THE CENTER FOR ENGINEERING EDUCATION AT THE COLORADO SCHOOL OF MINES: USING BOYER'S FOUR TYPES OF SCHOLARSHIP

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Abstract—*The Center for Engineering Education (CEE) at the Colorado School of Mines promotes both educational research and improvements in teaching. In order to connect the potentially competing activities of research and teaching, CEE has used Ernest Boyer's model of the four forms of scholarship to describe the Center's activities. According to Boyer, the word "scholarship" should not only describe the activities of those conducting original research (which he called the scholarship of discovery) but should also be extended to include the scholarships of integration, application, and teaching. This paper describes Boyer's model and provides examples of how these four forms of scholarship display themselves in CEE-sponsored projects.*

Index Terms—*educational research, engineering education, Ernest Boyer, student learning*

INTRODUCTION

This paper begins by describing the historical events that led to the development of the Center for Engineering Education (CEE) at the Colorado School of Mines, followed by a statement of CEE's mission and its goals. Next, Boyer's four forms of scholarship are presented as the framework that was used to guide the development of CEE's projects and activities. This paper concludes with a description of two CEE-sponsored projects that illustrate the four forms of scholarship.

HISTORICAL DEVELOPMENT

The faculty at the Colorado School of Mines (CSM) have been interested in education and educational research for over twenty years. In the late 1970s and earlier 1980s, CSM sponsored a Seminar Series on Education [1]. Offered once a month, these popular seminars gave interested faculty the opportunity to talk with well-known engineering educators. These seminars were so successful in stimulating faculty interest in both educational innovation and educational research that many faculty became actively involved in educational efforts that spanned beyond their classrooms.

In reaction to the growing interest in education, the Office of Teaching Effectiveness was formed in the mid-1990s. The Office of Teaching Effectiveness provided both professional development for new and experienced faculty and instructional training for graduate teaching assistants. Since CSM's primary focus is on engineering and the physical sciences and therefore had no college of education, the Office of Teaching Effectiveness became the sole institutional support system for the improvement of teaching and learning.

In 1990, a new entity was conceptualized — the Center for Engineering Education (CEE). The purpose of CEE is both to provide professional development opportunities to faculty and graduate students and to foster educational research at CSM. After ten years of discussion, the Center for Engineering Education (CEE) was formally established in January, 2000. The professional development duties of the Office of Teaching Effectiveness were immediately assumed by CEE, and CEE took on the additional role of supporting the educational research efforts that were taking place across campus.

CEE'S MISSION STATEMENT AND GOALS

The first task for the new center was to articulate its mission and its goals. The mission of CEE is to improve the learning of science and engineering, thereby increasing the accessibility of these disciplines to a broader population of students. The goals of CEE are as follows:

(1) to conduct world-class research on the teaching and learning in science and engineering,
(2) to use the results of that research to continually improve instruction at the Colorado School of Mines to better support the learning process of our students, and
(3) to support the educational needs of science and engineering instructors at both the K-12 and the college level.

BOYER'S MODEL: FOUR FORMS OF SCHOLARSHIP

In *Scholarship Reconsidered*, Boyer [2] argued that the intellectual rigor that defines scholarly activities should

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extend beyond conducting original research and publishing results. Boyer suggested that the same scholarly rigor be applied in four inter-related activities: discovery, integration, application, and teaching. These four kinds of scholarship do not exist in isolation, but often overlap.

Boyer's framework was immediately recognized as an ideal structure to guide CEE's actvities [4]. This section briefly describes each of Boyer's four forms of scholarship. For greater detail concerning these forms of scholarship see Boyer [2] and Glasic, Huber & Maeroff [3]. For a more in-depth discussion of how these forms of scholarship display themselves through CEE activities see Streveler et. al. [4].

The scholarship of discovery is the act of creating new knowledge within a given discipline. This is the traditional view of research on college campuses. Discovery is central to the advances of any given discipline, and is driven by what an individual investigator or team of investigators desire to know.

The scholarship of integration connects or links information between different disciplines and areas of knowledge. Integration is the act of taking facts and concepts that emerge through separate investigations and linking these facts in a meaningful manner.

The scholarship of application builds upon the scholarship of discovery and the scholarship of integration. After new knowledge is discovered, the question becomes, "how can this knowledge be used?" The scholarship of application is the use of new knowledge for practical purposes.

The scholarship of teaching puts the results of research into action. The teacher's laboratory is the classroom. Much like research, quality teaching requires the testing and verification of educational hypotheses. Scholarly teaching is an on-going process that requires the assessment and evaluation of the impact of new innovations on the learning process.

The majority of CSM faculty cannot be categorized into a single form of scholarship; rather, most faculty lie in the intersection of one or more forms of scholarship. We believe that given an appropriate structure, the diverse skills of the faculty can be assembled in a manner that improves the teaching and learning process.

EXAMPLES OF THE FOUR SCHOLARSHIPS AT WORK

CEE sponsors a number of different programs that support the different forms of scholarship. The two programs that will be discussed here were selected since they illustrate all four forms of scholarship within a single program.

Student Misconceptions in Engineering

Some CEE faculty are actively exploring the question of "why are some concepts in science and engineering so difficult for students to learn?" Evidence from the literature in cognitive psychology suggests that science and engineering students do not conceptually understand many fundamental molecular-level phenomena such as heat, light, diffusion, and electricity [8]. These types of phenomena are examples of emergent processes, processes that involve uniform, parallel, independent events with no beginning or end. Emergent processes are contrasted with causal processes. Causal processes involve distinct, sequential, goal-oriented events, that have an observable beginning and end.

It has been proposed that conceptual misunderstanding arises when students incorrectly think of emergent processes as having the attributes of the causal processes that they have seen in everyday life [9]. For example, students may view the observed structure or patterns emerging from a series of random events such as Brownian molecular motion (the result of an emergent process) as being the result of a causal process. They often incorrectly describe molecules as moving with intent in a linear and sequential process that stops at some point.

Students tend to resist changing their causal models, even after instruction. Therefore, they continue to explain emergent phenomenon incorrectly. Thus, this theory explains why students persist in their belief that light acts as a flowing substance, heat moves from hot to cold bodies, and electricity flows through wires [8].

Many fundamental topics in engineering also involve emergent processes that are incorrectly viewed by students as causal. Thus, engineering students may describe molecular momentum transfer as faster molecules "dragging slow molecules along," heat as a "substance stored in hot objects," heat transfer as a "flow of hot molecules to cold objects," and molecular processes as "stopping" when they reach equilibrium. None of these explanations are correct and each leads to incorrect explanations of other related phenomena (for example, incorrectly predicting the absence of a temperature effect on equilibrium processes or predicting that no molecular diffusion occurs in laminar fluid flow). There is also evidence in the literature that causal explanations are often incorrectly invoked in textbooks, and by faculty members [8, 10].

Studies are now being formulated at CEE to investigate what concepts engineering students find difficult, and to develop an assessment instrument to measure student misconceptions in engineering. Eventually, methods of instruction are expected to be created that will help students understand emergent processes.

Since the discovery of knowledge is paramount, at first it may appear that this research project is solely concerned with the scholarship of discovery. However, closer examination shows that all four kinds of scholarship are at work. Certainly the primary focus of this project is to discover new knowledge (scholarship of discovery). However, the integration of knowledge, particularly from cognitive psychology, is vital to the project's direction (scholarship of integration). The results of this project will be applied to create an assessment instrument to measure student misconceptions (scholarship of application). Finally, new forms of instruction are expected to be developed to help students better understand these difficult concepts (scholarship of teaching). Thus, the scholarships of discovery, integration, application and teaching can all be witnessed in this single project.

Teaching Doctoral Students About Teaching

Another example of a CEE activity that illustrates all four forms of scholarship is the effort to educate engineering faculty in educational research. This type of effort has been supported by recent literature [11].

CSM has established a 2-credit graduate course called "Fundamentals of College Teaching" designed for engineering doctoral students who are contemplating a career in academia. This course is taught every fall and three CEE faculty serve as the instructors. Table 1 contains a brief description of the course, a list of the course objectives and an outline of the course activities.

At first glance, this course appears to focus upon the scholarship of teaching and indeed the scholarship of teaching is a primary activity. Students learn about and practice teaching methods, and read Wilbert McKeachie's classic work *Teaching Tips* [12]. Students practice, and are given feedback on teaching, through short presentations called "microteaching." However, as with the research project described above, all four scholarships are involved. The students in the course are doctoral students, most of who are deeply involved in their original research projects. Students are encouraged to share what they have learned in their research through their microteaching assignments, thus the scholarship of discovery is brought into the course.

A central component of the course is integration of knowledge from educational and cognitive psychology. The initial topic for the course is "how people learn" and we also use readings from the book of the same name [13]. Students in the course learn about how knowledge is organized, how that organization changes as one gains expertise in a field, and the role of one's previous knowledge in learning. Thus, the scholarship of integration is a vital component of the course. The scholarship of application is also an essential component. In order to give effective presentations, students need to apply the teaching principles that have been discussed in the course. Therefore, the scholarships of discovery, integration, application and teaching are all a part of this course.

CONCLUDING REMARKS

When discussing engineering education, it is valuable to think of "scholarship" in the extended way proposed by Boyer. Traditional research is not the only way to conduct scholarly activity. The scholarships of integration, application and teaching are also important in engineering education.

The Center for Engineering Education at the Colorado School of Mines has found Boyer's model very useful in organizing its activities. Not only do the activities of CEE span all four kinds of scholarship but, as illustrated in this paper, the four forms of scholarship may also be part of a single project.

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TABLE 1
FUNDAMENTALS OF COLLEGE TEACHING

Course description

The course, designed for graduate students planning to go into academics and for interested CSM faculty, will focus on:

- Principles of learning and teaching in a college setting.
- Methods to foster and assess higher order thinking.
- Effective design, delivery and assessment of college courses or presentations.

Learning objectives

The course will help students become better able to:

- Describe and apply the principles of learning and teaching in a college setting.
- Design, deliver, and assess a college course
- Apply methods to foster and assess higher order thinking.

Course schedule

Week 1	Introduction. How students learn.
Week 2	Models of intellectual development. Perry, King and Kitchenor. Students take the Kolb Learning Style Inventory, and the Myers-Briggs Type Indicator (MBTI).
Week 3	Learning styles. Interpret the Kolb Learning Style Inventory, and the Myers-Briggs Type Indicator. Implications for teaching and learning.
Week 4	Active learning principles and methods.
Week 5	Cooperative learning principles and methods.
Week 6	Cooperative learning principles and methods, continued. Preparation for classroom observations
Week 7	Discussion of classroom observations.
Week 8	Designing a course or a class presentation.
Week 9	Discussion of planned microteaching topic and final project.
Week 10	Microteaching presentations and critique. Collect journals.
Week 11	Assessment of learning. Creating and scoring exams.
Week 12	Alternate methods of assessment.
Week 13	Microteaching presentations and critique.
Week 14	Roundtable discussion of final projects. Turn in final projects. Turn in journals.

It is expected that students will:

- Keep a journal that records your observations and reflections about teaching and learning. (Questions to be addressed in the journal will be given each week.)
- Complete assigned readings before class. Be prepared to discuss those readings in class. Make entries about the readings in your journal.
- Complete the Kolb Learning Styles Inventory and complete and turn in the Myers Briggs Type Indicator.
- Observe a class session and record your reactions.
- Prepare and deliver two brief presentations to the class of topics in your discipline. (This is called "microteaching".)
- Create a detailed, written plan for a one-semester course. (This is referred to as the "project.")

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