AC 2010-1747: INTEGRATING THE ENGINEERING CURRICULUM THROUGH CROSSDISCIPLINARY STUDIOS

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Integrating the Environmental Engineering Curriculum through Crossdisciplinary Studios

Abstract

Traditional curricular approaches within and beyond engineering education tend to be fragmented, with opportunities for synthesis being predominately limited to freshmen and senior year design courses. In this paper, we are proposing a curricular model, the Synthesis and Design Studio, as an example implementation to combat the tendency towards fragmented curricula. The proposed approach attempts to negotiate the realities of fragmented curricula by providing an integrative learning component. The pedagogical features of an interdisciplinary studio with engineering and art students that was implemented in the Fall 2009 will be described. Preliminary analysis of student feedback indicates some integration of students' learning across different domains. Future research will include analysis and results from the case study and evaluation.

Introduction

It is increasingly critical that every engineering student graduate with a well-rounded education, with abilities ranging from engaging in complex thought, analysis, quantitative and qualitative reasoning to communicating effectively.[1-5] Unfortunately, the implementation of this drive to provide breadth to an undergraduate education often results in a general education curriculum with a set of disparate and disconnected courses, instead of an integrated experience.[6-7] We believe that the undergraduate experience must provide some coherence across courses, extracurricular activities, service learning and student life. In the Greater Expectations report, the Association of American Colleges and Universities recognizes the "fragmentation of the curriculum" as a significant "barrier to high quality".[8] Similarly, the Boyer Commission on Educating Undergraduates in the Research University explains that "the freshman experience needs to be an intellectually integrated one, so that the student will not learn to think of the academic program as a set of disparate and unconnected requirements."[9]

An analysis of the relevant literature suggests that some integrated learning opportunities exist in typical engineering programs.[7, 10-11] Indicative of this are efforts to integrate student learning in engineering through capstone Senior Design experiences and more recently through freshmen engineering courses.[11] This approach to an integrated curriculum with a freshmen engineering course at the beginning of the curriculum paired with a capstone course at the end of the curriculum has moved us closer towards the goal of an integrated curriculum, thus giving the students more opportunities to integrate their learning.[11]

With integrative opportunities at the beginning and end of typical engineering curricula, engineering education as a discipline is uniquely positioned to lead the effort towards more integrated curricula. This is true especially at a time when other professional disciplines are creating capstone courses and experiences to begin to integrate their curricula.[12] On the basis of the body of knowledge created through these curriculum integration efforts, we propose a continuous integrative approach to engineering education as a possible next step in this

development. This approach provides an explicit curricular element to encourage students to integrate disparate learning throughout their entire university experience as they progress through the program. This leverages the strengths of traditional courses in existing programs while making the connections between courses explicit in this curricular innovation.

The implementation of this approach to a continuously integrated curriculum at the University of Georgia (UGA) involves the design and implementation of the Synthesis and Design Studio Series in an Environmental Engineering program;[13] the first iteration of this new course having been completed in the Fall of 2009. The following describes both the theoretical curriculum model and the pedagogical characteristics to achieve curriculum integration and subsequently explores how these were implemented through concrete design features within the course.

Proposed Model

The developments at UGA outlined in the sections below were based on the outcomes of the Engineering Think Tank, with interdisciplinary members from visual arts, cellular biology, pharmacy, geography and engineering. In a series of interdisciplinary focus groups with undergraduate students, graduate students, faculty members and administrators the Think Tank first developed the profile of the UGA Engineer and based on this devised a curricular model for attaining this type of student. The resulting profile of a UGA Engineer consists of technical excellence, humanism and innovation. Moreover, the Think Tank report[14] specifies the following three components of innovation: lifelong learning, creativity and adaptation. Also the report conceptualizes humanism as critical in facing global issues that require engineers to be embedded in the human and environmental contexts of their work.

To implement this vision, the Faculty of Engineering at UGA is currently designing and developing its Environmental Engineering curriculum. This integrative curriculum is intended to overcome engineering students' commonly observed difficulties in developing innovative and humanistic designs for local complex systems.[15] In each of the semesters of their program, Environmental Engineering students will be required to take Synthesis and Design Studios with a focus on observation and modeling, management and communication, problem framing, and synthesis. As illustrated in Figure 1, the Studio approach focuses on integrating the traditional curricular elements in order to support students' holistic development including their creative problem solving and design skills. The bottom tier in Figure 1 represents the fundamental and traditional courses that are required for engineering students. The top tier in Figure 1 shows the desired UGA Engineer with attributes of technically excellent, humanistic, and innovative. The integrative studios will provide a means to bridge from the traditional curricula to achieve the UGA Engineer.

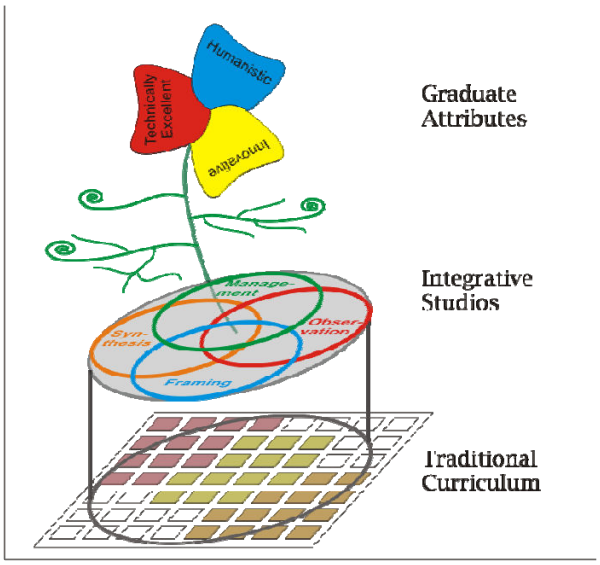

Figure 1: Concurrent curriculum integration through Synthesis and Design Studios

Curriculum integration occurs at different levels and intensities in an educational program. The lowest level involves integration within one discipline, the next involves integration across several disciplines and the highest level involves integration within the learners themselves.[16] The lowest level implies a fragmented model, which involves separate courses that rarely make explicit connections between courses. For example, in most engineering fundamentals courses there is an implication of a connection to other courses through prerequisites and co-requisites. At the other end of the spectrum, the ideal of a fully integrated curriculum synthesizes fragmented engineering and non-engineering courses as well as the students' prior and current life experiences (See Figure 2). This reflects current knowledge about how people learn, highlighting the importance of connecting academic knowledge to real-life experiences.[17]

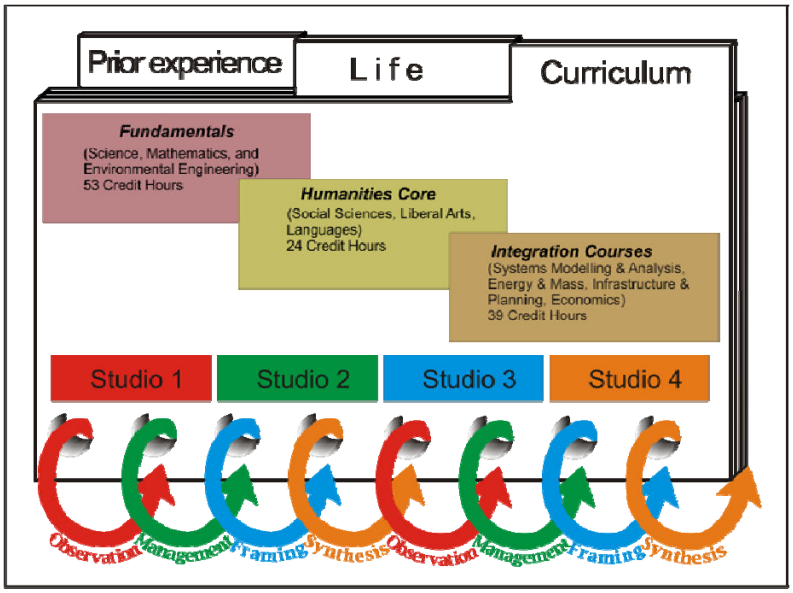

Figure 2: Holistic student development through the concurrent integration of the curriculum with prior and current life experiences

The main objective of the Synthesis and Design Studio Series is for students to develop a deep understanding of larger systems in which engineering is situated. Throughout the four years, students will develop an understanding within themselves of the interrelationships between engineering, social sciences, and humanities, thus reaching a high level of integration as described above.[16] Our premise is that as a result of the Studio Series, the students will become systems thinkers with the ability to think holistically as well as reductively in order to be prepared to deal with complex issues in their careers. The Studios of the different years will meet simultaneously to encourage near-peer learning and mentoring among the students, for example seniors will provide mentoring to sophomores. These Studios are modeled after the graduate-level studios that have been implemented in the Department of Educational Psychology and Instructional Technology over the last 10 years.[18-19]

The Synthesis and Design Studio Series consists of studio sessions throughout every semester of the curriculum that will provide students with an environment that encourages them to establish synergies among their engineering courses, between their engineering courses and humanities or social science courses, and between their education and their life outside of the university (See Figure 2). These Studios provide a concurrent integration of students' educational and life experiences (prior and current) as is shown metaphorically in Figure 2 with the binding of the pages. The fundamentals in the curriculum are unchanged from typical and traditional curricula with science, math, engineering sciences, humanities, social sciences and engineering electives. The themes and a brief description of all of the design Studios are provided below:

Observation and Modeling (Freshmen). The main objective of the first year of the Synthesis and Design Studio is to introduce engineering undergraduate students to design through an experiential group design experience and to teach them observation, modeling, the use of metaphors, and creative thinking strategies through an ill-structured sustainability design project.

Management and Communication (Sophomores). The second year of the Synthesis and Design Studio will continue with project-based learning and will focus on learning strategies for managing teams that are working on large-scale, complex issues. Within their design project, the students will develop a business plan that includes scope, time, performance, and team management. The course is intended to develop students' marketing, finance and entrepreneurial business skills, which are commonly seen as critical in developing America's workforce.[20] The modules will be taught by the course professors and include guest appearances by alumni and faculty from the business school.

Problem Framing (Juniors). The main focus of the third year Studio is for students to develop an understanding of framing problems within a complex, global landscape. As with the other years of the project, this will involve project-based learning centered on the issue of sustainability and will include workshops or modules for students to continue to hone their skills of convergent and divergent thinking.

Synthesis (Seniors). The main objective of the senior level Synthesis and Design Studio is for students to continue in their development of a deep understanding of design through an in-depth, project-based design experience that requires synthetic thinking and understanding.

As the Synthesis and Design Studio is threaded throughout the curriculum, all Studios will be similar in that they embody the characteristics of concurrent integration: project-based, service-oriented, reflective, relevant, and synthesis-focused.

Pedagogical Features and Implementation

The Studios described above are based on the notion of concurrent integration as a learning strategy or experience that establishes the link between the courses of a curriculum and promotes students' development into holistic engineers (See Figure 1). We propose that concurrent integration embodies each of the following characteristics:

Project-based. Project-based learning is an extension of problem based learning, but specifically involves challenges that are current, global, implementable locally, and ill-structured.[21] An important aspect of project-based learning is that it is student-driven, thus involving learner-centered experiences that are motivated by the students' desire to learn instead of motivated by the instructors' desire to cover material.[17] Additionally, this student-driven approach to integration will result in peer and near-peer learning and mentoring among the students.[17, 22-23]

Service-oriented. Connecting material across the curriculum alone will not achieve concurrent integration. The Studios require the integration of concepts and knowledge with the local community, as this helps explicitly connect concepts and knowledge to the prior and current experiences of students, resulting in deeper learning of concepts.[24-26]

Reflective. Developing and encouraging reflection and metacognition will enable students to be aware of what they know and to realize when they need to learn or explore more.[17, 27-29] Multiple opportunities for reflection and metacognition will encourage more learning to take place and potentially help students achieve synergies between disparate aspects of their learning.

Relevant. By focusing on relevant design challenges surrounding issues, such as sustainability, the Studio will be designed to continuously to respond to the changing global context of engineering.[30]

Synthesis-focused. Through explicitly connecting materials across the curriculum and across students' education, life, and prior experiences they will begin to achieve curriculum integration.

For this first implementation of the Studio model, it was decided to integrate the environmental engineering students with art students for the potential synergistic possibilities as both disciplines have a significant design component. The Studio consisted of ten art students (mostly juniors and seniors) and nine engineering students (freshmen with a few transfer students) and was co-taught by two faculty from engineering and one from art. The Studio met twice a week for three hours per session. These Studios were significantly different from typical courses encountered in the engineering or art curriculum. To demonstrate how the above characteristics were implemented into the Studio offered in Fall 2009, we describe in more detail three pedagogical features and their intent: (i) ill-structured and personally relevant projects, (ii) deliberate reflective activities, and (iii) synthesis-focused learning.

Projects. In the interdisciplinary Studio offered in Fall 2009 interdisciplinary teams engaged in two projects. The first was a small project that lasted for two weeks on the waste management system in the engineering building. The intention of this project was to expose the students to a design project and to expose the students to our expectations of their work in the class. The second, larger project involved observing, abstracting, modeling, and problem-framing within the context of energy encompassing one of the following sectors in the local community: residential, transportation, commercial, infrastructure, food, and ecosystem. The project was structured with deliverables including reports at multiple milestones. These milestones included a report focused on observing and abstracting energy within their system, a second report with modeling and problem framing, a final report including observing, abstracting, modeling, problem framing, an implementable example initiative, and a process reflection. Each of these milestones was assessed using rubrics. The primary intention of the second project was for students to understand the importance of developing a deep and broad understanding of a system prior to proposing solutions. The design projects were essential to integrating the curriculum for both engineering and art students.

Deliberate Reflective Activities. A key component of the Studio was students' guided, deliberate reflection on their overall development focused on interdisciplinarity, creativity, interpersonal skills, and identity formation. Reflective activities in the Studio include the following: a visual journal, reflective critiques, in-process critiques, focus groups, and a process report. Students kept visual journals and were required to keep notes from team meetings, reflections of the team interactions and individual reflections, notes from required readings, minute papers, and individual work. At the end of all in-class activities students participated in a reflective critique which included one of the following: a group discussion; a written discussion of the intent of an individual's work and a written discussion of the possible intent of another's work; minute papers reflecting on the process and based on specific questions from the instructors. In-process critiques occurred at two times during the semester—each two weeks before a major deadline. These in-process critiques consisted of a 10 minute presentation describing the team's progress and two or three focused questions to encourage helpful feedback from the class. Focus groups based on critical incident techniques were conducted at three times during the semester to elicit students' accounts of critical learning experiences and to purposefully structure their analysis. Through these deliberate reflection activities, opportunities were provided for students to draw connections across their curriculum and their lives, possibly leading to concurrent integration of the curriculum.

Synthesis-focused learning. One of the opportunities afforded in this Synthesis and Design Studio arose because of the interdisciplinary nature of the course. One challenge that arose was in how to balance content and ways of thinking from the different disciplines involved, and this challenge led to an opportunity to achieve concurrent integration. In this Studio, we challenged students and ourselves to incorporate multiple modalities creatively in representing learning and assessment. Students were asked to develop an example initiative of how they would raise awareness about the problem they framed regarding energy in their chosen system. The final projects included a common element of design, but each group representation reflected a synthesis of content, tools, and thinking dispositions from both disciplines that resulted in something more than just an art exhibition or an engineering report. The students' initiatives and some of their selected work created over the semester were presented in an exhibition during the

last week of classes. As a final performance assessment, this exhibition revealed a third space in the interdisciplinary curriculum that was a hybrid of content and ways of thinking characteristic for engineering and art. This third space provided openings for creative thinking and dialogue about pressing issues related to energy use in local systems, which can have a larger impact than working within each discipline's boundaries. By providing these tensions and resulting synthesis between two seemingly disparate disciplines, we planned to move closer to a concurrent integration model of the curriculum.

Discussion

The section above details the pedagogical features for achieving curriculum integration and illustrates three of these features in the context of a Synthesis and Design Studio that was implemented with engineering and art students. In this way we hope to connect the theoretical curricular models with concrete experiences from educational practice.

To illustrate the usefulness of both the overarching model and the pedagogical features beyond the detailed description of their implementation, the following explores some early evaluation data through the voices of students who participated in the course. This is not intended to serve as a comprehensive evaluation of the pedagogical innovation but rather to fill in theory and instructor intent with the life of students' shared experiences of the course.

The interdisciplinary nature of the course with its challenges, tensions and learning opportunities served as one of the catalysts that involved the students and reached beyond the immediate course content. Engaging with the current and personally relevant projects prompted students not only to bring their disciplinary expertise but also their personal perspectives to bear in the project. Supported by the deliberate reflective activities this resulted in fundamental processes of self-definition and professional development for some students. One art student expressed this process of living through an intellectual but also personal transformation as:

"The different mindsets of engineers and artists were evident in this class at the beginning, yet everyone merged I feel as the semester went on, which was really interesting to see and experience."

Elaborating on the different levels on which this integrative experience occurred, an engineering student commented:

"This course helped me eliminate my stereotypes of artist and engineers, so I can see the broad scope of possible applications of art and engineering in society; particularly, the fusion of the two disciplines can be synergistically productive."

This illustrates that for these students the synthesis of learning, as described above, does not only include the application of knowledge or ways of thinking across domains but also extends to attitudinal aspects such as the genuine appreciation of the societal relevance of new ways of thinking. The observation of such developments seems promising, with a view to helping students develop into the technically excellent, innovative and humanistic professionals as was envisioned by the think tank and described in the beginning of this paper. Future work will

further evaluate this and explore the interplay of specific influences and the range of concrete outcomes to share an effective model for innovation in engineering education curriculum well-suited to the challenges of the 21st century.

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