2006-2007 Learning Technologies Grants Proposal

Project Information

Training Innovative Engineers In Nanotechnology with Multimedia Case-Based Learning
Project Title

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Project Director(s)

Department of Biological and Agricultural Engineering
Department of Educational Psychology and Instructional Technology
Requesting Department(s)

$20,669
Amount Requested Year 1

$4,250
Amount Requested Year 2

Project Directors' Signatures

Proposal Endorsement Signatures

Department Head(s)

Dean

Proposal Abstract

Engineering is a practical art learned from scientific knowledge, mathematical logic and applied experience to design and create under constrains. A recent UGA Engineering Think Tank identified three characteristics for profiling a future UGA engineer: 1) **technical excellence** in science, mathematics, analysis and synthesis; 2) **innovative curiosity** for creative adaptation from learning, unlearning and relearning; and 3) **humanistic consciousness** grounded in humanities, arts and social sciences. In this project, an engineering professor and an education professor will collaborate to develop and implement multimedia case-based instructional modules in order to enhance future engineers' scientific, innovative, adaptive, and ethical problem solving ability.

Training Innovative Engineers In Nanotechnology with Multimedia Case-Based Learning

Section I: Project Description

Nature of the innovation

In a recent UGA Engineering Think Tank report, the following three characteristics are identified for profiling a future UGA engineer: 1) **technical excellence** in science, mathematics, analysis and synthesis; 2) **innovative curiosity** for creative adaptation from learning, unlearning and relearning; and 3) **humanistic consciousness** grounded in humanities, arts and social sciences. In order to prepare future engineers with ability to solve complex problems for improving the quality of life, it is urgent for us to develop and implement innovative ways for the engineering education. Thus, the goal of this project is to cultivate UGA engineering students' scientific, innovative, adaptive, and ethical problem-solving ability in nanotechnology.

The proposed innovation (Multimedia Case-Based Learning Modules for Innovative Engineers, MCBL) applies emerging technologies (Internet, streaming video, etc) and learning theories to a case-based learning context. This innovation will help future engineers (a) experience real-world engineering problems, (b) understand the complex and context-bounded nature of engineering problem-solving, (c) apply their scientific knowledge into design practices, (d) build adaptive expertise (transferable knowledge to novel problems) in engineering problem solving, (f) develop and communicate the rationale for their engineering solutions, and (e) critically evaluate their solutions. The innovation will be developed based on the following two main constructs/factors that we believe predict innovative ability in solving engineering problems. These constructs/factors are personal epistemology and argumentation skills and adaptive expertise (transferable knowledge to novel problems). We assume that each factor will not only be strongly related to students' innovative ability in solving engineering problems but also influence their ways of building innovative expertise during engineering education.

Personal Epistemology and Argumentation Skills

Personal epistemology means one's belief about knowledge, knowing, and learning (Hofer & Pintrich, 2002). It is personal beliefs about what is knowledge, "how knowledge is constructed, how knowledge is evaluated, where knowledge resides, and how knowing occurs" (p. 4). This belief system determines one's way of approaching learning process, evaluating information, constructing new knowledge, building arguments, creating solutions, and making decisions in complex, undefined problems (Perry, 1970/1999; King & Kitchener, 1994; Kuhn, 1991). Recent empirical studies indicated that students' *personal epistemology plays a critical role in solving unclearly defined, complex problems.* Kitchener (1983) initially verified that unclearly defined problems requires epistemic monitoring skills while well-defined problems requires only cognition and metacognition, which has been confirmed by later studies (Schraw, Dunkle, & Bendixen, 1995; King & Kitchener, 1994). Perry (1970/1999) began to question why college students responded in totally different ways in their college experience and found that individual's different stages/positions of their epistemology play a crucial role in organizing their ways of learning process and dealing with unclearly defined problems. His model suggested that there are at least four distinct positions: Dualism (black-and-white types of thinking), Multiplicity (acknowledging uncertainty), Contextual Relativism (acknowledging the importance of contexts for meaning-making), and Commitment within Relativism (adding ethical and moral responsibility and professional commitments to contextual relativism). Previous research indicated that college students are ranged between late Dualism stage and early Contextual

Relativism stages during their college experience and their positions influence their learning and ability to build expertise.

Most problems that engineers encounter in their professional life pose uncertainties in the problem situations, multiple or conflicting perspectives/goals among different stakeholders, multiple solutions (or no solution) among different experts, and multiple criteria for solution evaluation (e.g., Kitchener, 1983; Jonassen, 1997; 2000; Shin et al., 2003; Voss & Post, 1988; Woods, 1993). In order to be innovative engineers, they need to critically reflect theoretical assumptions on which they are based, continue to learn, unlearn, and relearn as life-long learners, and create solutions or make judgments with ethical responsibility and professional commitments. Especially during their college/graduate experience, we assume that *engineering students' position/stage in the spectrum of personal epistemology systems will play a significant role in shaping their approaches to organizing their learning process and building their expertise, and dealing with real-world, unclearly defined engineering problems* in which an engineer can reasonably disagree with another engineer's opinion on problems identified or solutions proposed. *Therefore*, *the proposed instructional innovation will be* designed in ways to enhance engineering students' innovative problem-solving abilities through *promoting changes in their positions of epistemology in engineering curricula*.

<u>Adaptive expertise</u>

Building knowledge or expertise in a way that is transferable to novel situations is a fundamental challenge that engineering educators have faced. Many studies revealed students are struggled with transferring problem-solving skills to another situation that has similar problems (Gick & Holyoak, 1983; Reed, 1987). Even some experts struggle with adapting their skills into new situations due to a certain way of building their knowledge. Hatano and Inagaki (1986) identify two types of experts: routine and adaptive experts. While routine experts hold procedural and algorithmic approaches and focus on speed, accuracy, and efficiency of their performance, adaptive experts take an experimental approach and invent and modify procedures through monitoring their current expertise and procedures (Bransford et al., 1999; Brophy et al., 2004). Nanotechnology and Bioengineering are rapidly changing fields. Thus, it is important for the future engineers to have adaptive expertise so they can flexibly modify their knowledge to the new situation and continuously revise their understanding as a life-long learner.

In order to build flexible and adaptive expertise that can be transferable to another situation, engineering students have to integrate three types of knowledge: <u>situational knowledge</u> (knowing contextual information; how to identify, interpret, and evaluate situational cues, etc), <u>strategic knowledge</u> (knowing what and how to apply/modify rules and theories; monitoring problem solving process and results; how to reason, etc), and <u>content knowledge</u> (knowing general facts, concepts, principles, theories, etc) around core principles or fundamental themes of engineering field (Alexander 1992; Alexander & Judy, 1988; Bransford et al., 1990; Bruner, 1993; Choi, 2005; Williams, 1992) through continuous cognitive conflicts-and-reconstruction cycles (Choi, 2005; Choi & Jonassen, 2000; Piaget, 1985; Shank, 1999). Recent learning theories, such as situated cognition (Brown et al., 1989), everyday cognition (Lave, 1998), and constructivism (Jonassen & Land, 1999), emphasized the importance of *contexts* in learning and performance. Knowledge is connected to the situation in which the knowledge is constructed. So when knowledge is constructed in real-world or authentic settings, it is more easily retrieved and utilized later in real-world problem solving settings (Bransford et al., 1999). Furthermore, within authentic contexts, constructing deep understanding around fundamental themes or core principles (Bruner, 1993) is critical for interpreting problems in flexible ways and for generating best solutions in innovative ways, which is a strong case for especially interdisciplinary field such as nanotechnology and bioengineering. *Therefore*, *the proposed instructional innovation will be* designed in ways to enhance engineering students' innovative problem-solving abilities through *integrating the three types of knowledge in engineering courses*.

This project will be conducted by an nanotechnology engineering expert (Dr. Zhang) who has accumulated extensive experience in teaching and research in nanotechnology and bioengineering over the past decades and by an instructional technology expert (Dr. Choi) who has extensive experience in research and development of various case-based e-learning environments and its design models across different disciplines over the past decade.

Need/Rationale

There are urgent needs in redesigning the way of teaching engineering. Engineering is a practical art learned from scientific knowledge, mathematical logic and applied experience to design and create under constrains. Engineering creations are successful solutions to problems that lead to improvements in our quality of life. In a report by the National Academy of Engineering (NAE) "*The Engineer of 2020: Visions of Engineering in the New Century*," innovation is identified as the key task for the US to maintain its economic leadership and engineering is essential to this task. The NAE and other leading organizations of industry and academia have been visioning new ways to revamp engineering education. A converging vision is that future engineers must be creative, innovative, life-long learners, effective communicators in technical and non-technical forums, and competitive in a global environment. It is a daunting challenge for the engineering profession and engineering education to remain relevant to a changing world. Future engineers will have to wrestle with problems that today are rooted in physical sciences, biological sciences, environmental sciences, and arts and social sciences, in addition to engineering problems.

Thus, it becomes obvious that technical competence is an uncompromising requirement for future engineers. UGA engineers need to reach beyond competence and achieve excellence in the fundamentals of engineering and mathematical sciences and the practice of design. They must acquire intellectual breadth that enables integration of discoveries from multiple fields and global views, and possess strong analytical skills for the objective evaluation of decisions in a real-world environment. The curiosity in the UGA engineer embraces the three important concepts of innovation: 1) *life-long learning* – a continuum of learning, unlearning and relearning, 2) *creativity* – inspired awakening/recognition of unexpected complementarity in disparate systems and the creative synthesis of new ideas beyond the prevailing paradigms, and 3) *adaptation* – relearning complexities of the changing, sometimes unfriendly, environment for innovating solutions that are practically successful. Humanism is the internal quality of deep consciousness for humanity that enables one to draw meaningful observations from the human expressions in arts and literature and history of civilizations to form a moral and ethical compass that guides actions for the future of human development. To alter the way engineering is being taught and to connect it to a real world, we need to design and implement instructional innovations to the current engineering curriculum through which students develop the desired qualities.

In this project, as the first step of our efforts exploring successful and effective ways of teaching engineering, we will redesign one of most challenging engineering courses, Finite Element Analysis (ENGR 4350/6350). There are two key reasons to choose this course as our first project. First, this course is highly interdisciplinary which challenges not only the instructors who teach it but also the students who learn it. Because of the interdisciplinary nature, many fundamental and yet interdisciplinary concepts need to be discussed in this course, thus demanding the students to develop a deep grasp of the content. Very often the instructor wrestles with the dilemma whether to train the students to know almost nothing about everything or everything about almost nothing. Second, this course is an essential undergraduate/graduate course in which students learn not only basic scientific knowledge but also the application of the basic knowledge to design and analyze engineering solutions to everyday problems. Their design outcomes should be innovative and based on scientific knowledge, and they should directly solve the problem without causing any unexpected consequences (e.g., environmental or ethical problems). The instructor of this course has often observed that the students struggled in transforming their basic knowledge into novel solutions to real world problems.

The proposed innovation, which will be implemented both in undergraduate and graduate levels through the Internet, will help to enhance future engineers' basic scientific knowledge, innovative and adaptive problem-solving abilities, and ethical and moral commitments for their design solutions. By doing so, we can better prepare well-equipped engineers.

Relevance of the project to unit and University priorities

The proposed project corresponds with the University of Georgia's commitment (a land grant university) to the preparation of the high quality agricultural engineers. Nanotechnology at UGA has been one of the essential and emerging areas in agricultural science. Providing high quality education for prospective engineers is critical to the quality of human life in Georgia and beyond.

Specific courses benefiting from the project

The instructional resources developed in this project will be directly used for the following engineering course taught by Zhang.

- ENGR 4350 Introduction to Finite Element Analysis (senior undergraduate course)
- ENGR 6350 Introduction to Finite Element Analysis (graduate course)

Choi will also be using the innovation developed in this project as an example in his undergraduate and graduate classes, such as EDIT 4160, 4210, 6190, 6200, and 6210, where students learn how to design and develop technology-based instructional innovation.

Number of students served including undergraduate, graduate/professional or both

A total of about 80 students per year in the Biological and Agricultural Engineering program will be served with the instructional resources. We will share the instructional resources/strategies with other instructors who are teaching similar courses. The average number of students who have taken Choi's undergraduate and graduate courses listed above is over 120 per year.

Section II. Budget

Proposed Budget: The First Year

Item	Quantity	Total Cost	Requested from LTG	Provided by Other Sources
Computers, Software, Web space	-	-	-	OIT, EPIT, ENGR
Supplies (digital storages & video tapes)	-	$700	$700	0
Engineering Software	1(25)	$2,000	$2,000	0
Laptop Computer	1	$4,000	$4,000	0
Design & Production	300h	$13,500 (300h)	$7,650 (170h)	$5,850 (ENG,EPIT;130h)
Research Lab -- Rm 333 Aderhold	1	-	-	EPIT
Computer Lab -- Rm 219 Driftmier	1	-	-	ENGR

Faculty Release Time	1	$6,319	$6,319	0
Total		$26,519	$20,669	$5,850

Budget Justification Narration: The First Year

Computers, Software, Web space.	The Office of Instructional Technology (OIT), The Department of Educational Psychology and Instructional Technology (EPIT), and Engineering Department (EGNR) will provide necessary equipment, software, and Web space for digitizing, editing, developing, and implementing the innovation for this project.
Supplies	Digital storage such as hard disks, CDs, DVDs, and digital videotapes are necessary to save and manage digital content and data, and backup files.
Engineering Software	Annual license fee for COMSOL Multiphysics software for 25 seats is requested. This package is needed for teaching engineering design and analysis using a multidisciplinary approach.
Laptop Computer	A high memory laptop PC is needed for running the COMSOL Multiphysics software for developing demo design projects. The students will have access to the 25 desktop computers in the Lab 219 in Driftmier.
Design & Production	Approximately 300 hours of design and development service will be necessary for developing engineering problems/cases, videotaping expert interviews, editing video clips, developing content, programming database and developing the Web site. This is budgeted based on $45 per hour. The Head of ENGR (Dr. Dale Threadgill) and the Head of EPIT (Dr. Randy Kamphaus) have made commitments to a total of 130 hours in-kind support for this project.
Research Lab	Room 333 in Aderhold hall allocated by EPIT department will be used for conducting this project (Design and Research).
Computer Lab	Room 219 in Driftmier Engineering Center allocated by ENGR department will be used for conducting this project (Implementation).
Faculty Release Time	The project directors will be responsible for analysis, design, implementation, and evaluation of the innovation. This will be used to release one course for Choi during the academic year 2006-2007. This has been approved by Dr. Kamphaus.

Project Timeline: The First Year

Date	Objective	Person(s) Responsible
Aug. – Dec. 06	• Previous curriculum analysis • Previous class observation	Zhang & Choi Choi
Jan. – July. 06	• Curriculum revision and Case collection • Web-based modules development • Evaluation Instruments Development	Zhang & Choi Choi & Zhang Choi & Zhang

Proposed Budget: The Second Year

Item	Quantity	Total Cost	Requested from LTG	Provided by Other Sources
Supplies (CDs, DVDs, Tapes)		$300	0	$300
Engineering Software	1 (25)	$2,000	$2,000	0
Design & Production	100h	$4,500	$2,250	$2,250
Total		$6,800	$4,250	$2,550

Budget Justification Narration: The Second Year

Supplies	Additional digital storages will be supported by EPIT and ENGR.
Engineering	Annual license fee for COMSOL Multiphysics software for 25 seats is

Software	requested. This package is needed for teaching engineering design and analysis using a multidisciplinary approach.
Design & Production Service	Approximately 100 hours of design and production service will be necessary for revising the Web site based on the implementation results.

Project Timeline: The Second Year

Date	Objective	Person(s) Responsible
Aug – Dec. 07	• Implementation • Data collection	Zhang & Choi Choi & Zhang
Jan. – June 08	• Learning outcome analysis/evaluation • Revision of the Web-based modules • Institutionalization into the curriculum	Choi & Zhang Choi & Zhang Zhang & Choi

Section III. Learning Outcomes

Learning Outcomes

The instructional innovation aims to produce the following learning outcomes:

First, improvement of innovative problem solving abilities: (a) identifying and assessing problems from multiple perspectives, (b) generating possible solutions, and (c) choosing a solution with rationale, (d) generating a simulation model, and (e) evaluating the results.

Second, promotion of epistemological stages: Dualism, Multiplicity, Contextual Relativism, and Commitment within Relativism.

Method for evaluation

The goals and methods of evaluations are tabulated below.

Evaluation	Goal/Content	Instrument/Method
Usability Test	Improvement of innovation usability	• Questionnaire, Focus group interview, and/or Usability observation
Reaction Test	Satisfaction of innovation	• Questionnaire and/or Interview
Learning Outcome Test	Innovative Problem Solving Skills	• Open-ended design problem/Pre/posttest • Interview on the problem-solving process
	Personal Epistemology	• Epistemological beliefs inventory/Pre/posttest

Potential applications in other academic areas

The instructional innovation will promote students' adaptive expertise and innovative problem-solving skills in complex environment, which is crucial in many other professional fields. The proposed innovation can be applicable to many academic fields producing future problem-solvers, who make deliberate and reflective decisions in messy, complex design problems, such as, architectural science and engineering, biomedical science and engineering, environmental science and engineering, agricultural science and engineering, business, and teacher education.

Section IV. Support Plan

The website will be used in the engineering courses taught by Zhang and voluntarily maintained by the project directors. The required system (Internet server space) will be continuously supported by the College of Education. External funding will be actively sought by the project directors between 2007 and 2008 in order to expand and make the Web resources available for current UGA and other universities. The potential funding source is the National Science Foundation (Engineering Education Program). We envision this project will be a step stone for us to facilitate an engineering educational reform at UGA and beyond.