a grounded theory approach and a method of open and axial coding of educational practices reported in ASEE conference proceedings. Conference proceedings provide a good image of current practices because the publication process is relatively quick and accessible to practitioners. Shulman[10] notes that it is expected for signature pedagogies to change over time, and thus the literature analysis was limited to the past five years of publication. To create this image, paper titles and tagged topics from 2012-2016 international conference sessions were queried for mentions of pedagogical practice using the following search terms: "pedagogy" OR "teaching practice" OR "teaching method" OR "teaching technique" OR "teaching approach" OR "innovative teaching" OR "innovative method." This search returned 316 articles. The goal of this search is to gage the relative frequency of methods being disseminated. An open coding method[11] using up to 4 codes per article used the following procedure:

1. Review paper title. If obvious (e.g.: Understanding the Benefits of the Flipped Classroom in the Context of Sustainable Engineering) then create new code or fit into existing codes
2. If practice was not obvious from title move on to abstract and look for practices to code.
3. If practice was not obvious from abstract, open full document and scan article to determine practice. Code as above.
4. If no educational practice was evident after steps 1-3 leave code blank.

Using the list of open codes, a process of axial coding[11] was applied to categorize the different open codes. Categories were chosen based on the aspect of the practice (e.g. overall course format, specific technique, general approach). The frequency of open codes was then calculated to identify most prevalent themes and practices.

## Results

The process resulted in 125 open codes which were axially coded into six categories: format, approach, technique, enhancement, supplemental and assessment. Figure 1 shows these categories and frequency of the open codes under each. Open codes which occurred less than 0.5% of the time were grouped into 'other' categories.

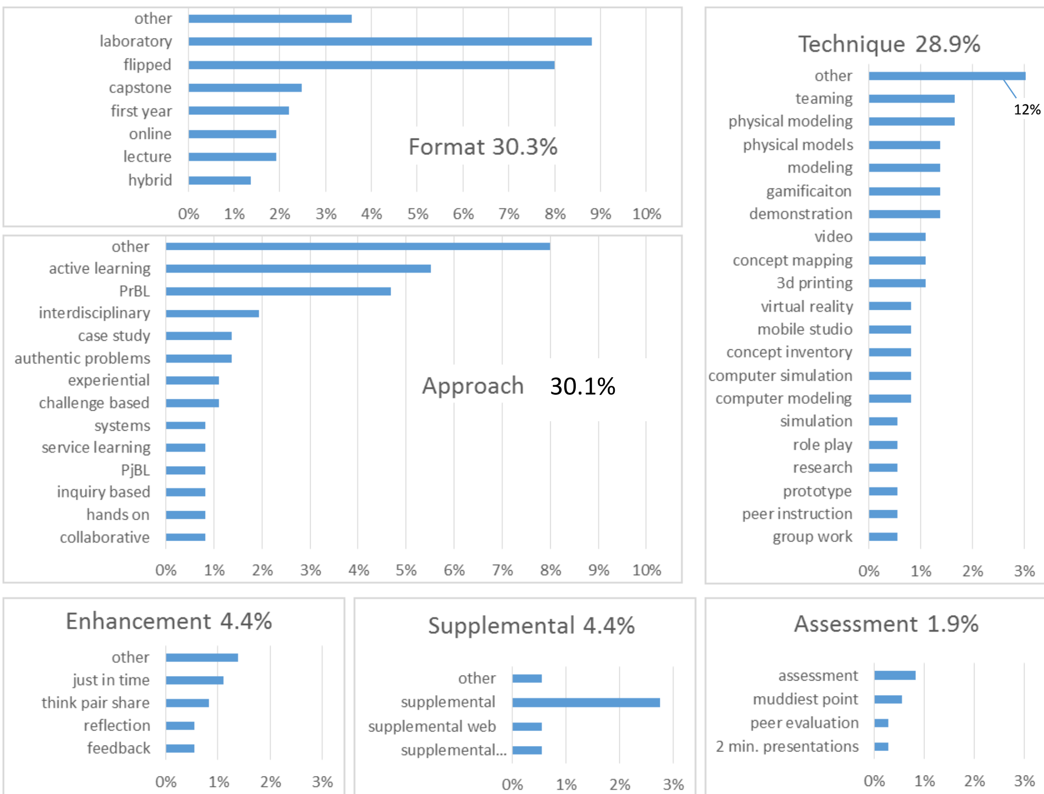


Figure 1: Themes in ASEE International Conference Titles 2012-2016

## Analysis and Discussion

The **Format** of a class encompasses delivery methods and class formats. Thirty percent of the coded practices relate to the format of the class. Confirming the traditional engineering format, articles on laboratories was most prevalent, with the flipped classroom format a close second. Hybrid and online course formats were separated from flipped classrooms, although they share an online component. Consistent with the ABET requirement of a culminating experience[6], the capstone course gets attention, as does the first-year experience. Less than two percent of the articles were explicitly about the lecture format, but upon further review, it appears that many of the other approaches, techniques and enhancements were presented in the context of the traditional classroom.

Thirty percent of the codes fell into the theme of educational **Approach.** This includes general articles on curricular philosophy and overall approach to teaching and learning. Active learning dominated this category. Many of the codes in this category could be grouped under authentic and experiential learning practices which have long been associated with engineering education. Problem-based (PrBL) and Project based (PjBL) learning methods are also common in this category as are case studies and interdisciplinary learning.

It is not surprising that engineering educators use **Techniques** that rely on a myriad of modeling techniques, ranging from computer simulation, to creating physical models, to using demonstrations in the classroom. Almost twenty nine percent of the codes mapped to practical educational techniques. These complement the active, problem-based and experiential learning approaches previously identified. Engineering educators are using cutting-edge technologies like virtual reality and 3D printing in the classroom.

Engineering educators **Enhance** and **Supplement** their courses. Enhancement includes practices that draw on the research on teaching and learning[14] to help students learn better. Supplements in the form of text books have long been a staple of the traditional course, however, engineering educators are also using supplemental instruction (via teaching assistants) and web resources. This is most evident in the flipped, blended and online formats.

About two percent of the codes mapped to the **Assessment** practice theme. Many of these are consistent with Angleo and Cross' widely known Classroom Assessment Techniques (CATs)[15]

**Conclusions:**

The engineering laboratory is the format that is most common format reported in these articles. Few authors laude the lecture format, but rather take it as a given and publish on ways to enhance it via supplemental materials, formative assessment and techniques. The flipped classroom format is very popular. Current engineering education scholars are talking about philosophical approaches that are dominated by active learning and project/problem based learning. Authentic, experiential, and service learning are also common.

Surface Features of the signature pedagogy of engineering can be characterized as the enhanced lecture which relies on physical and virtual model demonstrations, problem based learning and active learning approaches, combined with laboratory courses. The use of formative assessment is reflected in the literature. Enhancement comes in the form of providing supplemental learning opportunities that go beyond the textbook and include teaching assistant (TA) guided instruction, use of web resources and enhanced guided notes. There is a prevalence of leveraging technology to blend or flip classes. Authentic environments that include interdisciplinary, experiential, collaborate, inquiry, challenge, and service learning are also prevalent.

**Future Work**

A trend analysis of the frequently identified practices may help characterize whether a particular topic is becoming more or less popular. Additional work to characterize the deep and implicit structures is needed to provide the full picture of the 'signature' of engineering education.

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