Outcomes-based Design of a New Graduate Program

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Dr. David A. Delaine is an Assistant Professor at The Ohio State University Department of Engineering Education. Within this newly formed department he strives to creatively impact engineering education and society through investigating community-based learning and its potential impact on students and communities. The goal of this research is to establish knowledge in how STEM CBL can support broadening participation and promote social justice and citizenship through evidence-based approaches.

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Outcomes-based Design of a New Graduate Program: A Case Study

Introduction
Graduate curricula (i.e., requirements for plans of study leading to masters or doctoral degrees) are important elements of graduate programs. Numerous graduate curricula have been designed and implemented, including graduate curricula for post-baccalaureate degrees in engineering, including engineering education. The National Science Foundation’s annual solicitation for the NSF Research Traineeship (NRT) program, previously called the Integrative Graduate Education and Research Traineeship (IGERT) program, was initiated in 1998 to catalyze cultural change in science, technology, engineering and mathematics (STEM) graduate education. The NRT / IGERT program highlights a national need for innovation in the graduate space, and many advances have been funded by this program. However, after searching the literature and studying graduate curricula from other engineering education departments, the authors were unable find a graduate curriculum that had been designed following an outcomes-based, backward design approach (Wiggins and McTighe, 2005). The authors advocate this design methodology, and the resulting graduate curriculum developed using this approach provides an example that can inform development of other graduate curricula. In addition, as a newly established academic department of engineering education in a large, public research-intensive university, we wanted to establish a clear identity that would distinguish the program from those at peer institutions and illustrate elements of instructional design to the students enrolled in the program.

The authors could find very little guidance in the literature for developing an outcomes-based graduate curriculum in which program learning outcomes were explicitly tied to program assessment activities (e.g., doctoral qualifiers, candidacy exams), course learning outcomes, course assessment activities, and course learning activities. Therefore, the faculty committee charged with designing the graduate curriculum reached out to the university faculty development center which had already established support for course and curricular design, although mostly developed with undergraduate education in mind. This paper reports how an outcomes-based design process was applied and adapted to create a new graduate program in a newly formed department.

Outcomes-Based Design in Higher Education
Outcomes-based, backward design of academic courses and curricula is a sound approach to building coherent learning experiences. The concept of backward design in education is most frequently traced to the work by Grant Wiggins and Jay McTighe, as presented primarily in the book, Understanding by Design (1998, 2005). In simplest terms, they claim that learning experiences are most effective if they are designed beginning with the goal and moving backward through a fully-aligned structure of learning outcomes, evaluative tools, and student assignments, rather than the traditional process of starting with a collection of informational content to be covered. This process, when done well, allows the creation of courses or curricula that focus on the intended learning outcomes and provide clear data about student achievement of those outcomes, both individually and in the aggregate. In the three decades since the first edition was published, this process has been adapted, tested, and studied in many contexts, and the book has been cited over 8000 times in the scholarly literature per Google Scholar.
Following this trend, our university's faculty development center has instantiated backward design, mainly through 15-hour long Course Design Institutes (CDI). Originally developed in 2009 to support university faculty in anticipation of the 2012 conversion from quarters to a semester academic calendar, this program continues to be in demand and successful (Johnson et al., 2017). Our version of backward design incorporates elements from Fink (2013) as well as Wiggins and McTighe (2005), and other evidence-based pedagogies. In addition to assisting individual instructors to design courses, staff at the faculty development center have also worked with groups of faculty members on revising programs using a similar process.

Since 2000, the ABET engineering accreditation focus has shifted toward learning outcomes and continuous improvement and away from prescriptive curricular requirements (Prados et al., 2005). Beyond engineering, the entire learning outcomes assessment movement suggests that an intentional outcomes-based process should be valuable. It is much easier to assess the achievement of program goals and learning outcomes if these are clearly stated in advance and if the course level outcomes are aligned with and mapped to the program level outcomes. However, designing a well-aligned curriculum requires significant rethinking of both program content and faculty work processes, often scrapping the entire existing program and starting from scratch. In our experience and in our review of the literature, this does not seem to occur very often, and when it does, it does not seem to be founded on a strong conceptual base.

In addition to determining the shape of the program and creating the course list and curricular map, because this project was designing a new PhD program, we discovered that we needed to do holistic program design. Many of the activities that support and assess the intended learning do not happen within the structure of a class. Milestone exams, structured research activities, and professional development opportunities all need to be created in alignment with program goals and outcomes, to make certain that the program fulfills its stated goals and that successful students graduate with all intended competencies.

To define terms and design structure for the purposes of this paper, program goals are broad descriptions of student understanding, abilities, and dispositions, which may not be measurable. Program outcomes are measurable, observable statements of students’ understanding, abilities, and dispositions in practice at the desired mastery level upon graduation. Successful completion of a set of outcomes implies successful achievement of the aligned goal. Proficiencies are beginning, intermediate, and mastery level component skills or abilities or dispositions that lead to the aligned program outcome. Figure 1 summarizes this organizational structure. Successful completion of a set of proficiencies implies successful completion of the aligned outcome. Learning activities are then aligned to one or more proficiencies within the settings of courses or other learning opportunities. Therefore, a well-designed program will have explicit alignment in both directions, from learning activities to all levels of proficiencies to outcomes to program goals.
Constructive Alignment in Interdisciplinary Graduate Curricula
The authors found very few studies examining design of graduate curricula that applied the understanding by design framework developed by Wiggins and McTighe (2005). The most comprehensive study examining constructive alignment among learning outcomes (or objectives), assessment, and learning activities in graduate curricula that the authors found was a study of interdisciplinary graduate programs funded by the NSF IGERT program. The study used the understanding by design framework and emphasis on constructive alignment (Biggs, 1999) to evaluate graduate curricula proposed by these programs. The study found "that many interdisciplinary graduate program proposals lack strong connections between desired outcomes, evidence, and learning experiences, and suggest that more thorough integration of each of these goals may better support new and continuing interdisciplinary programs” (Borrego and Cutler, 2010, p. 356). Before we began, we looked to existing engineering education PhD programs to learn about their goals, objectives, and courses. The programs did influence the design of our program; however, we were only able to find high level information about the programs. The detail we were looking for was not available and is one of the reasons that this paper makes a valuable contribution to design of graduate curricula.

Design Process
The current standard format for a Course Design Institute (CDI) at The Ohio State University is an intensive learning experience engaging a cohort of approximately 12 instructors, meeting for five, three-hour sessions to learn and apply the backward design process, in order to provide a high-impact opportunity for community building and buy-in peer support. Each participant takes away a draft of a fully-aligned, integrated course plan for their target class. Typically, the university faculty development center has offered this opportunity to seven or more groups per year, including several that are adapted to the needs of specific types of courses (e.g., online, international). Since the inception of the program in 2009, more than 1100 participants across all ranks, and from all colleges and most departments have engaged in the process, including several members of the Engineering Education faculty. Faculty development center staff members have developed significant experience and expertise in course design, and have studied the social, intellectual and metacognitive outcomes for participants (Johnson et al., 2017).
The design process is valuable beyond the level of the individual course. Curriculum review and design projects inhabit the space between the CDI and student outcomes assessment activities. One of the co-authors has been deeply engaged in unit development efforts focused on curriculum design, creating a process that extends what we had learned about course design to extend across multiple levels of a program, and to include a large enough group in a department to build buy-in. For curricular projects to succeed, multiple stakeholders must be involved and collaborative participation of an entire instructional community is necessary.

The design process follows a sequence of stages:

(a) Select the big rocks (i.e., conceptual must-haves)
(b) Develop program goals
(c) Develop program-level learning outcomes
(d) Develop two to four proficiency levels for each learning outcome
(e) Distribute the proficiency levels across the program's curricular and co-curricular elements, creating a curricular map / spreadsheet
(f) Design the courses and co-curricular elements to ensure that the assigned proficiency levels are appropriately taught and assessed
(g) Collect periodic quantitative program assessment data on aggregated student achievement of the proficiencies and qualitative feedback from instructors and students
(h) Regularly analyze the collected data and revise program (courses, co-curricular elements, curricular map) as indicated by gaps in achievement and negative feedback
(i) Intentionally onboard new members of the community (faculty and students), introducing them to this approach and including them in ongoing refinement of the program

Case Study (Subtitle: It’s simple, but it ain’t easy)

The following is a case study of the design of a doctoral program in engineering education.

Big Rocks
The big rocks are the decisions we made for our Ph.D. program that directed our thinking about the design of the curriculum. Questions we asked ourselves included “What do we want our Ph.D. program to be known for?” and “What impact will our graduates make in the community?” These brainstorming sessions ended up with a brand statement for our program along with our vision of how our program will fit into the engineering education community. This led directly into the program goals following the conceptual framework.

Conceptual Framework
At the time work began on the curriculum design effort discussed here, engineering education was a new department at The Ohio State University. It would certainly have been possible for the faculty committee charged with proposing a new PhD degree to have taken the description of a program from an aspirational peer institution and made minimal adaptations to it. The Graduate Studies Committee reviewed several existing programs to understand to range and scope of what other universities were doing in this space. They also explored what literature exists about such programs. However, in order to create a program that would be the signature of the department and the center of its identity, the design team decided to design a program from the ground up, instead.
Having made that decision, the committee members looked to the research literature to find a system for designing such a program. While graduate programs in engineering education are increasing in number, they are still relatively few. Worldwide, there are twenty-nine institutions that specifically offer engineering/STEM education doctoral programs (ASEE-SD and CELT, 2019). As such, there is not a large body of established curricula to inform what and how PhD students in engineering education are taught.

Our own department of engineering education was formed in November 2016, having previously operated as a center offering large service courses for the College of Engineering, such as first-year and technical communications courses. In the transition from center to department, the committee was charged with the creation, approval, and implementation of a doctoral curriculum in engineering education.

To accomplish this charge, both retained and new faculty partnered with the university faculty development center to undertake an evidence-based approach to curriculum design by participating in a multi-week workshop (described above) during the summer of 2016. The committee invested substantial time, energy, and work beyond participating in the workshop.

In terms of scope, this paper describes the overarching framework for curricular design that the committee used, with some concrete examples of the results. Understanding that all educational and institutional contexts are unique, the committee offers its reflections on this process as a case study for an anticipated growing phenomenon—the design and refinement of curricula in graduate-level engineering education as a formal discipline (Walker et al., 2008).

**Program Goals**

The committee spent the first several meetings brainstorming, developing, and refining clear broad descriptions of what students in the engineering education doctoral program would know and be able to do at the time of graduation. Some of these were standard graduate level cognitive goals, others were affective and psychomotor, some were disciplinary, and all were ones that the faculty thought should be distinctive to our program. The five program goals are that successful graduates of this engineering education doctoral program will be able to:

1. Identify, discuss, and address critical issues facing engineering education in alignment with stakeholder needs
2. Design, conduct, and critique research in engineering education
3. Demonstrate, value, and apply engineering expertise
4. Create, teach, and assess courses and curricula in engineering
5. Identify, demonstrate, and value appropriate personal and professional skills, mindsets, and traits

These goals were based on a variety of sources including standard, traditional goals of all graduate educations such as “become an independent scholar in the field,” core elements of the discipline that are parallel to peer programs, like “identify, discuss, and address critical issues facing engineering education,” and professional identity and dispositions desired by local faculty members, such as, “Identify, demonstrate, and value appropriate personal and professional skills,
Learning Outcomes
The committee viewed program goals as internal goals for the successful student graduating from the program. As written, they are not directly measurable, and therefore serve as the program's internal goals. In order to transform these high-level internal goals into something externally measurable, the committee refined the goals into sets of intended learning outcomes, which are more specific, measurable or observable and form the basis for students to demonstrate their achievement of the goals. Each of the five goals translated into four to ten learning outcomes, resulting in 36 total outcomes. Once the committee had drafted the goals and outcomes, it moved to developing three proficiency levels for each outcome, to better explicate the progression of student abilities and the growing mastery intended as a student moves through the program. Descriptions of what achievement of beginning (B), intermediate (I), and advanced (A) levels of mastery for each outcome were written. More importantly, we discussed what level of proficiency in each outcome would be required for completion of the degree. Figure 2 presents an example of the results of building out program goal 1 to its aligned outcomes and proficiency levels.

Having constructed an initial listing of goals, outcomes, and proficiency levels, the committee began to map the curriculum. In this stage, the committee attempted to align courses and co-curricular milestones to the structure of program goals, program outcomes, and program proficiencies. Alignment was done to assure that students will encounter every outcome at every necessary proficiency level in some element of the PhD program and will be evaluated to
demonstrate their attainment of that level of proficiency. The resultant curricular map was a 37 by 20 grid (Figure 3). The mapping process allowed the committee to see gaps, where intended outcomes were not actually taught, and overlaps, where students would be asked to recapitulate the same learning at the same level. This is not to say that some designed repetition might not be useful, but only to ensure that it is not an unintended redundancy.

![Curricular Map](image)

**Figure 3. Outcomes-based curricular map for a doctoral program in engineering education.**

The curriculum map allowed the committee to assign specific learning outcomes clearly to the core required courses and to divide the effort of designing those classes to individual faculty members and smaller teams. Other co-curricular milestones were also mapped to the 36 outcomes, including an annual review of graduate students, Qualifying Exam, Proposal and Candidacy Exam, research group interactions, teaching opportunities, dissertation research documentation, and oral defense.

Once the curriculum was mapped, the committee began considering outcomes-based design of individual courses. The committee transitioned from the curricular design framework to design
of individual courses. The committee distributed relevant learning outcomes across the 14 weeks of a semester. The next step was to identify what type of assignment would be used to assess each objective at the specified proficiency level for that course. As the week-by-week course skeleton was developed, assignments and teaching methods were allocated to each week’s theme. Figure 4 shows an example of this development process for one of the program's required core courses.

Figure 4. Outcomes-based course skeleton for ENGREDU 7900: Professional Development in Engineering Education.

Participants and Timing
When the committee was ready to begin developing the doctoral program in the summer of 2016, it drew on support from the university faculty development center. The committee invited the center to participate and two teaching consultants agreed to facilitate the design process. The committee and the two consultants began by meeting daily for nine days in early June, then shifted to weekly meetings for a month, and then met daily for another week in late July. The committee met occasionally thereafter over a period of nine months, with additional preparatory work in between team meetings. The committee then met biweekly and spent a portion of each meeting using backward design principles to collaboratively create curricular milestones, such as the Qualifier and Candidacy Exams.

Once the program had been collaboratively designed and documented in a 24-page proposal (plus lengthy appendices), the approval process began. This involved presentations, discussions, peer reviews, revisions, and faculty votes for approval by the department, the college, the graduate school, the university-level Council on Academic Affairs, the University Senate, the university Board of Trustees, the Chancellor’s Council on Graduate Studies and the Chancellor
of the [state name deleted for blind review] Department of Higher Education. From start to finish, the entire process ultimately took 25 months to complete.

**Lessons Learned**
As with any project of this scope, there were many lessons learned including the following:

A good curriculum is a living entity; the committee is constantly assessing, revising, and improving the curricular map and process.

Use three levels of proficiency for each outcome, especially if building from scratch. The three levels create a developmental model for students' progress through the program. It is important to consider what would be the most natural path through the three levels of proficiency for students to learn any given outcome.

A detailed curricular map is not the end point; it is a starting framework to design the classes that make it possible for students to achieve the desired proficiency levels.

Use outcomes-based design for both individual courses and non-course elements (e.g., qualifying/candidacy exams, annual reviews) of the doctoral program.

Incorporate assessment and closing the loop in the both program development process as well as ongoing evaluation and fine-tuning of the program.

Do not underestimate the amount of work required to do this process well; departmental administration must be supportive of resourcing this amount of faculty time.

Facilitating a group of faculty members, no matter how dedicated or engaged, requires openness to adaptation of the process as we learn what is and isn’t working, as well as patience and the ability to build consensus.

Plan for and incorporate assessment of aggregate student performance and closing the loop in the program development process and ongoing fine-tuning of the program (e.g., adjusting where each outcome is addressed in the program, and scaling back any overly ambitious assumptions about what can be achieved in a single course).

Plan for an annual course round-up that allows the design team to reflect on what worked well and what needs ongoing improvements. It also provides a forum for shared decision making about course and curricular changes.

This collaborative team approach is somewhat contrary to the more prevalent academic pattern where individual faculty members have a sense of ownership toward the courses they teach but rarely have developed a sense of shared ownership, as a community of scholars, of a well-designed curriculum that meets the goals set for it.
Plan for a structured onboarding of new instructors, so that faculty who were not part of the original program design team can contribute to the ongoing program development and gain a sense of shared ownership for the overall program.

This graduate program leading to a PhD in engineering education is an example of outcomes-based curricular design developed to fit very local needs, goals, and constraints. It cannot simply be adopted in entirety and dropped into another institutional framework. The committee advises faculty who are contemplating embarking on a similar program development or renewal process at their own institution is to adapt the model, not adopt it. The process is key, not the particulars that this process achieved when applied in one specific context.

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