INTRODUCTION

In recent years the interest in applying information technology (IT) for teaching and learning in a wide range of subject areas at all levels has grown rapidly. This development has been accelerated by the significant reduction in cost of the Internet infrastructure and the easy accessibility of the World-Wide-Web. Rapid advances in computer technology and the Internet have created new opportunities for delivering instruction and have revolutionized the learning environment. It is anticipated that these technologies will dramatically change the way instruction will be imparted throughout the educational system. For example, in a digital environment an engineering student would be able to participate in the interactive problem solving process. A virtual industrial sector could be designed for engineering students to consult the personnel in any department, to listen to the comments given by the employees through the Voice Lists, and to browse available online company documents in the form of hypertext and video presentations. Engineering students would be able to work in virtual engineering laboratory systems on the Internet enabling them to adjust to employment and conditions of the world of work and preparing them for productive employment after training. As these emerging technologies impact the design and implementation of web-based engineering education programs at the university level, it is also important to consider the multifaceted interrelated aspects of the educational system that will be impacted, for example how k-12 educators can respond to the potential of these technologies. In this preface I will give a review of an engineering education program in a Midwestern USA city that identifies some of the issues facing recruitment and retention of students in university engineering programs followed by overviews of the fifteen chapters in the book.

ARROWS: Achieving Recruitment, Retention & Outreach with STEP

This description will review the professional development aspect of the ARROWS (Achieving Recruitment, Retention and Outreach With STEP) program. ARROWS is a program that provides high school students, especially under-represented groups such as women and minorities, career mentoring opportunities. This project is funded by a US National Science Foundation grant and designed to develop new understandings about educational opportunities in the science fields for urban high school students. ARROWS provides urban students in a Midwestern USA city with an overview of the varied careers computer scientists and engineers can pursue and connects their high school curriculum with engineering applications. This grant is a collaborative program between the School of Education and the School of Computing and Engineering at the University of Missouri-Kansas City (UMKC). The goal of this program is to develop student understanding of the varied careers of engineers by providing this
information in an engaging and relevant manner that increases student interest in pursuing engineering and computer science degrees.

This grant tries to address the need to increase the number of minority students interested in STEM areas in the university. Student attitude and perception about the field of engineering does impact retention in the university (Besterfield-Sacre, Atman & Shuman, 1997). Many urban high school students do not conceptualize engineering as career and therefore do not consider it when they examine career options (Yates, Vos, & Tsai, 1999). Only 25% of high school students surveyed could name five engineering disciplines (Hirsch, Gibbons, Kimmel, Rockland & Bloom, 2003). However, 65% of high school students who completed an introductory engineering course offered by the Infinity Project said they wanted to be engineers (Delissio, 2006). The ARROW project exposes students to the career possibilities from a computer science or engineering undergraduate degree.

A lack of role models is a serious psychological barrier for minority students and is a significant factor in minority student recruitment and retention (May & Chubin, 2003). 41% of females attending Discover Engineering, a summer program designed to expose females to careers in engineering, stated that direct exposure to female role models had a impact on their choice to study engineering (Anderson & Gilbride, 2006). Frequent feedback and interaction with mentors has been shown to increase student self-confidence and expectations of success in engineering (Colbeck, Cabrera, & Terenzini, 2001). Self-esteem and self-confidence, for both males and females, is improved when students become involved in student leadership activities (Astin & Kent, 1983). The ARROWS program’s focus on under-represented groups such as women and minorities provides a positive contact and career mentoring opportunities with role models including minority university students currently enrolled in engineering and computer science programs.

The ARROWS project involves students in engineering and computer science projects that demonstrate the relevance and application of their high school science and mathematics curriculum along with exposing the students to the types of team work and design environments they would be likely to work in should they choose a career in computer science or engineering. Introduction to Engineering, a laboratory module experience at the University of Florida increased retention of women and minorities in their undergraduate program (Hoit & Ohland, 1998). A University of Massachusetts Dartmouth review of literature revealed consistent supporting evidence that collaborative learning techniques result in better understanding of material and higher levels of response in an integrated engineering program (Fortier, Fowler, Laoulach, Pendergrass, Sims-Knight & Upchurch, 2002). The ARROWS program recreates the academic and social community by engaging students in collaborative modules in the summer Engineering Essentials.

**Engineering Essentials**

The ARROWS program provides multiple forums for recruitment and outreach with urban students, however, this description will focus on the summer program. The summer program, called Engineering Essentials, consists of seven days where high school students and high school teachers come to the university. The students engage in three activities 1) discussing careers with engineers, 2) working on the problem-solving modules and 3) tours of the university and engineering firms in the city. The high school teachers that attend the labs with the students in the morning go to a professional development program focusing on the design of problem-based learning units in the afternoon. The School of Computing and Engineering (SCE) faculty developed integrated laboratory modules for use in this pre-college program.
summer program. After the laboratory module sessions, students attend sessions focusing on the intellectual, social supports and campus life students have available at SCE. These modules are designed around real-world science problem solving activities focused on four modules including: 1) Biometric Personal Identification (Electrical Engineering), 2) Understanding and preventing ACL among athletes (Mechanical Engineering), Building Structures to withstand Earthquakes (Civil and Mechanical) and 4) Web Page Design

Biometric Personal Identification

Biometrics is the science of determining or verifying the identity of an individual based on her or his unique physiological or behavioral traits. Fingerprints, face, hand geometry, iris, voice, signature, gait, keystroke dynamics, and palm and eye vein patterns are examples of such traits utilized for Biometric identification. Applications range from law enforcement, border control, and financial transactions to computer login and building access. An ideal biometric trait must have the following characteristics, universality, permanence, acceptability, uniqueness, practicality and must be spoof-proof. In this unit the participants are introduced to the concept of Biometric identification. First, the participants are asked to brainstorm different recipes for automated personal identification through observation and monitored discussion. Then, the actual devices built upon such concepts and methods are presented. The Bio-Identification lab, where four computers are set up running the following Biometric includes 1) a hand geometry system; 2). Two fingerprint systems (one using optical and one using CMOS technology, 3). an Iris-scan system, 4). a face-recognition system. The participants are divided into groups and will be rotated across the aforementioned test platforms. They study and investigate each technology according to the six required characteristic of a Biometric system. This module will conclude with a moderated discussion on the pros and cons of Biometric systems in practice.

Multimedia and Web Page Design (Computer Science Module)

In this module they investigate how to create digital multimedia and integrate this media into a web page to understand how multimedia is created and how web pages are designed. During the laboratory component the students divide themselves into groups and use digital equipment (digital still cameras, MP3 recorder, digital HDTV camcorder, lapel microphones and a green screen) to record multimedia. Once a group has generated media, they then design web pages using that media.

Understanding and Building Structures to withstand Earthquakes (Civil Engineering Module)

The energy released at the epicenter of an earthquake is transmitted to the surface of the earth in the form of waves. This wave motion results in a ground motion that is oscillatory in nature. The response of a building or a bridge to an earthquake depends on a number of factors. They include: a) the nature of the ground motion, b) the stiffness of the structure, c) the mass of the structure, and d) the height and number of stories (if it is a building). The response is in the form of predominantly horizontal accelerations. The accelerations when multiplied by the mass results in forces in the buildings and bridges. Buildings are designed to ensure that they are able to withstand these horizontal forces. The didactic portion of the module is to explain these concepts in a simple manner. The laboratory component involves two types
of small-scale building frames that have been built. These include a one story and a two-story building. Accelerometers are attached to the base and each of the stories and measurements can be made using a data acquisition system. The goal is give a certain ground motion and measure the input and response accelerations. Different masses will be placed while performing the experiment in order to measure the influence of the mass factor.

Understanding and Preventing ACL Injury Among Athletes (Bio-Mechanics Engineering Module)

Female athletes have an eight-times-greater risk of tearing their anterior cruciate ligament (ACL), a fibrous band that connects the shinbone (tibia) to the thighbone (femur), than males. Basketball, soccer and other sports that require cutting moves or jumping put female athletes at risk for ACL injury. The biomechanics lab will use the tools and techniques of mechanical engineering to explore possible causes for the discrepancy in female to male ACL injury risk. Measurements will include the activation level of the quadriceps and hamstring muscles using electromyography (EMG). Muscles are “activated” by an electrical signal that is sent from the central nervous system to the muscle. This electrical signal in the muscle can be measured with a sensor placed on the skin close to the activated muscle. In addition, knee flexion angle and ground reaction forces will be simultaneously measured along with muscle activation while the test subjects jump in the air. Drawing from knowledge of the anatomy and function of knee joint tissues and from the lab measurements collected on both male and female volunteers, participants in the lab will evaluate possible reasons for the eight-fold difference in ACL injury between male and female athletes.

Teacher Professional Development

The ARROWS Engineering Essentials program includes high school teachers from participating school districts in a professional development program that focuses on the design of a problem-based learning curriculum. The professional development program and the supporting online forums were designed and implemented by Donna Russell at the UMKC School of Education.

Problem-Based Learning

Problem-based learning units provide students with the opportunity to engage in simulations of real-world computer science and engineering problems (Savery & Duffy, 1996). Problem-based learning develops higher-order thinking abilities in students by asking them to respond to authentic issues from the field (Jonassen, 2000). Additionally, studies have shown that in underrepresented and underserved student populations inquiry-oriented strategies as part of a problem-based learning project enhanced scientific ways of thinking, talking and writing for language learners and helped them acquire language and reasoning skills (Rosebery, Warren, & Conant, 1992). In a problem-based learning unit students are asked to develop new ideas and share knowledge by completing research on the problem space. These types of inquiry-based projects can be used to illustrate concepts and connections in science (Anderson, Reder, & Simon, 1997). During a problem-based unit students are asked to respond to simulations of a real-world issue thus situating the learning in an authentic context (Lave & Wenger, 1991). This provides the students with a meaningful, authentic, and collaborative learning environment that develops the
advanced cognitive processes, communicative skills and functional knowledge needed to be successful in science and engineering careers.

The ARROWS program provides teachers with professional development that they can use in their teaching practice. During the summer Engineering Essentials program teachers design a problem-based unit. Since teachers come from both Kansas and Missouri the units develop science, technology and engineering standards from both the Kansas science standards and Missouri Show-Me standards for science as well as the local districts’ science and engineering objectives. These standards are part of these state’s compliance with the Federally-mandated No Child Left Behind Act. All the units created are shared on the ARROWS professional development website.

The high school teachers attend the modules with students in the morning and participate in professional development activities in the afternoon. The teachers receive a brief overview of the principle characteristics of problem-based learning. The teachers use a Problem-Based Learning (PBL) Design Template created by Dr. Russell to create their PBL units. The teachers create potential science and technology units for their classrooms using the template. The teachers use a wiki site designed by Dr. Russell to download and upload documents and communicate using a discussion board. The teachers post their new units to the wiki. Dr. Russell designed a syllabus for a 3-credit Continuing Education course from the School of Education that the teachers can enroll in as part of their participation in the ARROWS program.

The teachers complete two pre and post surveys to identify changes in their ideas and beliefs about problem-based learning and science instruction methods in their classroom. The teachers respond to their interactions in the ARROWS lab activities in the morning by completing Reflection Notes each afternoon using guiding questions. Additionally the teachers used the ARROWS Professional Development Blog site to respond to surveys after each day’s workshops. The main ARROWS Professional Development website is located at http://education.umkc.edu/arrows. The main teacher PD site is shown below as Figure 1.

Additionally the blog site was used by the ARROWS teachers to dialog about important issues in the design and implementation of advanced science programs in urban settings. The blog site is shown below in Figure 2.

The ARROWS PD websites includes a wikispace. In this site ARROWS teachers can develop collaborative curriculum documents and access documents created in past workshops. The PBL Design Template is accessible for use in the design of future curriculum. The curriculum loaded into this site in the summer of 2009 included a collaborative curriculum where students in two classes would design an interactive gaming environment using the core concepts of physics, and a curriculum that engages students in designing robots. The main page of the wiki is shown below as Figure 3.

The purpose of the discussion forums is to identify major concepts and also issues that aid or detract from the ability of these high school teachers from implementing PBL STEM-based units based on the modules in their classrooms. Examples of the teachers’ dialogs and comments from the wiki and blogs are shown below.

Why I Liked ARROWS

1. The use of technology – Using technology or information systems in any capacity is vital to the success of students and teachers today. In ARROWS, we created web pages and we practiced using photo editing software, voice analysis programs, and green screen technology. Teachers used a weblog to write reflections. In addition, we all use computers to complete online assessments and surveys.
Figure 1. PD Website

![PD Website Image]

Figure 2. PD Blog Site

![PD Blog Site Image]
2. The emphasis on diversity – The ARROWS workshop supported a diverse group of students, teachers, and professors. I think it is important to reach out to under-represented groups, and the attitude of the staff is the same.

3. Hands-on learning – The constructivist approach to teaching leads to deeper learning because students solve their own problems and attach personal meaning to their learning. Hands-on learning promotes engagement, cooperation, and problem solving skills. At ARROWS, we built towers, created web pages, wrote curriculum, and participated in several other activities during the modules.

4. The emphasis on partnerships – Most of the teaching workshops I attend involve teachers teaching teachers. At ARROWS, teachers, students, and parents worked together to make new connections between like-minded people from the community, secondary schools, and university. The presentation for parents on the last day was a wonderful, culminating event for all. Because of the partnerships, ARROWS has a greater impact on the participants.

5. Climate - The UMKC staff, the food, and the way the activities were designed provided an atmosphere conducive to learning and interacting. We never sat for too long and the trivia game was fun. Students and teachers enjoyed the building contests. I think the climate and atmosphere created by the leaders is fundamental to the success of any program.

6. Assessment – The pre and post tests provided measurable feedback for ARROWS. The web pages, curriculum materials, and building contests provided an opportunity for participants to internalize concepts. In addition, they provided evidence of learning and engagement in the program.

7. Feedback opportunities - We were given several opportunities to provide feedback and input for future ARROWS programs. Clearly, the UMKC staff is flexible and willing to continuously improve an already successful program.
An example of another teacher’s comments on the blog are listed below.

So far, I have participated in 3 modules. I have enjoyed them all in terms of gaining new knowledge. In earthquakes, I enjoyed the teamwork aspect of designing a building that could withstand the forces of an earthquake. In biometrics, learning the evolution of the field and what is currently available was interesting, and I liked seeing the actual devices. In web page design, we learned quite a few aspects of design that I had not done before, so that was enjoyable to see a product after just a few hours. In terms of what I can take to my students, I think a unit incorporating building structures would be something to develop teamwork and problem solving skills. For biometrics, many of my students voice an interest in CSI and crime, so I think they would be curious about biometrics and learning some of the technologies would be an interesting hands-on lab to kick off discussion of genetics in biology class. The web page development module is also fascinating, and could serve to get students working on computers in order to develop the communication aspect of all sciences. The bridge module was good in that there was little lecture, a short demonstration, brief criterion, and then we were able to create and build. The biometrics module was interesting and information heavy, but we did not create anything, or produce a product. That probably would be hard based on the nature of the subject. A project where we identified someone using the technology would be engaging. Perhaps two teams, one as criminals trying to enter, the other as security.

Each afternoon the teachers were asked to respond to the engineering and technology modules from the morning activities. The teachers were asked to identify the module, the module topic and are this viable for your classroom in a daily discussion board. The teachers enjoyed the modules and found them to be viable for their classrooms. The teachers also used the reflection discussion board to share resources such as websites for their unit development. Some examples of their responses are below:

Module: Robotics
Topic: How to build a staccitio robot. This was over the top fun. I enjoyed this a lot and would love to try this with my students.
Is this Viable
Yes!!!! Need more of this!!!!

Module: Mechanical Engineering
Topic: Human powered vehiciles and biomechanics of the ACL of the knee. Very interesting presentation using the video’s of actual HPV projects showcased. We also were introduced to the gait lab to see how pressure plates and video camera’s could capture human movement.
Is this Viable
Yes. Applied science at its best.

Module: Web/ Multimedia
Topic: How to implement Multimedia (webpages/ sound/ video) into the classroom. I will definitely use this topic, since I am in a 1-1 laptop school and I need much assistance in this area. I will be using multimedia for projects and presentations. I am interested in learning how to get this access for my students to make projects for my classes.
Is this Viable
Yes!!!! Need more of this!!!!
Module: PBL
Topic: Discussion: What projects are being implemented?
I have changed my topic to roller coasters since this will address more standards and benchmarks for my subject of physical science. I saw that another teacher was working on this topic for physics and after thinking about it overnight I realized this would be a better fit for me.

Module: Biometrics
Topic: Measuring the physiology of human beings.
Very fascinating. I am trying to think of how to implementing this topic since I know it will generate student interest.
Is this Viable
Yes
What didn’t work
N/A Everything was appropriate

Module: PBL
Topic: PBL Project and Using Second Life in the classroom I selected the unit sound and energy to work on. So I can work on two benchmarks standards at once.
Is this Viable
Second Life...I fear that my school will not allow this usage because of possible abuse by students. (Cyberbullying, etc.) But if this is allowed I would like to learn how to use it. It sounds like fun.
Is this Viable
Yes!!!

The teacher’s feedback included responses to the surveys in the discussion board. Below are examples of teacher responses to the daily surveys in the ARROWS PD discussion board.

In response to our discussions yesterday, I would like to get feedback on your ideas concerning STEM (science, technology, engineering and math) areas.

Do you currently teach in a STEM area? If yes please briefly describe your area.

I teach Biology, Anatomy & Physiology, and an integrated science class that combines geology, astronomy, physics and technology. I work with the students a great deal outside the school day on a FIRST robotics team, helping them build and design a competitive, programmable mechanical device.

Are you more or less able to design your own course when compared to 5 years ago – or previous years? Explain why yes or no.

I have been a high school teacher at the same small charter school for three years I was given the freedom and responsibility to develop the science curriculum. I essentially framed it within the state standards, implementing it using the constructivist learning principles I had learned during my graduate work.

What is the single most important reason that you do, or do not, design your own curriculum? Explain why.
I design my own curriculum because my school needed someone to do it and they felt I was qualified to do it. We are expected to have it aligned to the state standards (the newly released “course level expectations”) and help prepare students for the state test. While I respect the expectorations of the state and I feel that most of their standards are valid/ relevant, it does limit our ability as teachers to create rich, hands-on, integrated, cross-curricular projects.

If you wanted to develop integrated STEM courses, are you aware of any professional development programs available to teach you how to design such a unit?

Yes. FORD PAS, Geoworlds and Project Lead the Way are some examples. These may or may not help the schools meet the AYP they need to keep afloat.

Did the ARROWS modules and PD help you think about potential STEM activities or units in your classroom? If yes, briefly describe your idea for a unit or activity?

For my integrated science class and robotics team, I could use much of the info presented in the modules. I could also implement a PD designed unit in my integrated class provided that I actually teach it this coming year, which is still up in the air. My unit idea is actually for Biology, which I know I will be teaching. It relates to biotechnology application in the “real world.”

An example of another teacher’s response is below.

Do you currently teach in a STEM area? Yes. If yes please briefly describe your area.

I teach biology and integrate both technology and mathematics.

Are you more or less able to design your own course when compared to 5 years ago – or previous years?

Less likely.

Explain why yes or no.

I am no longer likely to design my own course due to the standards in the district as well as standardized testing at the state and national levels that require students to learn particular information that five years ago I would not have considered content of a biology class.

What is the single most important reason that you do, or do not, design your own curriculum. Explain why.

From past experience I have seen teachers who do not teach to a standardized test fired or reprimanded due to their students not performing well on state end of instruction tests.

If you wanted to develop integrated STEM courses, are you aware of any professional development programs available to teach you how to design such a unit?
No, I am not.

Did the ARROWS modules and PD help you think about potential STEM activities or units in your classroom? If yes, briefly describe your idea for a unit or activity?

Yes, they did. Because I am no longer teaching environmental science and zoology, I will have honors biology. Having my students realize the importance of biometrics and how it will affect their lives and what exactly this technology is will challenge my students. They will need to understand its importance, who should use this system, and the ethical dilemmas that come from using it.

**Problem-Based Learning Units**

Each afternoon the teachers used the PBL Design Template to develop a PBL unit. PBL Design Template is included in supplemental materials for this book. Only one teacher had previously written a PBL curriculum. This teacher works in a gifted education program in the Rockwood School District, a suburban district outside of St. Louis. She had heard about the ARROWS program and knew Dr. Russell. She scheduled a long visit to Kansas City to coincide with the Engineering Essentials program and enrolled.

During discussions of problem-based learning characteristics and design, Dr. Russell emphasized the importance of developing a project that involves resources, organizations and activities outside of the classroom including guest speakers, presentations, and field trips. Most teachers are given standards as well as goals and objectives for their content areas. In Missouri these are tested at the end of the year in grade level exams. However Missouri is switching to course level exams that will be given at the end of each course requiring a much more specific ‘fit’ between the student activities, the curriculum and the testing process.

When asked to develop a unifying theme for the science, engineering and technology units all the teachers were able to develop a concept based on these the state standards for science, technology and math using the PBL Design Template. Some of the units created included a water quality unit, an examination of bacteria and virus, a unit where the students design a new game in Second Life, an amusement park unit to teach physics and an environmental awareness unit. The teacher working on the Second Life game unit teaches in a one-on-one laptop program in Kansas City Kansas School District. She wants her students to be able to work collaboratively to design a game in Second Life. She would set them up in groups to develop the ideas for the educational games, such as teaching history to fourth graders, and they would then design the interactions in Second Life using the open coding system in Second Life. The students would interview the teachers and the students then write the code and create the objects in Second Life. The bacteria and virus unit would develop the science concepts identifying differences between the characteristics and functions of bacteria and viruses focusing on the issue of human diseases and treatment for both.

Another unit that was developed was a water quality unit. The teacher teaches at an inner city high school. The unit was developed to include interactions with a local water quality monitoring program already in place in Kansas City metro area. In the PBL Design Template the teachers are asked to list community organizations that can provide expertise and mentor the students. Below are examples of the curriculum she developed during professional development with ARROWS. She contacted a local agency via email during her professional development time and they responded that they would work with her
to implement the unit during the next school year. Her response to the questions in the Problem-Based Unit Design Template are listed below:

Why is this unit meaningful?

Water quality issues are continually being discussed in the community. These issues are easy to conceptualize and the solutions are quickly experienced. Making this problem something that students can easily relate to on many levels.

What is the nature of the problem students will tackle in this unit? Students will tackle a complex problem: water quality in the urban environment. They will learn background on water quality (causes of pollution, how we know the water quality, etc.).

List the benchmarks/objectives/standards addressed in this project, based on my district goals relate to the science and technology benchmark unit, see below:

Standard 5 Science and Technology, Benchmark 1, Indicator 1 (5.1.1)
The student understands technology is the application of scientific knowledge for functional purposes.

Benchmarks
• Technology is driven by the need to meet human needs and solve human problems.
• Engineering is the practical application of science to commerce and industry.
• Medicine is a practical application of science to human health.
• All technological advances contain a potential for both gains and risks for society.

Objectives
• I can …
  o Differentiate between science and technology.
  o Relate scientific discoveries to the development of a technology.
  o Describe the benefits or risks of a particular technology.
  o Read an article about technology, describe the technology and analyze the benefits and risks of that technology.

Why do you think students will find the problem in this unit meaningful?

Students will find this meaningful because it is problem they see every day walking around and living in their neighborhood. They may know someone that has been negatively affected by pollution in the form health problems like asthma, cancer, or other health issues. In addition, they will learn how this pollution can cycle into their own drinking water, even though it has been “treated”, for example, caffeine, oral contraceptive hormones, and antibiotics are now found at trace levels in tap water.

In addition, work on this project has already begun. I will post the email I send to the EPA recently regarding findings that a local creek is quite poor water quality. I am currently trying to follow up.

The teachers, in all cases, were able to design an overview of a PBL unit of study based on the design template given to them by Dr. Russell and using the morning modules as guides for an interactive learning experience.
Professional Development Research

The ARROWS program includes a research model designed to understand changes in the teachers’ concepts about teaching and learning in science, technology and engineering areas. The goals of the research program for the teachers was to 1) identify changes in the teachers’ attitudes about problem-based learning in STEM areas, 2) identify changes in the teachers’ attitudes about science teaching and learning in their classroom, 3) define the issues that impact the development of PBL units in STEM areas in their classrooms. The teachers participating in several online forums including uploading new curriculum in the wiki site, a discussion board with daily questions, a reflection on their daily ARROWS activities and two surveys. All of this information was reviewed in order to identify changes resulting from the professional development activities and to analyze their responses for issues impacting the development of STEM courses based on PBL principles. The professional development data has been collected since 2005 when the ARROWS program was funded.

Teacher Surveys

In order to understand changes of PBL design principles as a result of participation in the professional development program and the design of a problem-based learning unit Dr. Russell designed the ARROWS Teacher Survey of Attitudes and Beliefs based on six areas described in constructivist education research as characteristic of PBL units. The areas assessed in the survey include 1) scaffolding, 2) mediation, 3) goal-directed, 4) meaningful, 5) constructivist and 6) inquiry (Jonassen, 2000). The PBL Survey was scaled form 1-5 to identify the teacher’s awareness of these key characteristics of PBL.

The mean answer to all the scaled questions in the pre test was 3.5. The mean answer to the scaled questions in the posttest was 3.96. The sum of the averages for all scaled questions was 3.76. This increase is a reflection of the teachers’ increased awareness of the terminology as well as the characteristics of a constructivist-based learning response. The area that scored lowest on both the pre and posttest was the area titled collaboration. In this area the scaled questions totaled only 3.4. The teachers expressed a lack of comfort with the purpose and assessment of the collaborative processes built into a constructivist-learning unit of study. The area that scored highest on both pre and post was mediation. The teachers scored mediation as 4.0. Mediation, which entails the use of scientific tools and the development of the scientific process, was rated highly by the teachers and included as a major influence in their new unit.

The survey included an open response at the end of each section. Some of their comments to the open-ended sections are copied below:

How do you get students interested in learning that is outside their comfort zone. How do you encourage students to explore different levels of problem solving- how not to only explore the first solution but to explore other options.

The idea of PBL is familiar to me, but the jargon is not. I come from a chemistry/biology background, and worked in industry for 3 years before becoming a secondary science educator. One difficulty in my district is that every teacher is required to teach the same 14+ units with the same 2 exams per unit, but with relatively few resources both in terms of curriculum, money, and supplies. These benchmarks and objectives do not necessary match the textbook, and the exams often involve vocabulary and concepts beyond the scope of the current course. This is frustrating because our curriculum is becoming “a mile
wide and an inch deep”. We compartmentalize knowledge to the point that the big picture is hazy, fuzzy, or not there. In addition, there is not enough time for the number of labs I would prefer to offer. Half of the 28 exams from August to December or January to May (due to our college-like semester schedule) are supposed to be Performance, but in reality this has not yet happened due to a variety of restraints above. I think our district IS making progress, but many teachers now have their hands tied and cannot teach to their strengths as much. It has some benefits, but I disagree with the fact that our students can retake tests as many times as they want. This is not preparing them for reality.

Science in the Classroom Survey

The Science in the Classroom survey was designed to identify the teachers’ concepts about student interest and abilities in a science classroom. These concepts included Learning to communicate, Learning to learn, Learning to speak out, Learning about science, Teacher support in learning science, Interest in learning science and Learning about the world. The responses are scaled 1-5 from almost always to almost never. There are six responses in each of the seven categories with a total of 42. The teachers were asked to respond as a student in their own class would respond. Of the seven categories the lowest level of response was in the category of interest in learning science with an overall mean response of 3.3. Next was the Teacher support in learning with 3.9. Then Learning to learn with 4.0. Learning to speak out with 4.0. Learning about science with 4.1 and finally Learning about the world with the highest level of response at 4.3.

In some ways the results of the student perspective survey contradicts the teacher reflections and discussions. In online and face-to-face discussions, the teachers expressed concern over the logistics and assessment of group work and discussions but in this survey, responding from the perspective of their students in their classrooms, they included talking about science as an important aspect of their classroom. Additionally all the teachers except one had never developed a PBL science unit based on a real world issue or problem but they scored this type of learning by the student, meaningful learning, at the highest level because they felt that students would be making the connections between science in their classrooms and the real-world of science and technology outside of their classroom. The teachers noted the need to make science meaningful and important to students in their PBL design survey but scored student interest in science as the lowest category of student science response. Perhaps this denotes a disconnect between their ideas about the design of a meaningful learning environment by the teacher and what they perceive as the students’ ability to pay attention, be motivated and engage collaboratively during these units.

Summary of Teacher Responses

The teachers responded to several daily forums and two surveys during their professional development program. As a result they discussed several issues impacting the implementation of a PBL unit to develop STEM concepts and knowledge in their classrooms.

Professional Development Issues

In summary, the teachers have good ideas about how science can be taught using PBL principles but the lack of training on the design and implementation of these constructivist-based units inhibits their
ability to implement them. The teachers described a high degree of frustration with the fragmentation of the curriculum in their schools that is needed to prepare students for standardized testing. The isolation of content for the standardized assessment decreased the potential to implement an integrated unit, like a PBL unit, in their schools. The teachers wanted to be able to coalesce the curriculum standards into meaningful units of study however only one teacher had received prior training in how to design an integrated unit of study based on a unifying theme such as a PBL unit. In their discussions and surveys, the teachers understood the importance in the type and quality of learning that is possible in a PBL unit, but they were unsure how to design the interactions and the subsequent assessments that would develop the learning. One teacher discussed her interest in using groups in her course but was afraid of the lack of discipline that could result.

Assessment

The teachers identified assessment as a major issue. Assessment of problem-based learning is a core issue that must be dealt with if teachers are asked to develop constructivist-based learning environments. They are unsure how to assess the group work, collaborative projects, inquiry processes and other student responses in a PBL unit. Additionally, standardized testing makes it much more difficult for teachers to implement these innovative units as teachers find it difficult to match the assessment of the PBL processes possible with the traditional testing assessment model. Teachers noted that there are penalties for themselves and their students if they do not raise test scores. Implementing innovative new units are difficult in this atmosphere. Additionally, one state, Missouri, has changed assessment from grade level evaluations to course level evaluations. This requires the teacher to teach specific content during each course reducing the potential to integrate content.

Concepts of Learner Characteristics

The two surveys, one from the teacher’s perspective on the characteristics of PBL units and the other from the perspective of a student in their classroom identified differences between their concepts of PBL and their classroom. They identified a disconnect between their response to the need for collaborative work but their lack of use of this instructional process. Although identifying student engagement as a primary aspect of PBL, they were unsure how to manage this including questioning whether students would be motivated to engage in these activities. The classroom management tasks of focusing group work, identifying and assessing individual responses and managing behaviors were mentioned as difficulties that ultimately contradicted their responses in the PBL survey.

Lack of Resources

The teachers were concerned with the cost of a PBL or science unit. The modules that they participated in during ARROWS Engineering Essentials program all used expensive equipment or software that they and the district cannot afford. Another resource that is limited is their time. They are not given a lot of professional development time and would have to develop a PBL unit on their own using their own resources.
Scheduling

The high school teachers also discussed their schedules at the school as an impediment to implementation. Because they are all departmentalized it is difficult to find the time to develop an interdisciplinary topic in depth. Several were teaching in different science areas from year to year such as teaching biology one year and earth science the next based on enrollment and other issues. This makes it difficult to design large integrated PBL units.

CONCLUSION

The ARROWS program is a long-term outreach program in an urban community with the goal of motivating more computer science and engineering undergraduate students to achieve the skills needed for careers in computer science and engineering. The professional development aspect was designed to develop new understanding and knowledge about problem-based learning as a model for teaching STEM content knowledge. The teachers were asked to develop a PBL unit and respond to multiple forums for discussion on the potential of these units to teach advanced STEM content knowledge to their students. The analysis of the teachers’ responses identified several issues including the lack of professional development, lack of resources, standardized testing, scheduling, and the teachers’ concepts of their students’ ability to engage in problem-based learning.

There is an urgent need for more minority students in science and engineering programs at the university level. Problem-based learning units support the development of the advanced cognitive abilities needed to be develop the STEM content knowledge needed to be successful in science and engineering programs. It is important for urban high school teachers to be able to implement PBL units in the science and engineering courses to develop these students’ capabilities to enter and be successful in university programs. This research identified several important issues that impede the ability of urban high school teachers to develop these units.

Ultimately, it is important to understand that both sides of the educational continuum in the US, the k-12 educational system and the university system, need to focus on responding to this need by developing a coherent forum for dialog and the implementation of collaborative efforts, such as the ARROWS program, that focus on increasing the number of minority students capable of successfully completing a degree in STEM areas.

Overviews of the Chapters

This book was conceptualized to provide a comprehensive review of web-based engineering education focusing on the development of real-world problem-based learning skills. The chapters provide in-depth descriptions of multiple educational settings.

Chapter 1. Designing of E-Learning for Engineering Education in Developing Countries: Key Issues and Success Factors by B. Noroozi, M. Valizadeh, & G. A. Sorial. Traditional education for engineers has shifted towards new methods of teaching and learning through the proliferation of Information and Communication Technologies (ICT). The continuous advances in technology enable the realization of a more distributed structure of knowledge transfer. This becomes critically important for developing countries that lack the resources and infrastructure for implementing engineering education practices.
The two main themes of technology in designing e-Learning for engineering education in developing countries focus either on aspects of technological support for traditional methods and localized processes, or on the investigation of how such technologies may assist distance learning. Commonly such efforts are threefold, relating to content delivery, assessment and provision of feedback. This chapter is based on the authors ten years’ experience in e-Learning, and reviews the most important key issues and success factors regarding the design of e-Learning for engineering education in developing countries.

Chapter 2. Architectural Web Portal and Interactive CAD Learning in Hungary by Attila Somfai. This chapter describes the use of a teaching web portal at a university in Hungary. The Internet has created potential new and effective ways of cooperation between lecturers and students of the university and other institutions of higher education. The teaching web portal of the Faculty of Architecture at Széchenyi István University (www.arc.sze.hu/indexen.html) realizes the diversity and complexity of architecture with efficient grouping of information and being attentive to high professional standards. Computer Aided Architectural Modelling (www.arc.sze.hu/cad) is one of the new types of online lecture notes, where many narrated screen capture videos show the proper usage of CAD software instead of texts and figures. This interactive type of learning assists students to become more independent learners. This type of teaching modality provides the opportunity for students who need more time to acquire subject matter by viewing video examples again. Additionally, the success of our departments’ common web initiations can be measured through Internet statistics and feedback of the students and external professionals.

Chapter 3. Adapting Engineering Education to the New Century by A.K. Haghi, & B. Noroozi. In this book chapter, the authors summarize their retrospections as an engineering educator for more than 20 years. Consideration is given to a number of educational developments to which the authors has contributed during their career in academia and the contribution made to engineering and technological education. Increasing emphasis is being placed on establishing teaching and learning centers at the institutional level with the stated objective of improving the quality of teaching and education. The results of this study provide information for the revision of engineering curricula, the pedagogical training of engineering faculty and the preparation of engineering students for the academic challenges of higher education in the field. The book chapter provides an in-depth review of a range of critical factors liable to have a significant effect and impact on the sustainability of engineering as a discipline. Issues such as learning and teaching methodologies and the effect of E-development and the importance of communications are discussed.

Chapter 4. 3D Virtual Learning Environment for Engineering Students by M. Valizadeh, B. Noroozi, & G. A. Sorial. Virtual Reality and Virtual Learning Environments have become increasingly ambiguous terms in recent years because of changes in essential elements facilitating a consistent environment for learners. Three-dimensional (3D) environments have the potential to position the learner within a meaningful context to a much greater extent than traditional interactive multimedia environments. The term 3D environment has been chosen to focus on a particular type of virtual environment that makes use of a 3D model. 3D models are very useful to make acquainted students with features of different shapes and objects, and can be particularly useful in teaching younger students different procedures and mechanisms for carrying out specific tasks. This chapter explains that the 3D Virtual Reality is mature enough to be used for enhancing communication of ideas and concepts and stimulate the interest of students when compared to 2D education.

Chapter 5. Online Automated Essay Grading System-As a Web Based Learning (WBL) Tool in Engineering Education by Siddhartha Ghosh. Automated Essay Grading (AEG) or Scoring (AES) systems
are more a myth they are reality. Today the human written (not hand written) essays are corrected not only by examiners and teachers but also by machines. The TOEFL exam is one of the best examples of this application. The students’ essays are evaluated both by human & web based automated essay grading system. Then the average is taken. Many researchers consider essays as the most useful tool to assess learning outcomes, implying the ability to recall, organize and integrate ideas, the ability to supply merely than identify interpretation and application of data. Automated Writing Evaluation Systems, also known as Automated Essay Assessors, might provide precisely the platform we need to explicate many of the features those characterize good and bad writing and many of the linguistic, cognitive and other skills those underline the human capability for both reading and writing. This chapter focuses on the existing automated essay grading systems, the basic technologies behind them and proposes a new framework to show that how best these AEG systems can be used for Engineering Education.

Chapter 6. Future Challenges of Mobile Learning in Web-Based Instruction by Chandre Butler, Rochelle Jones, & Pamela McCauley-Bush. Mobile learning is becoming an extension of distance learning, providing a channel for students to learn, communicate, and access educational material outside of the traditional classroom environment. Because students are becoming more digitally mobile, understanding how mobile devices can be integrated into existing learning environments is advantageous however, the lack of social cues between professors and students may be an issue. Understanding metrics of usability that address the concern of student connectedness as well as defining and measuring human engagement in mobile learning students is needed to promote the use of mobile devices in educational environments. The purpose of this chapter is to introduce contemporary topics of applied mobile learning in distance education and the viability of mobile learning (m-learning) as an effective instructional approach.

Chapter 7. Designing Animated Simulations and Web-Based Assessments to Improve Electrical Engineering Education by Doug Holton, & Amit Verma. Over the past decade, our research group has uncovered more evidence about the difficulties undergraduate students have understanding electrical circuit behavior. This led to the development of an AC/DC Concept Inventory instrument to assess student understanding of these concepts, and various software tools have been developed to address the identified difficulties students have when learning about electrical circuits. In this chapter two software tools in particular are discussed, a web-based dynamic assessment environment (Inductor) and an animated circuit simulation (Nodicity). Students showed gains over time when using Inductor, and students using the simulation showed significant improvements on half of the questions in the AC/DC Concept Inventory. The chapter concludes by discussing current and future work focused on creating a more complete, well-rounded circuits learning environment suitable for supplementing traditional circuits instruction. This work includes the use of a contrasting cases strategy that presents pairs of simulated circuit problems, as well as the design of an online learning community in which teachers and students can share their work.

Chapter 8. Use of Living Systems to Teach Basic Engineering Concepts by Kauser Jahan, Jess W. Everett, Gina Tang, Stephanie Farrell, Hong Zhang, Angela Wenger & Majid Noori. Engineering educators have typically used non-living systems or products to demonstrate engineering principles. Each traditional engineering discipline has its own products or processes that they use to demonstrate concepts and principles relevant to the discipline. In recent years engineering education has undergone major changes with a drive to incorporate sustainability and green engineering concepts into the curriculum. As such an innovative initiative has been undertaken to use a living system such as an aquarium to teach basic engineering principles. Activities and course content were developed for a freshman engineering class at Rowan University and the Cumberland County College and K-12 outreach for the New Jersey
Chapter 9. The Use of Applets in an Engineering Chemistry Course: Advantages and New Ideas by B.M. Trigo, G.S. Olguin, & P.H.L.S. Matai. Since the sprouting of the personal computers, around 1980, computer science has been gaining importance, becoming a supporting instrument for other daily activities of ours. With the introduction of computing in a certain area or activity, barriers and difficulties can be overcome. Consequently, new paradigms, possibilities and challenges are created. In education it is not different, computing is more and more present, assisting the learning process in a variety of ways, creating new challenges that compel us to re-think the way education is performed, considering new delivery methods instead of only the traditional chalk-and-talk method. “While we may feel comfortable with traditional approaches, the new technologies provide us with the tools to challenge these positions, and open up the teaching/learning questions for some rethinking” (Roy & Lee, 1999). With the sprouting of the Internet, it was created what we today understand as the web-based teaching, a method that brings innumerable benefits and challenges for the educators. This chapter describes the development of Applets in a General Technological Chemistry (QTG) course covering the topics of the discipline and joining them in a main “host” Applet, creating a virtual chemistry laboratory, which would be available for the students in the discipline’s website.

Chapter 10. Competitive Design of Web-Based Courses in Engineering Education by Stelian Brad. Developing engineering study programs of high quality, able to satisfy customized needs, with flexible paths of study, with easy and rapid access to the most appropriate educational facilities and lecturers is a critical and challenging issue for the future of engineering education. The latest developments in communication and information technologies facilitate the creation of reliable solutions in this respect. Provision of web-based courses in engineering education represents one of these solutions. However, the absence of physical interactions with the training facilities and the specificity of remote collaboration with lecturers rise up additional challenges in designing a high-quality web-based engineering course. In order to define superior solutions to the complex set of requirements expressed by several stakeholders (e.g. students, lecturers, educational institutions and companies), a comprehensive planning of quality and an innovative approach of potential conflicting problems are required during the design process of web-based engineering courses. In this context, the present chapter introduces a generic roadmap for optimizing the design process of web-based engineering courses when a multitude of requirements and constrains are brought into equation. Advanced tools of quality planning and innovation are considered to handle the complexity of this process. The application of this methodology demonstrates that no unique, best-of-the-world solution exists in developing a web-based engineering course; therefore customized approaches should be considered for each course category to maximize the impact of the web-based educational process.

Chapter 11. WIRE: A Highly Interactive Blended Learning for Engineering Education by Yih-Ruey Juang. Many researchers have shown that blended learning can more effectively enhance motivation, communication skills, and learning achievement compared to single-form teaching methods. However, the crucial issue that needs to be addressed in blended learning is the question of how to integrate the selected blended format, technology, and teaching strategy into a coherent learning model, and while maintaining interaction between the teacher and students both inside and outside the classroom. Most useful functions of e-learning tools have not been meaningfully integrated into teaching and learning strategies, or into the course management systems that have been used in most campuses. This chapter introduces a highly interactive strategy, the WIRE model, for blended learning that incorporates web-based
and face-to-face learning environments into a course by linking the Warm-up before class, Interactive teaching in class, and Review and Exercise after class, creating a sustained learning experience through meaningful use of technology in engineering curricula.

Chapter 12. Sights Inside Virtual Engineering Education by Giancarlo Anzelotti & Masoumeh Valizadeh. The critical tenet of engineering education reform is the integral role of virtual environment capabilities that is provided by fabulous advances in information technology. Current technological progresses combined with changes in engineering content and instructional method require engineering instructors to be able to design intensive and concentrated lessons for exploration and discovery of the engineering concepts through appropriate computer applications. In actual practice, however, most computer applications provided for engineering education consist of software designed for a specific educational purpose. Furthermore, economical constraints often stand in the way of incorporating such special purpose software into an instructional setting. This chapter discusses an alternative to the traditional approach that shifts the instructional focus from specific computer applications to more sophisticated uses of general purpose software. In particular, educational uses of purpose-oriented small software that can be implemented in multi purpose software are examined as an introduction to this approach.

Chapter 13. Effective Design and Delivery of Learning Materials in Learning Management Systems by Mehregan Mahdavi, John Shepherd, & Mohammad H. Khoobkar. Learning Management Systems (LMS) enable effective design and delivery of learning materials. They are Web-based software applications used to plan, implement, and assess a specific learning process. LMSs allow learners to connect to and interact with the educational material through the Internet. They enable tools for authors (instructors) to design learning materials that include text, html, audio, video, etc. They also enable learner activity management in the learning process. Moreover, they provide tools for effective and efficient assessment of the learners. This chapter explores learning management systems and their key components that enable instructors organize and monitor learning activities of the learners. It also introduces the authoring features provided by such systems for preparing learning material. Moreover, it presents assessment methods and tools that enable evaluation of the learners in the learning process. Furthermore, existing challenges and issues in this field are explored.

Chapter 14. Web-Based Training: An Applicable Tool for Engineering Education by Masoumeh Valizadeh, Giancarlo Anzelotti & Salesi Sedigheh. Due to its singular capabilities, web-based learning has entered and is widely used in every field of science and technology. It is not only warmly welcomed at schools and universities, but also in factories and houses. However utilization of web-based learning technique requires tender and comprehensive attentions in designing, applying and assessing configurations, directed by when, where and for which purpose it is being employed. Among different branches of human knowledge and sciences, engineering as well as medicine is more involved in practical and daily-life aspects, where the virtual utilities and educational software can be utilized to consummate the practical features of engineering education. Furthermore the virtual environment of e-learning courses can provide cheaper, safer, more comprehensive and more inclusive approaches to engineering educational material. What usually the students need to learn in laboratories and workshops and it is costive and demanding for the universities and the schools. The aim of this chapter is to count the requirements of engineering education and to accord the facilities and inadequacies of e-learning as training technique in engineering instruction.

Chapter 15. A Diagnostic System Created for Evaluation and Maintenance of Building Constructions by Attila Koppany. The successful diagnostic activity has an important role in the changes of the repair costs and the efficient elimination of the damages. The aim of the general building diagnostics is to
determine the various visible or instrumentally observable alterations, to qualify the constructions from the suitability and personal safety (accidence) points of view. Our diagnostic system is primarily based on a visual examination on the spot; its method is suitable for the examination of almost all-important structures and structure changes of the buildings. During the operation of the diagnostic system a large number of data – valuable for the professional practice – was collected and will be collected also in the future, the analysis of which data set is specially suitable for revaluing construction and the practical application of the experiences later during the building maintenance and reconstruction work. For using the system a so-called “morphological box” has been created, that contains the hierarchic system of constructions, which is connected with the construction components’ thesaurus appointed by the correct structure codes of these constructions’ place in the hierarchy. The thesaurus was not only necessary because of the easy surveillance of the system, but to exclude the usage of structure-name synonyms in the interest of unified handling. The analysis of which data set is specially suitable for revaluing earlier built constructions and which data can help to create knowledge based new constructions for the future is the topic of this chapter.

SUMMARY

This book evaluates the usefulness of advanced learning systems in delivering instructions in a virtual academic environment for different engineering sectors. The learning process discussed in each chapter will include a walk-through of a case problem solving exercise in the virtual company environment. This will enable the reader to adjust to conditions of the world of work. This volume will demonstrate how to enter the virtual company module, select a company and a case problem of their choice. Each chapter plays a key role in designing and producing workable solutions. Each chapter provides the reader with opportunities to think critically and approach problems analytically. Hence, the reader will be able to link diverse skills and knowledge to tackle problems and maximize productivity in the design and implementation of web-based engineering education. Finally, this volume aims at providing a deep probe into the most relevant issues in engineering education and digital learning and offers a comprehensive survey of how digital engineering education has developed, where it stands now, how research in this area has progressed, and what the prospects are for the future. As a result this volume will be of significance to those interested in digital learning and teaching and training focusing on the university and industrial context. This book is also a productive resource to industrial engineering professionals who would like to see how digital learning works in practice. In addition, the book will be highly valuable to those researchers in the field interested in keeping abreast of current developments in the confluence of their fields of expertise and technological settings.

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