Integrating Research into Undergraduate Curriculum: A Vehicle for Developing Skills and Competencies for the Twenty-First Century

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Abstract
According to one recent study, pedagogical initiatives in many institutes of higher education are still largely drawn from faculty intuition and their experiences as students and teachers. The same report calls for future enhancements, particularly those related to the learning environment, to be grounded in learning theory. One approach for enhancing student engagement in higher education is the practice of integrating research components in undergraduate courses and programs of study. However, in order for undergraduate research to be incorporated successfully into curricula, research skills need to be foregrounded in the general education years of the degree program. This paper describes a program of study, initially designed to compensate for a range of twenty-first century skills and competencies found to be lacking in students, and developed to promote engagement, enhance communication and research skills, and to foster cognitive development. The two Communication courses described here target first year undergraduate students at an engineering school in the Middle East, where English is the medium of instruction. For the vast majority of this population, English is an additional language, and the approach to studying and learning is one they had not experienced in high school. As well as developing undergraduate skills and competencies, engaging students in basic research at an early stage provides them with hands-on experience of how knowledge is created and shared through the simulation of adult, professional activity.

Keywords: First-year students, undergraduate research, learning theory, life-long learning

Introduction

Perhaps one of the biggest barriers for higher education to overcome, and meet the challenges of the twenty-first century, is the traditional ivory tower perception that knowledge is power. While knowledge is central to both teaching and learning, it is the ability to generate and share knowledge that is of the utmost importance in a knowledge society. Du Toit (2000, p. 188), suggests that in order to create high levels of learning, and of innovation, a culture of open dialogue is required. Wenger (2004) believes that moves towards building communities of practice (COP) address this issue. Such developments, in which voluntary groups of practitioners with shared interests meet and learn from each other, transform outdated notions of power, to an understanding that while 'knowledge is power, sharing knowledge is more powerful' (Spisiakova, 2012).

Much has been written on the subject of knowledge management and of COP (Barab & Duffy, 1998; Du Toit, 2000; Wenger, 2004; Witt, McDermott, Peters, and Stone, 2012; Skyrme, 2012). However, the future of universities lies not only in generating and sharing knowledge; if universities are to take such bold steps then a paradigm shift is needed to develop a culture which present and future generations of students adopt and become participating members of the community themselves.

One relatively recent study (ASEE, 2009, p4) stated that while there has been a commitment to improving (engineering) education, "there are major gaps between our reports and our curricula, our desire to graduate diverse talent and our ability to deliver, and our encouragement for educational innovation and our follow through to support it." Such a statement came a decade (or more) after arguments for a change from traditional teaching methodologies such as lectures and tests, to pedagogies which promote critical and creative thinking, active learning and collaboration. Hainline, Gaines, Feather, Padilla, and Terry (2010), called for the new paradigm to encourage undergraduates to be "discoverers rather than receptacles of knowledge" (p7). Unfortunately, Jamieson and Lohmann (2012), state that the main barrier to effective educational innovation is that fact that, in engineering education at least, it is largely based on "faculty intuition drawn from personal experiences as students and teachers." They are also critical of the lack of assessment of effectiveness in achieving stated objectives of initiatives which are implemented.

Towards the paradigm shift

One of the main concerns of higher education today is that it prepares undergraduates to participate meaningfully in society, communities, and in regional and global economies. If students are to embrace and contribute to the challenges of the twenty-first century, and fully understand how modern knowledge society functions, then the learning environment needs to change, as the present education system was not designed for Generation Y (Prensky, 2001) or indeed, Gen Z. The gap between the skills taught in high school and in undergraduate education, and those required in the work-place, (Moylan, 2008) still exists today. The range of skills students need includes critical thinking, analysis, teamwork, and problem solving which along with information and communication technology (ICT) literacy, are prerequisite for a knowledge based society.

One approach to enhancing undergraduate education which would address some of these concerns, encourage knowledge sharing and learning, and facilitate future

participation in learning communities, would be to integrate research into the undergraduate curriculum. Informed by findings from the learning sciences, the integration would promote the acquisition and development of research and thinking skills, and enhance abilities to work in a team, enabling undergraduates to develop into contributors and not just consumers (Buckley, 2011; Karantzas, Avery, Macfarlane, Mussap, Tooley, Hazelwood and Fitness, 2013). This, of course, demands that the focus of faculty changes significantly, from that of imparting knowledge to one of creating stimulating learning environments (Adam & Felder, 2008; Bransford, Vye, and Bateman, 2002; Duderstadt, 2008, NRC 2000). Such a shift in approach, it is believed, facilitates the development of cognition through the acquisition, internalization and articulation of knowledge. Studies into the impacts of engaging undergraduate students in research suggest a wide range of benefits. Among those most highlighted are increased academic development and metacognition (Kinkead, 2003), improved ability to persist with ambiguous problems (Guteman, 2007), greater self-motivation and appreciation life-long learning, enhanced higher order thinking and deep learning (Gomez, 2013), teamwork, and communication skills, higher self-confidence, and greater problem solving abilities (Karantzas et al, 2013). These are competencies deemed important by all disciplines and professions, and endorsed by accrediting bodies. Zhan (2014) states that research experience for undergraduates has shown to be effective for enhancing the overall educational experience, thereby improving student retention, and also that students graduating with such experience are likely to have stronger hands-on experience and as such make a quicker and more effective transition from academia to the workplace. Helm and Bailey (2013) also believe that it serves as important preparation for post-graduate courses.

The potential of undergraduate research to address so many areas of development should not be surprising. Research from the learning sciences over the last twenty five years shows that higher order thinking skills, are activated when "individuals encounter unfamiliar problems, uncertainties, questions, or dilemmas," (Zhan (2014). The author continues to state that the result of successful application is an understanding that is "critical, logical, reflective, meta-cognitive, and creative." Kinkead (2003), says that learners "are active agents involved in constructing knowledge, refining their understanding, and learning socially through sharing with peers and teachers." Young adults in particular learn best when working together, sharing their learning, and building on knowledge and understanding (Mariam and Caffarella, 1991; Chau), and they find the approximation of real-life, adult, professional practice considerably more appealing, and as such more conducive to learning.

However, in order for undergraduate research to be incorporated successfully into curricula, research skills need to be foregrounded in the early years of the degree program.

Context

The Petroleum Institute University and Research Center (PI) was established in Abu Dhabi, capital of the United Arab Emirates in 2001 with a goal of becoming a world-class institution in both engineering education and energy industry research. The PI currently has nearly 2000 undergraduate and graduate students, over 200 faculty, and has quickly become a leading teaching and research institution in the Middle East

region. The PI is fortunate in that its sponsors and affiliates include the Abu Dhabi National Oil Company (ADNOC) and four major international oil companies that include BP, Japan Oil Development Company, Shell and Total. It offers baccalaureate degrees in Chemical Engineering, Electrical Engineering, Mechanical Engineering, Petroleum Engineering, Petroleum Geosciences Engineering, and recently added Material Sciences. It was accredited by ABET in 2012. Students initially follow a two-year program in the Arts and Sciences Program (the freshman and sophomore years) which provides a broad educational foundation in mathematics, chemistry and physics, communication and a range of humanities and social sciences subjects. The program also offers two introductory engineering courses, known as STEPS - Strategies for Team-based Engineering Problem Solving, which aim to facilitate good engineering practices with a focus on team and communication skills, and the engineering design process.

The vast majority of students at the PI are studying in an additional language, as the medium of instruction is English. Most undergraduates arrive after completing a traditional, public school system that generally focuses on the transcription, memorization, and repetition of material delivered in the classroom. As such the shift to an enquiry-based approach is a substantial and significant change for them.

Learning to research

Learning how to participate in research projects, whether as part of a course or an independent project, provides students with opportunities to discover how knowledge is created, how research contributes to the development of the knowledge society, how a modern knowledge society functions, and perhaps most importantly at this stage, how to access, verify, and differentiate the quality and reliability of different sources of information. Acquisition of the skills needed to do this, as shown in Table 1), and an ability to transfer these skills to other courses and beyond, requires that students are introduced to them at an early stage in their academic career.

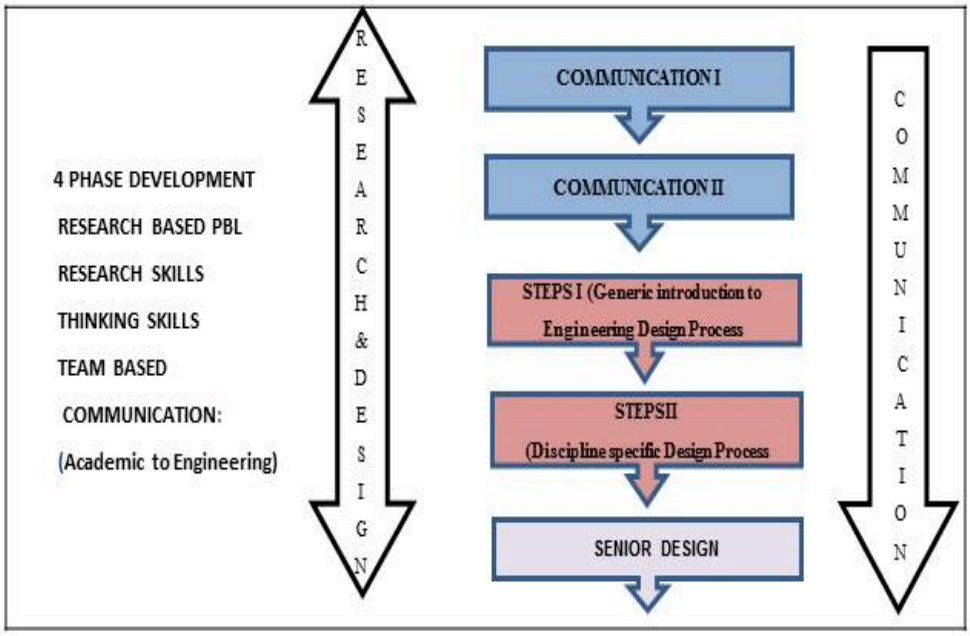
Table 1: Basic research skills for first year undergraduate students

Research skills	Critical Thinking
Search strategies	Identification of problem /issue
Critical reading	Perspectives, context & assumptions
Source analysis and evaluation	Application of Bloom's taxonomy
Note taking and annotation	Assessment and evaluation of key data/evidence
	Conclusions, implications & consequences

Research is seldom undertaken alone and implicit in a research-based approach is that participants will build on existing knowledge, be actively and purposely engaged in

the pursuit of a deeper conceptual understanding of the research topic, and thereby facilitate higher order thinking. Opportunities need to be provided for students to engage in situations and tasks which require knowledge sharing, problem solving, analysis and interpretation of data, and effective communication. As these skills are generally developed as part of a relatively long-term process, it is important that they are introduced early, and carefully supported across a spine of undergraduate research across the curriculum, as shown in Fig 1, below.

Fig 1: Learning to Research across the Curriculum



As suggested by the two headings immediately above and below, the approach to Inquiry Guided Learning (IGL) in the first two years of study at the PI has its basis in the Learning to Write-Writing to Learn approach of the Writing across the Curriculum (WAC) movement, established in higher education the US over 30 years ago. At the PI, research projects are introduced during the first semester of degree studies starting in Communication I, and continuing through further phases of development across the curriculum, as shown in Figure 1.

Communication I and II are primarily designed to develop the language and communication are required for undergraduate study. Four broad learning outcomes are addressed: effective written, spoken and graphic communication, an ability to develop and use data gathering instrument(s), an ability to work effectively in teams, and life-long learning. An integral part of the development is the focus on critical reading and writing. Knowledge gained, analyzed and evaluated, is articulated in formal recommendation reports and culminates in oral presentations, as shown in Table 2, below.

Table 2: Communications skills for sharing research

Technical & Academic Writing	Technical &Academic Presentation
Recognition of genre, functions, conventions	Effective use of appropriate media & graphics
Effective synthesis & integration	Cohesive & coherent delivery
Individual & collaborative writing	Appropriate non-verbal communication

These skills are developed in a context of team research projects, which also target the development of time management skills, teamwork and meta-cognition. The first step is for the team to identify global issue for further investigation. Topics are selected by students (with guidance from faculty) and have recently included educational related topics (transition issues, skills for undergraduate study), social concerns (use of mobile phones, gaming) and technical issues (use and abuse of water and electricity). Search strategies for identifying and selecting suitable sources of information are then taught using library data-bases. Once the literature review is drafted, each team states the purpose, scope, focus, hypothesis and main research questions of its localized research project. This is followed by the development of appropriate data gathering instruments (normally quantitative for the first course, and a combination of quantitative and qualitative in Communication II). Data is collected, collated and analyzed graphically to enable team members to answer and support their research questions. The next step is to attempt to explain their findings, comment on likely causes, short and longer term consequences before making recommendations.

Researching to learn

The development of the team is of particular importance as it facilitates the development of a range of essential skills, not just for the immediate task in question but for life-long learning and self-esteem. Team-based research provides natural opportunities for skills practice and confidence develops through project ownership and sharing common goals with team members.

Table 3: Inter and intra-personal skills for team-based research

Interpersonal communication & Teamwork	Intrapersonal communication: Metacognition/Professional Awareness
Development of responsibility & accountability	Recognition of learning styles & methods
Understanding of roles	Understanding of task requirement, standards and expectations
Decision making	
Conflict identification & resolution	

First year students have varied experiences and perspectives, and as such knowledge and understanding is distributed among team members. In order to arrive at a common and shared understanding, team-members work within their ‘zone of proximal development’(Vygotsky, 1978) communicating explanations, interpretations and queries, before arriving at a reconstructed vision. In this way, undergraduate research

promotes learning through hands-on experience, collaboration and building on knowledge and understanding. Such real world, adult activity engages these young 'apprentice researchers', and higher order thinking demands that they use language as a tool to aid understanding and learning.

The introduction to research in the first year of undergraduate study is developed in each of the following years of study through a 'spine' of research and design (see Fig. 1). The approach of foregrounding research early on enables undergraduate students to take responsibility for their own learning, and address each new phase with more confidence. While development across all skills and competencies varies, particularly in terms of analysis and synthesis, students do develop a sense of learning through sharing, and are able to participate, not only in required course projects but also in national and international undergraduate competitions and conferences. Further evidence of the success of the approach includes feedback from junior and senior year faculty who indicate that the vast majority of their students are able to collaborate effectively.

Conclusion

This paper has highlighted an approach to addressing concerns that initiatives, particularly in engineering education, are not informed by best practice as indicated by research from the learning sciences. The description of how undergraduate research can be integrated into the curriculum to foster deep learning and provide a platform for continuity may provide higher education with a means to promoting lifelong learning, and engagement in the learning process through the sharing of knowledge. In this way graduates may be better positioned to contribute to society as participating members of communities of practice.

Further research into the impact of such an approach perhaps might focus on evidence of participation in professional societies, and community service after graduation. Only then will we be able to confirm that shared knowledge is indeed more powerful than merely possessing it.

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