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Reflections on Scholarship of Integration as a Model for Problem-Based Learning in Undergraduate Engineering Education*

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> 'The student who can begin early in his life to think of things as connected, even if he revises his view with every succeeding year, has begun the life of learning. The experience of learning is the experience of having one part of the mind teach another, of understanding suddenly that *this* is *that* under an aspect hitherto unseen, of accumulating, at an ever-accelerated rate, the light that is generated whenever ideas converge. Nothing that can happen to men is more delightful than this, and it is a pity when it does not happen to them as students.' [1]

INTRODUCTION

ENGINEERING EDUCATORS contribute to educating students in a number of other disciplines. Construction engineers teach facility management (i.e. heating, ventilation, and air conditioning systems as well as electrical systems) to hotel and restaurant management students. Agriculture engineers explain industrial food processing systems to food technology students. In quality control courses, industrial engineers welcome food science students as well as students from other disciplines. Engineering faculty serve as members of dissertation committees for many fields. Interaction with other disciplines helps scholars appreciate multidisciplinary work, which is a component of the scholarship of integration (SI).

This paper presents integrative scholarship as a problem-based learning strategy in undergraduate engineering education. For background information, the authors first provide a brief review of integrative scholarship. The next section links SI and problem-based learning (PBL). The third and fourth sections of the paper describe the central problem of the project and summarise the outcomes of the project, respectively. Section five discusses how the consumer science and education faculty investigator interacted with the undergraduate engineering student researchers. Finally, the conclusions present the benefits of the methodology to engineering education.

SCHOLARSHIP OF INTEGRATION

Integrative scholarship emerged as the fourth and newest widely proposed addition to the traditional American scholarship triad (i.e. teaching, research, and service) due to the late E. L. Boyer's seminal work, *Scholarship Reconsidered* [2]. Boyer proposes an academic paradigm shift to better reflect faculty activities. He argues that the four types of scholarship that best represent faculty work are discovery, teaching, application, and integration. The scholarship of discovery, encompassing research, represents the creation of knowledge. The scholarship of teaching represents the work needed to stay current and relevant in one's field, to disseminate information to students, and to promote student learning and development. The scholarship of application represents the work of faculty to distribute discipline-valued information in a non-academic setting, such as within the community or industry. The scholarship of integration is a multidisciplinary approach to understanding knowledge.

To articulate the values of the scholarship of integration is one of the challenges for American colleges and universities in the 21st century. Boyer [2] describes the scholarship of integration as:

> '. . . the need for scholars to give meaning to isolated facts, putting them in perspective. By integration, we mean making connections across the disciplines, placing the specialists in a larger context, illuminating data in a revealing way, often educating non-specialists, too . . . [W]hat we mean is serious, disciplined work that seeks to interpret, draw together, and bring new insight to bear on original research.'

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When discussing SI, authors use terms such as 'connections', 'disciplines' and 'non-specialists'. As with the traditional American scholarship triad, each discipline has the opportunity to articulate the values of integrative scholarship. Those disciplines that have begun to articulate the values of integrative scholarship include library sciences, communications, medicine, and management. Chu's [3] article on library science focuses on SI in undergraduate education. Chu discusses a method of teaching undergraduate students to conduct cross-disciplinary literature searches for assigned reports. Barbato's [4] article on the communications profession summarises the need for intra-disciplinary SI. Even though he demonstrates that communication is multidisciplinary by nature, Barbato argues that SI helps to merge different perspectives within communications. Dauphinée and Martin [5] discuss SI in the medical sciences. For them, the benefits of SI include a multidisciplinary approach to problem-solving. Dauphinée and Martin encourage medical professionals and researchers to overcome barriers that lead to disciplinary isolation. Weick [6] concludes that executive education is integrative scholarship because of efforts to 'undermine our isolation'. Thus, the scholarship of integration seeks to build bridges within and between disciplines in order to promote a greater understanding of knowledge.

LINKING THE SCHOLARSHIP OF INTEGRATION AND PROBLEM-BASED LEARNING

'Necessity is the mother of invention' is a possible motto for SI, because effective solutions require effective approaches to problem-solving. Thus, SI and problem-based learning (PBL) are easily fused, for they share *the problem*. The essence of PBL in undergraduate engineering education is to help students understand that, 'when needs, goals, time constraints, and available resources are unambiguous, engineers can solve problems' [7]. In addition, engineers must still solve problems when any or all of these factors, at first glance, are or appear to be ambiguous.

The work of educators concerning PBL has yielded principles, statements of professional orientation, and characteristics of PBL. Based on the theoretical work of Glaser [8], Gijselaers [9] argues that three principles are central to the nature of learning and teaching PBL, and these are: the process of learning as constructive, enhanced by knowledge about learning (or metacognition) [10], and impacted by context and social interactions. De Graaff and Cowdroy [11] provide an overview of PBL, highlighting the didactic principles (students are responsible for their own learning; co-operation rather than competition; and 'active acquisition of knowledge and skills') of and professional orientation (holistic orientation towards professional practice; integration of knowledge from different domains; integration of knowledge, skills and attitudes) to PBL as well as the contributions of Canada's McMaster University's medical program [12, 13]. Likewise in the United States, medical schools were one of the first professional education systems to introduce PBL. When discussing medical education, Barrows [14] outlines six characteristics of PBL:

- Learning is student-centred.
- Learning occurs in small student groups.
- Teachers are facilitators or guides.
- Problems form the organising focus and stimulus for learning.
- Problems are a vehicle for the development of problem-solving skills.
- New information is acquired through self-directed learning.

Kolmos [15] outlines additional characteristics of PBL, such as selection of disciplines and methods based on the problem, emphasising analytical skills, and preservation of 'core choices' for students promoting involvement and interest. Kolmos also states that the nature of PBL is frequently interdisciplinary. Thus, by definition, PBL requires that faculty organise student-learning experiences around a problem, and PBL necessitates integrative scholarship to solve some problems.

NATURE OF THE PROBLEM: MONITORING FLUID VISCOSITY

The problem described here originated in the local healthcare community. Nursing-home staff, family members of residents, and healthcare surveyors from government agencies or accrediting bodies determined that residents received inappropriately thickened liquids. Residents needed foods prepared as prescribed by the attending physician in consultation with a swallowing specialist, typically a speech pathologist. (Physicians prescribe fluids with modified consistencies to manage swallowing disorders, or dysphasia.) The foods were to have a certain 'thickness' or viscosity. Developing a means of monitoring the viscosity of fluids in a nursing-home setting was the goal. Time and money imposed limitations. Due to the limited budget of the target audience, the apparatus or procedure needed to be inexpensive (e.g. $10 or less). In addition, the apparatus or procedure was needed for data collection during subsequent phases of the study.

Speech pathologists diagnose swallowing problems and recommend diet consistency modifications. However, speech pathologists characterise fluid viscosities using descriptive subjective terms such as thick as 'honey', 'nectar', or as having a 'pudding consistency'. The limitation of subjective terms is evident even to speech pathologists. One researcher concluded that, when speech pathologists are asked to make several samples of the same fluid viscosity, there are variations within and between subjects, the latter more so than the former [16].

Medical doctors and speech pathologists prepare the prescription, but registered dieticians (RDs) are responsible for implementing fluid viscosity modifications. Working with modified food starch thickeners (thickening agents used in many healthcare centres) is a topic addressed in dietetics education. In addition, dieticians articulate the characteristics of fluids in both subjective and objective terms. This is important, because overuse of the subjective assessment procedures contributed to the problem. When surveyors cited food-service departments for failing to prepare the correct diet order, the RD is responsible for the solution. In this study, the solution centred on objectivity. Objectively characterising and measuring the viscosity of materials is an engineering function. The nature of the problem was compatible with undergraduate studies. Therefore, the investigators asked engineering students to validate, within time and cost constraints, an apparatus or procedure to measure fluid viscosity in community nursing homes.

OVERVIEW OF THE PROJECT: INTEGRATION OF APPROACHES

The team members represented two fields: engineering and dietetics. The dietetic researchers included: a faculty member, who was also the principal investigator (PI); a clinical dietician in geriatric practice; and a dietetic intern graduate student. The engineering researchers were headed by a mechanical engineering faculty member. Three undergraduate engineering students agreed to participate in the project.

All team members became familiar with the PI's approach to the problem, thus resulting in the two-way training of non-specialists. The RDs communicated the nature of the problem to the engineers and the engineers communicated the nature of the solution to the RDs. The undergraduate engineering students' work on the project represented community-based research. The procedures validated by undergraduate engineering students were used to collect data in local nursing homes. The researchers analysed the data using quality control tools. In addition, the researchers developed educational tools for the training of non-professionals (e.g. healthcare students, nursing-home staff and resident healthcare staff) in procedures to appropriately thicken liquids.

THE RD RESEARCHER'S PERSPECTIVE ON WORKING WITH THE UNDERGRADUATE ENGINEERING STUDENT RESEARCHERS

Since the engineering students are unfamiliar with dietetics and speech pathology literature, the PI provided a reference list to the students. Initial encounters between the student researchers and the PI centred on articulating the nature of the problem, ensuring that efforts were made to help the students understand the problem in order to be able to help solve it. As the project progressed, a team leader eventually emerged from among the undergraduate engineering students and this person guided the work of the student group and wrote the final report.

The PI served as the conduit between the community setting, the dietetics profession and the students. She exposed the engineering students to seeing how dieticians interact with problems and highlighted the community aspect of the problem, emphasising its impact on the health of the nursing-home residents. In addition, with the encouragement of the PI, the engineering students participated in the university's Works-in-Progress symposium, a process that helps to develop the research proposals of undergraduate students. Eventually, the engineering students acquired the dual view of the problem needed to help find a solution. During the latter stages of the project, the PI continued to interact with the student researchers to help guide their work. The students decided to compare a line spread test to a funnel test and made recommendations on a set of procedures suited to a nursing-home setting.

CONCLUSIONS

The education of non-professionals helps to lay the foundation for future SI projects. These critical interactions build a culture of multidisciplinary work. Some problems, which fit the skill set of engineers, identified by other professionals can be addressed through the work of undergraduate engineering researchers guided by engineering faculty, with targeted input from non-engineering professionals. This will enable engineering students to gain new and varied perspectives on a problem, promoting innovative solutions. Thus, the major benefits of conducting PBL in an SI framework is the opportunity for students to understand other disciplines and the contributions that engineers can make to other disciplines. Integrative scholarship helps students, faculty, and professional practitioners learn more about the activities needed to weave a tapestry of knowledge from seemingly isolated facts [17].

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