Globalization of Problem-Driven Learning: Design of a System for Transfer Across Cultures

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Abstract

In this paper, we report on an experiment in transnational exchange and cooperation between Georgia Tech in Atlanta, Georgia USA and Khalifa University in Abu Dhabi around the design of an introductory course in biomedical engineering delivered using problem-driven learning (PDL). Although the core of the PDL problems and scaffolding approach were adopted from GT, as well as the general course structure, the open-ended, ill-structured problems were specifically designed to "custom–fit" the KU and the UAE culture. In the process, the authors explored the design of an exportable system for PDL transfer across cultures. The main hypothesis lies in the successful globalization of PDL, through the design of a system for cross-cultural transfer based on the development of generic core problems with cultural-specific skins that address interdisciplinary skills unique to BME.

Keywords: Problem-Driven-Learning, engineering education , cross cultural transfer, 21st century skills;

1. Introduction

Engineering education stakeholders, from academic institutions, professors, and alumni to private sector industries, governmental education agencies and accreditation bodies universally agree that current engineering graduates lack the critical skills essential for the 21st century interconnected dynamic world that is rapidly being transformed by information explosion and monumental scientific and technological advances. Today's practicing engineer operates under multifaceted global, cultural, and business constraints, and hence needs a set of tools, skills and competencies to cope and compete within the boundaries of such unprecedented grand challenges. The National Academy of Science in the USA identifies five essential 21st century skills: *adaptability*, *complex communication/social skills, non-routine problem-solving, self-management/self-development* and *systems thinking* (National Academy of Sciences, 2010). These competencies are echoed in the UNESCO's report "Learning: The Treasure Within: Education for the Twenty First Century" (UNESCO's Report, 1999) and in a recent European Community's report which identifies eight key competences essential in a knowledge-based society (European Communities, 2007). The EU report emphasizes that these skills are not only critical in providing the flexibility in the labor force through allowing for quick adaptation to dynamic changes, but also serve as foundation pillars for innovation, productivity and competitiveness; proficiencies highly valued in a global world that has been encountering economic challenges in many of its countries (EU Report, 2007).

Research shows that the inadequate preparation of engineers in key competencies in fact extends internationally. A recent UNESCO report (Skills Gaps Throughout the World: an analysis for UNESCO Global Monitoring Report 2012) warns that skills gaps are constraining companies' ability to grow, innovate, deliver products and services on time, meet quality standards and meet environmental and social requirements in countries where they operate. The report identifies the lack of available talent and trained resources in the Middle East as the greatest threat for sustainable development of the region. Gulf leaders are among the least satisfied with the supply of employable graduates including engineers, with only 37 percent citing their satisfaction (Maktoum Foundation, 2012). Employability skills were classified into four categories (technical, cultural, interpersonal, and intrapersonal) and included fifteen specific skills: *independent task execution; appropriate approach to problem solving; ability to monitor and evaluate own activities; ability to relate specific issues to wider contexts; ability to apply knowledge to new situations; ability to devise ways to improve own actions; ability to deal with different cultural practices; openness and flexibility; negotiation and mediation skills; self motivation and initiative; ability to network; creativity and innovation; ability to relate to a wide range of people; team participation; and sense of identity and self confidence* (UNESCO Report, 2012). Misalignment between education and employers needs was cited as one of the main reasons behind the skills gap.

The current engineering curriculum, delivered by the vast majority of institutions worldwide including the Middle East, continues to follow the traditional science model of engineering education in which the first two years are typically devoted to basic sciences and mathematics, with minimal exposure to "real-world" engineering problems (Froyd and Ohland, 2005, Dym et al., 2007, Sheppard et al., 2009, Khalaf et al., 2013). Furthermore, engineering curricula continue to be mostly delivered by traditional passive lecture mode in which instructors start with theories and mathematical models, and then move to textbook

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examples, which may or may not ultimately extend to real world applications (Prince and Felder, 2006). The combination of the traditional model of engineering education, which clearly delays student exposure to engineering integrative thinking and experience, with deductive passive course delivery leads to the current mismatch between the traditional structure of the engineering disciplines and the emerging complexities of modern engineering systems (Litzinger et al., 2011). Research shows that students will not develop the aforementioned competencies by following mostly theoretical, disconnected curricula while sitting passively in lecture halls, taking notes and memorizing content (Newstetter et al., 2012). Even more interactive methods such as Personal Response Systems or Student-centered Active Learning Environments for Undergraduate Programs (SCALE-UP) (Beichner, Saul, Allain, Deardorff, & Abbott, 2000), both of which promote greater student interaction, are not specifically designed to help students develop these competencies because the nature of the problems given students in traditional engineering classes, while a first step in becoming a successful engineers, are not sufficiently complex to allow students to practice essential 21st century skills (Newstetter et al., 2012). These challenges in developing countries, such as the United Arab Emirates (UAE), have more severe implications, given that the industrial sector is in its infancy, and hence has an even higher need for problem solvers, critical thinkers, and independent learners.

1.1. Biomedical Engineering: A Discipline Under Construction

The field of Biomedical Engineering (BME) lies at the intersection of engineering, medicine and the biosciences. As such, in addition to the typical challenges mentioned above, biomedical engineering education entertains its own unique challenges. Newstetter et al. (2010) summarize the challenges as ones encountered on two main fronts: the educator front and the student front. From the perspective of educators, biomedical engineering education needs to bridge the gap between engineering and medicine and hence must combine the design and problem solving skills of engineering with medical and biological sciences knowledge and skills. And yet, to date, almost no textbooks specifically targeting BME exist at the undergraduate level. The learning challenges on the student front are significant. Learners must master three traditionally distinct intellectual faculties: 1) modeling and quantitative skills required for engineering; 2) qualitative systems analysis skills integral to the life sciences; 3) clinical sensibilities inherent in medicine. It is therefore obvious that biomedical engineering educators need to foster in students the cognitive flexibility inherent in true integrative thinking and system analysis in order to embrace the merging of these distinct practices and historically-separated disciplines (Newstetter et al., 2010).

An additional set of challenges in the highly interdisciplinary biomedical engineering education stems from the dynamic nature and fast pace of evolution of this young discipline. Educators and students alike operate in a discipline with continuously shifting grounds and highly dynamic boundaries and constraints. The typical biomedical engineer of the 1970's and 1980's whose main training was in electrical or mechanical engineering with a few "picked up as needed" courses in biology and physiology did not need the skills crucial for today's tissue engineer who works on designing entire organs from stem cells and hence faces a whole range of engineering, biological, clinical, and ethical complexities. The 21-century set of skills and competencies is not only critical here for innovation, productivity and competitiveness, but more importantly for maintenance and enhancement of the ultimate machine- the human body.

1.2. Problem-Driven Learning (PDL)

In response to the need for fostering the critical skills for successful modern engineers mentioned above, various pedagogical inductive learning models have started to make inroads into engineering education (Prince and Felder, 2006). These models include a wide spectrum of pedagogies ranging from discovery learning, and case-based learning to problem and project-based learning, active and cooperative learning and just in time lectures. The main feature shared by these models is the presentation of a specific challenge or complex problem to the students as the initial point of leaning after which they are coached to self learn upon recognizing the need for theories, facts, skills and concepts (Prince and Felder, 2006). Problem-based learning (PBL), as defined by H.S. Barrows who was one of the pioneers who developed and implemented PBL in medical education over three decades ago, is the learning method based on using problems as a starting point for the acquisition and integration of new knowledge (Barrows, 1986). As a pedagogy centered around problem solving of complex, open-ended, ill-defined and ill-constrained problems, PBL inherently aligns with engineering in which complex problem-solving is a main pillar, and offers engineering educators innovative and effective means to successfully engage students deeply with content (Capon & Kuhn, 2004), to apprentice them to the practices of a particular community, to practice a specific skill set such as spoken and written communication, and more importantly empowers them to assume responsibility to be self-directed and life long learners towards developing the necessary analytical and complex problem solving skills needed to tackle the multifaceted challenging engineering world of the twenty first century. (Johnson, 1999; Woods, 1996; Yadav, Subedi, Lundberg, & Bunting, April 2011).

For our purposes, we adopt a slightly different term—problem-driven learning (PDL). This term can be in essence interchangeably used with problem-based learning or PBL in our context. The word "driven" in PDL is used to replace "based" in PBL in order to emphasize the central role of complex problems in initiating and driving the learning process. In fact, we adopt this term from the research we have been doing in trying to understand reasoning, problem solving and learning in authentic sites of interdisciplinary practice---university research labs (Osbeck, Nersessian, Malone, & Newstetter, 2010). Over the last ten years we have investigated a tissue-engineering lab, a neuroengineering lab and two integrated systems biology labs using ethnographic research methods. We then sought to translate our findings on learning in those sites into new models for engineering education (Newstetter et al. 2010). We found in these sites of authentic engineering activity that learning is powered by the need to solve complex problems. Problem-driven learning fuels advances in knowledge and lab breakthroughs. However, the laboratory problems look nothing like textbook problems. They are complex, ill structured and ill constrained. They require the integration of knowledge and skills across the bioscience/engineering divide. Adapting to new and changing conditions both in terms of personnel, problem types and the ever-present impasses encountered in frontier science is a fact of life. Researchers need to navigate what, when and how they learn; they work collaboratively when the intractability of the problem demands a collection of heads and hands. Our investigations of these laboratories illuminated why BME majors need to practice early and often the skills of tackling, defining, constraining and working through complex, interdisciplinary problems to be able to effectively participate as complex problem solvers in industry or research. Thus the mantra of an introductory course in biomedical engineering needs to proclaim: *Empower students to be agents of their own learning who are fearless in the face of a complex problem*.

In this paper, we report on an experiment in transnational exchange and cooperation between Georgia Tech in Atlanta, Georgia USA and Khalifa University in Abu Dhabi around the design of such an introductory course in biomedical engineering. It is a story that has many twists and turns. Inspired by the success of the introductory BME course model developed at Georgia Tech. (GT) in Atlanta, a collaborative effort went into the design and development of a PBL introductory biomedical engineering course at Khalifa University (KU) in Abu Dhabi, UAE. Although the core of the PBL problems and scaffolding approach were adopted from GT, as well as the general course structure, the open-ended, ill-structured problems were specifically designed to "custom–fit" the KU and the UAE culture (Newstetter et al, 2012, Khalaf et al., 2013). In the process, the authors explored the design of an exportable system for PBL transfer across cultures. The main hypothesis lies in the successful globalization of PBL, through the design of a system for cross-cultural transfer based on the development of generic core problems with cultural-specific skins that address interdisciplinary skills unique to BME (Newstetter et al., 2012, Khalaf et al., 2013). This paper introduces this system (see appendix for definition of terminology).

2. PDL model at GT- the development of "generic" cross-cultural core problems

The development of a problem-driven learning curriculum at Georgia Tech commenced in 2000 as the newly founded Department of Biomedical Engineering was accepting its first PhD students. Faculty began by creating a first year graduate course that used the white board scaffolding found in Medical PBL in the context of six problems representative of the varied branches of biomedical engineering. Special PBL rooms were commissioned for the new BME building. In the following year, the first undergraduate course titled *Problems in Biomedical Engineering I* was piloted. Over the next three years, a number of new problems for this course were developed and run with student teams to determine their appropriateness and relevance for an introductory course in biomedical engineering. In time, three problems emerged from an iterative process of prototyping, running, analyzing and redesigning that we now consider as *cores* over which different *skins* can be affixed. To illustrate, the first problem focuses on screening or treatment in the context of disease (See example problem in appendix). The problem brings together probability statistics (sensitivity/specificity/positive predictive value) in health screening, issues of scale and systems in disease, and the development of quantitative methods of analysis for evaluation/decision-making in the face of conflicting and changing information. A significant intended learning outcome for the whole course generally but for this problem very specifically, is the development of efficient/effective inquiry skills, which are very much needed when sifting through the peer-reviewed journal articles. Each term, a new disease can be explored. Generally, skins would be one kind of disease or another (cancer, endometriosis and sickle cell disease have been typical problem skins at GT).

The second problem has experimental design at its core and the third has mathematical modeling and computer simulation. These core problems offer enough flexibility that each semester is very different for both students and faculty. For example, through modeling and simulation, students were asked one semester to determine what steps the campus should take to prevent the spread of H1N1 while the next semester they looked at the potential for experimental viral traps to halt the spread of HIV. This potential to "re-skin" the core problem each term with a different story line, a story line that often comes from current health and science news, keeps the course fresh and current for both faculty and students. Importantly, students really have the sense that they are working along side other biomedical researchers on significant problems rather than just doing homework sets from textbooks.

In conjunction with problem development, a rubric laying out the intended course learning outcomes and student behaviors was developed for facilitators to use in observing student behaviors on the teams and for students to self and peer assess. Rubrics for scoring each problem presentation and report as well writing guidelines for each problem were also developed. This collection of materials scaffold student activities across the problem making it possible for freshman teams to take on significant authentic problems. Finally, a strategy for a final exam was developed, piloted, evaluated and redesigned using the same "skin" concept as the problems. Prior to collaboration with Khalifa, the Georgia Tech team had reached a steady state whereby more than one hundred and fifty students were going through this experience every term facilitated by twelve or more faculty and post-docs a term.

3. Cross Cultural Globalization- the development of "cultural-specific" skins

The PDL model adopted at the Biomedical Engineering Department at Khalifa University is based on the system designed by GT in terms of *"the core"* problems described above. As previously mentioned, other attributes such as the scaffolding approach, the three problems per semester structure, as well as the general course structure were also maintained. On the other hand, what we refer to as *"skins"* or outer shells affixed to these open-ended, ill structured and poorly constrained core problems were specifically designed to "custom–fit" the KU and the UAE culture. The role of the facilitator is also is very different from an instructor. The facilitator is not an expert that provides information or directs the group towards a solution, but rather asks in depth probing questions at the process level in a guidance or scaffolding support role. This initial support is slowly reduced as the students develop greater proficiency and assume greater responsibility (Newstetter, 2006).

The following elements were incorporated in the process of the cross-cultural system transfer:

1. Problem Topics- Cultural Relevance: Motivation and Constraints

The topics were carefully selected based on cultural and societal relevance, emphasizing current health challenges in Abu Dhabi and the UAE. For example, as mentioned above, a typical core problem used at GT for the first problem is the identification of optimal methods for disease screening. In alignment with GT, this problem was selected due to the large amount of inquiry involved towards the solution ranging from the disease mechanisms at the molecular level, to the physics behind imaging technologies, to the protocols involved in a various screening, to the highly experimental research that has the potential to create new screening paradigms (Newstetter et al., 2010).

At KU, fresh skins were affixed to the core such that a cultural relevance and benefits were clearly established. For example the following two health challenges were selected at KU for problem one:

- Diabetes mellitus type 2: The United Arab Emirates has the second highest rate of type 2 diabetes prevalence in the world (19.6%), projected to increase to 63% by the year 2030.
- Obesity: The UAE has one of the world's highest rates in over weight and obesity (71% of men and women being either over weight (34%) or obese (36%)).

On the other hand topics such as HIV, drug abuse, or life support were avoided due to cultural constraints.

The main objective of the second core problem, which is typically related to investigating the accuracy of a particular (medical) device, lies in the design of an experiment meant to test a hypothesis. The team has to use the literature to develop a testable hypothesis. Then they need to develop an experimental protocol for collecting data to either verify or disprove their hypothesis. They must also design and set up an experiment so as to determine whether the results are statistically significant or not. Further, they need to determine what an appropriate sample size will be to achieve significance. And finally every team member has to individually become IRB certified and the group must get IRB approval beforehand (Newstetter et al., 2010).

An example of a skin affixed to such a problem at KU based on cultural relevance is *The Design and testing of an Intelligent Speed Control System*. Relevance is immediately established when the text of the problem states that Abu Dhabi has one of the highest rates of road deaths in the world amounting to an alarming 27.4 of 100,000 people, as compared to 15.2 in the US and 11.9 in the EU (HAAD health statistics, 2011).

2. Skill-based focus to promote metacognitive learning that is of particular importance yet nonstandard to culture

In addition to the skill deficiencies that engineering students suffer from on a global level (see introduction), students in a particular culture may require promotion/validation of certain skills, equally important for the modern engineer, yet lacking in that culture. One example is the empowerment of women in the UAE and the Arab world. Females in this part of the world typically attend all girl schools and aside from their male relatives do not interact socially with men. The PBL course is one of the first experiences in co-ed education and cross gender professional engagement, and hence provides an opportunity to promote women empowerment and leadership, through research on achievements of other women as related to the core problems, as well as particular focus on team and communication skills in a co-ed environment.

Another important skill that was particularly reinforced at KU is "learning to learn" or autonomous self-directed learning. Inherent to PBL, this skill is critical yet non-standard to a culture that mostly adheres to passive learning didactic lecture models and in which many students, particularly females, are the first generation in their family to attend college. Student teams were empowered to assume initiative and responsibility for their learning and were engaged in the selection, management and assessment of their learning activities. The main goal is to train life-long learners and independent thinkers equipped to undertake a leading role in a future knowledge-based economy.

3. Cultural-specific assessment-what works best in line of cultural values and constraints

Assessment in the PBL classes at GT targets four specific areas: self- directed inquiry, knowledge building, collaboration skills and problem solving strategies. Various alternative assessment methods are used cumulatively at GT towards assessing these skills through the semester. These include inquiry updates, post-problem self and peer evaluations, concept maps, written and oral presentations, and written assessment. While all of these are useful tools to monitor and assess the four target areas, cultural constraints may again play a role in the success of these assessment tools. For example, the concepts for peer and self-assessment at KU proved quite challenging, as specific cultural values resulted in systematic underestimation of the students of their own performance and overestimation of that of their peers. The solution (affixed skin) was to share the assessment rubric with the students and have them quantify each of the categories by developing "skill lines" as an instrument to gauge the progress. The students were hence engaged in the skill assessment and quantification throughout the problem cycle for each of the three problems in a quantitative manner that helped them overcome the cultural assessment constraint. This engagement helped them learn to calibrate and objectively gauge skills (both self and team members).

4. Conclusions

This paper reports on ongoing collaborative translational effort between Georgia Institute of Technology in Atlanta (GT) and Khalifa University of Science, technology and Research (KUSTAR) in Abu Dhabi around the design, development and implementation of an introductory course in Biomedical Engineering delivered using problem-driven learning (PDL). The main contribution of this work lies in the conceptual design of an exportable pedagogical system for PDL transfer across cultures. The system is based on the development of "generic core" problems that are specifically designed to promote the critical unique skills needed for biomedical engineers through scaffolded metacognitive apprenticeship, while ensuring the smooth and effective cross cultural transfer and relevance via affixing "cultural skins" to these problems. Future work includes the collection of comparative data using the system and the development of authentic assessment strategies.

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APPENDIX

Carcinoma of the pancreas has markedly increased over the past several decades and ranks as the fourth leading cause of cancer death in the United States. In 2011, of the estimated 44,030 new cases of pancreatic cancer, 37,660 will result in deaths (National Cancer Institute, 2011). The overall survival rate at all stages is <1% at 5 years with most patients dying within 1 year. At present there are no reliable screening tests for detecting pancreatic cancer in asymptomatic persons. The deep anatomic location of the pancreas makes detection of small, localized tumors unlikely during the routine abdominal examination. Even in patients with confirmed pancreatic cancer, an abdominal mass is palpable in only 15-25% of cases. Among healthy subjects, CA19-9, a serologic marker potentially used for screening, has good specificity---85% (Safi, Schlosser et al. 1996) but nevertheless generates a large proportion of false-positive results (positive predictive power 0.9%) due to the very low prevalence of pancreatic cancer in the general population. The predictive value of a positive test could be improved if a population at substantially higher risk could be identified.

Your team has been selected by the National Cancer Institute to investigate and evaluate current methods for pancreatic cancer screening, including the effectiveness of the most commonly used methods. You are then expected to identify and make recommendations regarding potential future screening strategies, which relative to current strategies enhance sensitivity without sacrificing specificity.

Safi, F, Schlossew,W, Falkenreck, S and Beger, H.G (1996) Ca 19-9 serum course and prognosis of pancreatic cancer. *International Journal of Gastrointestinal Cancer*. 20/3.

Terminology

Scaffolding: Providing sufficient support for students to operate at a higher level than otherwise possible. This typically includes facilitators' help (in the role of a coach or trademaster), score sheets, rubrics, and writing guidelines.

Skin: The storyline of the problem to frame it in a cultural/societal context as necessary.

Metacognetition: Learners' awareness of their own knowledge and their ability to understand, control, and manipulate their own cognitive processes.