Advances in Science and Technology, Vol. 3, No. 2, September / October 2009, pp 83 - 99

Antecedents, Constructs and Consequences of the Paradigm Shift In Engineering Education

Ifeyinwa E. Chika* and Djamel Azzi
Department of Electronic and Computer Engineering, University of Portsmouth, Anglesea Building, Anglesea Road, Portsmouth, PO1 3DJ, UK.

(Submitted: September 23, 2008; Accepted: June 26, 2009)

Abstract

It is generally acknowledged that there are problems with our engineering graduates and indication that the primary goal of engineering faculties, which is to facilitate students' maturation into skilled real-world problem solvers able to make reasoned decisions in challenging situations, is not being achieved. This implies that the students are not acquiring the real-world problem solving skills, such as technical competence, team work and lifelong learning, critical thinking and problem solving skills, needed to make sound engineering decisions and evaluation. Many factors contribute to this, chief among them being the way universities teach engineering. There is a gap between engineering as it is taught and as it is done and the learner is largely "unknown". There is need for an educational framework that builds experiences that would draw from real world examples and breathe life into the idealized models of the classroom. The traditional educational paradigm, which is content/instruction-based, places more emphasis on the memorization of facts and established procedures and content delivery. System dynamics have propelled a shift in paradigm to an educational framework for learning enhancement, promoting experiential learning and cognitive growth, fostering critical and sustainable thinking and acquisition of problem solving skills. In this paper, we detail the antecedents, constructs and consequences of the paradigm shift which requires a closer look at the constructs of student development. We also propose the virtual laboratory as a workable lab alternative in resource constrained environments. The paper is aimed at motivating and stimulating Engineering Educators to harness their potential to improve the quality of engineering education through creative teaching and make assessment more diagnostic in nature. We also hope to elicit some level of positive response from faculties towards more effective engineering curriculum.

Keywords: Engineering skills, paradigm shift, student-centred learning, diagnostic assessment and scholarship of teaching

1.0 Introduction: The Antecedent

The main goal of engineering faculties is to facilitate students' maturation into skilled real-world problem solvers able to make reasoned decisions in challenging situations. The pressure of rising population and societal dynamics necessitates that engineers will be called upon do design and implement sustainable systems and technologies with multidisciplinary implications (Huntzinger, 2007). The engineers will need to posses such skills as technical know-how, critical thinking, creativity, life-long learning and team work among others, which underpin an engineer's performance effectiveness in a wide array of settings or contexts. These skills (educational outcomes) are an integral part of what is expected from universities and therefore the responsibility of every engineering faculty to ensure that they are met through appropriate curriculum, instructional strategies and assessment.

However, these outcomes are often not adequately met with the traditional behaviourist educational paradigm, the "Instruction Paradigm" (Barr and Tagg, 1995), that encourages content delivery and memorization of facts. Behaviourist learning theory enforces authoritarian manipulation of people and sees learning seen as acquisition of new observable behaviour within the framework of universal laws (Carlile and Jordan, 2005; OPA, 2007). The overt behaviour acquisition is a series of learning events, rather than a process, with focus on a set of achievable and verifiable outcomes. There is no consideration for mental activities by the learner and

* Corresponding author's e-mail: Ifeyinwa.Chika@port.ac.uk

creativity and independent learning are not priorities. Passivity and rote learning are fostered. This educational paradigm is content/instruction-based with the instructor assuming the position of an all knowing authority and trainer and holds the key to learning success (OPA, 2007). Knowledge is separated into many mostly unconnected parallel parts and the teacher knows which parts are most important (Wimmer, 2005; Barr and Tagg, 1995). Motivation is by carrot and stick method and an engineer is "produced" when a student is assessed to have received the specified amount of instruction (Barr and Tagg, 1995). "I just don't feel that that is a way to increase students' learning fully. They may learn a lot, but they may also forget a lot very quickly" (Wiersema, 2000). Table 1 depicts the behaviourist educational procedure and the instructional events within this framework.

Table 1: Behavioural educational procedure

Behaviourist Educational Procedure	Behaviourist Instructional Events
• List specific objectives and learning outcomes. • Assessment must be based solely on these outcomes. • Break the course down into units. • Sequence these units according to the desired learning. • Present the rules for learning the units and their topics. • Ensure that learners respond and learn as planned by mastering the topics. • Provide opportunities for feedback. • Reinforce correct behaviour with immediate rewards.	• Call for and gain the learners' attention • State the objectives so they know what is expected • Remind learners of what has been learnt before • Highlight key features so they perceive what is important • Create a learning pattern • Promote learning events • Give opportunity for feedback • Evaluate assimilation progress and satisfaction • Signal future learning

Source: Carlile and Jordan, 2005

This behaviourist model is highly limited when there is need for deep learning, with learner identification, to foster creativity, initiative and originality and impact critical thinking and problem solving and other life skills.

Engineering education criteria are usually stipulated by recognized accreditors for engineering programs. Among the most respected accreditation organizations in the U.S., ABET (Accreditation Board for Engineering and Technology) provides leadership and quality assurance in engineering education (ABET, 2000). QAA (Quality Assurance Agency) does the same in the UK and has set Subject Benchmark Statements (SBSs) for engineering teaching and learning (QAA, 2007). So also have other bodies in other countries. The criteria and SBSs highlight the skills, qualities and attributes of an engineer (a graduated engineering student), and the criteria for engineering education curriculum content. They are usually a reference for academic review and evaluation of standards and outcomes for engineering education. Engineering students are expected to acquire and demonstrate these skills and qualities. The main expected engineering educational outcomes stipulated by ABET and corroborated by both QAA's SBS and others include the abilities to:

- Apply knowledge of math, science and engineering.
- Design and conduct experiments, analyze and interpret data.
- Design a system, component or process to meet desired needs.
- Function on multi-disciplinary teams.
- Identify, formulate and solve engineering problems.
- Understand professional and ethical responsibility.
- Communicate effectively.
- Understand the societal impact of engineering solutions, use the techniques, skills and modern tools necessary for engineering practice and engage in life-long learning.

Obviously, the behaviourist model is unsuitable for these current general requirements of engineering education despite building effective aspects of practice such as repetition, presenting strong and varied stimuli, planning, sequencing of learning events and objectives specification (Carlile and Jordan, 2005). Studies indicate that only 20 to 30% of life skills and competencies are acquired in schools, an indication of the accelerating ineffectiveness of the traditional ways of teaching (Wimmer, 2005).

The need for an educational framework that takes into account both the need for knowledge mediation and also the need to (know and) develop the whole personality of the learner has been the driving force for a paradigm shift from Lecture-Based/Teacher-Centred/Content-Delivery-based paradigm (Instructional Paradigm) to Student-Centred/Learner-Centred Paradigm, Learning Paradigm (OPA, 2007; Barr and Tagg, 1995). The learning paradigm, based on the cognitivist/constructivist learning perspectives, is for learning enhancement, fostering critical and sustainable thinking, promoting experiential learning and cognitive growth. The emphasis is no longer on teaching but on learning. Instructors are now required to not only change their use of the lecture time but lecture must be used in conjunction with other methods and techniques in order to facilitate learning (McCarthy and Higgs, 2005).

Cognition employs the concept of mental processing and focuses on the way that learners gain, view and organize knowledge (Wankat and Oreovicz, 1993; Carlile and Jordan, 2005). It emphasises development of intellectual skills which are the basic tools for design, analysis, discussion, evaluation, synthesis and problem solving generally. Constructivism, on the other hand, poses that people construct their own meaning from information by building on previous knowledge and experiences. Learners find individual meaning in situations based on different experiences and constructs of the world and reality which asserts learning autonomy (Carlile and Jordan, 2005). The instructor is no longer in charge of student learning, rather, the student is in charge of his/her learning with the teacher as a facilitator and mediator. The emphasis is not on accumulation of facts but on making meaning and understanding. This change in emphasis from teaching to learning has deep implications for teaching and assessment which suggests an intimate association as shown in Figure 1 (Felder and Brent, 2003). Changes or improvement in one may lead to reformation in all or any of the others.

This paper is focused on detailing this paradigm shift and the current and emerging strategies and tools for effective engineering education within the framework of the new paradigm. The aim is to help the engineering instructor, tasked with the production of globally competitive engineers, gain useful insights. The paper is also beneficial to the engineering student, the focal point of the discourse, whose familiarity with the term was found to be so poor that despite a University's student-centred policy, 60% of the students had not heard of the term (O'Neill and McMahon, 2005). In the final analysis, it is the instructors and students, working together to make the difference between excellence and mediocrity, that are the most directly able to actually improve learning (Cross, 1996). The introductory section describes the instructional paradigm and highlighted the paradigm shift to learning. Subsequent sections address the implications of the paradigm shift for assessment, instruction, the curriculum and the engineering laboratory education.

2.0 The Paradigm Shift: From Teaching to Learning

Universities' existed to provide instruction (the end or purpose), within the instruction paradigm, and corresponding structures were put in place to provide for the activity of teaching. Profoundly there is now a clear shift in purpose: to produce learning with every student (Barr and Tagg, 1995). Learning is holistic with knowledge as an interaction of inter-related parts. There is a huge amount of interwoven literature on teaching and learning with researchers using the various learning concepts interchangeably with varied definitions of learning. Honderich 1995 described learning as "the acquisition of a form of knowledge, ability or skill, through concept formation, involving mental process and the use of experience and practice", aptly captures the fundamental objectives of student-centred learning paradigm and clearly highlights the deficiencies of the content/teacher-based model of engineering education.

2.1 Student-Centred Learning (SCL)

The Student-centred learning paradigm seeks to improve the quality of learning through a redefinition of the learning environment, the roles of the instructor, the roles of the learner and the relationship among them" (Huntzinger, 2007). The emphasis is on participatory learning and understanding and increased responsibility and accountability on the part of the student (Lea, Stephenson and Troy, 2003). It advocates for reduction in the amount of lecture hours and an increase in problem-based activities and student independence and self-reliance with decreased reliance on instructors to provide answers to problems and questions. Students take responsibility for their own learning and the instructor takes the role of a facilitator, guide or mentor in the learning process. This is a significant departure from lecture-based learning which signifies a paradigm shift (Huntzinger, 2007; Barr and J. Tagg, 1995). Problem-Based Learning is a major student-centred teaching and learning tool which incorporates collaborative, active and experiential learning and has relevance in situated learning where learning is not only real-world based but a function of the activity, context and culture in which it occurs (Lave, 2007). SCL has been shown to be an effective approach to learning (Lea, Stephenson and Troy, 2003).

However, it is not entirely without criticism. It has been cautioned against allowing individual learning concepts to overshadow the learning needs of the entire class as a single body (Simon, 2005). Also, Students expect and may prefer instructor-centred learning due to their dualistic nature and secondary school experiences and therefore may not fully appreciate SCL. Studies show that students hold very positive views of student-centred learning as a feature of high quality education (Elen, Clarebout, Léonard, *et al.*, 2007; Lea, Stephenson and Troy, 2003). Instructors, on their own part, may see it as a breach of instructional tradition with the general feeling that nothing beats the traditional teacher controlled classroom (Wiersema, 2000). This is why adoption of SCL calls for a paradigm change in instructors' professional profile and change in conceptions. An instructor's conception affects both her activities as an instructor and the learning outcomes of the students. It has also been argued that SCL is mainly a Western approach and may not necessarily effectively transfer to countries in transition where there are limited resources, different learning cultures and large classes (O'Sullivan, 2003). This argument has been addressed by situated-learning in which knowledge is presented in an authentic context, i.e., settings and applications that would normally involve that knowledge and learners become involved in a "community of practice" that embodies certain beliefs and culture (Lave, 2007).

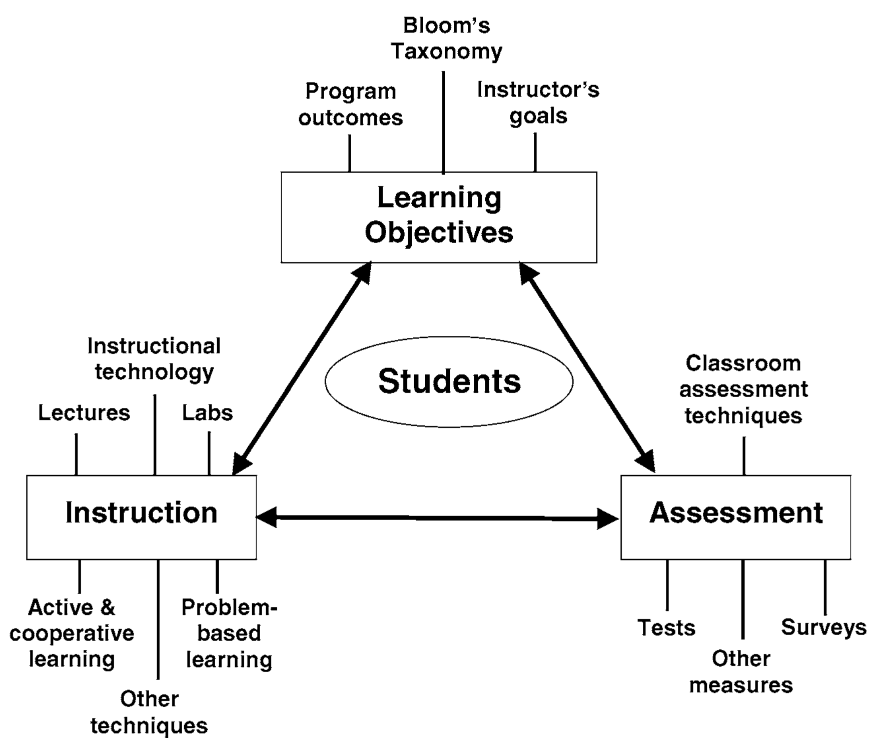

Figure 1: Elements of an engineering course (*Source: Felder and Brent, 2003*)

3.0 The Constructs of the Paradigm Shift

A number of strategies and tools have derived from specific instances of the paradigm shift. These tools have become the major instruments and integral parts of student-centred learning and range from problem-based learning to active-learning.

3.1 Problem-Based Learning (PBL)

PBL is about giving students repeated practice in formulating solutions to genuine real-life technologically and socially relevant problems, which is one of the best ways to inculcate the culture of lifelong learning (Felder and Brent, 2003). Learning results from working towards the understanding and resolution of a problem, where the problem is encountered first and students are forced to identify what they need to learn to solve the problem (Barret, 2005). Finding a solution to the problem requires students to think, reason, research, evaluate and engage in peer tutoring and self- and peer-assessment.

PBL originated from efforts to find an alternative to the traditional approaches of preparing medical students for future professional practice which was necessitated by the fact that medical professionals, like engineers, are often faced with new types of complex ill-defined problems requiring analytical and reasoning skills (Barrow and Tamblyn, 1980; Huntzinger, 2007). The main elements of PBL are the essential ingredients of student-centred learning as highlighted in Huntzinger, 2007 as:

- Students must take responsibility for their own learning.
- Problems should be ill-defined and allow for free inquiry by students.
- Problems must be multidisciplinary.
- Student collaboration should be encouraged in both group- and self-directed work.
- Students must constantly re-analyze problems as individuals and as a group.
- Students must reflect on what they have learned from the problem.
- Students must take part in self and peer assessment.
- Problems must have value in the real world.
- Student assessments must evaluate problem solving (and other) skills.
- PBL must be rooted in the curriculum, not episodic.

PBL has achieved widespread adoption and is so important that universities now facilitate PBL staff development initiatives (Barret, 2005; Huntzinger, 2007; Maricopa, 2007). Methods, approaches and initiatives for selected universities that have incorporated PBL into most or all of their undergraduate programs have been detailed (Huntzinger, 2007). A typical example is the application at the Colorado School of Mines where most undergraduates complete a projects course, specifically designed to harness the benefits of PBL, in six out of their eight semesters (Pavelich andMoore, 1996). The students work in teams on open-ended problems given to them by an industrial or government agency client while instructors mentor them through the experience. The project is reported to have yielded very satisfying results in meeting stipulated engineering education criteria. PBL application methods to address engineering education criteria have been articulated (Felder and Brent, 2003).

3.2 Collaborative Learning (CL)

This concept is usually confused with cooperative learning because of the overlap or inter-concept usage. Panitz (Panitz, 2007) has not only made a clear distinction between these concepts but has also given a clear and concise definition of CL. “Collaboration is a philosophy of (group) interaction ...not just a classroom technique. ... it suggests a way of dealing with people which respects and highlights individual group members’ abilities and contributions. There is a sharing of authority and acceptance of responsibility among group members for the group’s actions...” This is said to be distinct from cooperative learning, a classroom technique, in which students work in teams, with defined roles for each student, to accomplish a specific task at hand (Keyser, 2000), while each student is assessed individually (Prince, 2004). Cooperative learning is usually not an integral part of the curriculum, unlike collaborative learning. “Learning is enhanced when it is a (collaborative) effort... Sharing one’s ideas and responding to others’ improves thinking and deepens understanding” (Gerdy, 2007). A basic criterion is that a collaborative situation should be quite interactive to a certain degree which is defined by the extent to which the interactions influence the peers' cognitive processes (Dillenbourg, 1999). Measurements of the effects of collaboration indicate conceptual change, increased self-regulation, promotes learning outcomes and academic achievement and student retention (Dillenbourg, 1999; Huntzinger, 2007; Gerdy, 2007). The power of group work has also been demonstrated (Felder, 2004).

3.3 Active and Deep Learning (ADL)

Passive and Surface Learning (PSL) is enforced by the traditional lecture-based instruction. "Products of PSL may not effectively apply knowledge from learning unless the area of application is related to what has been lectured. The hallmark of a PSL product is lack of confidence and despondence in the face of problems, for failing to make learning an active endeavour" (McCarthy and Higgs, 2005).

This is a manifest of inherent problems of lectures: students' attention is inversely proportional to the lecture time; lectures promote surface learning of factual information. Learning is an active process (Carlile and Jordan, 2005). Active learning instructional approaches ensure students are involved in more than listening and are involved in "doing things and thinking (reflecting) about what they are doing" (Keyser, 2000). Active Learning activities enable tutors have a new role as facilitators, giving more responsibility to students and as shown in Figure 2, affords student a 75% retention rate.

The instructional strategies that promote active learning in engineering include simulations, student presentations, library/research assignments, problem solving, peer teaching, problem-solving exercises, writing tasks and homework. Details of these and so many other strategies are given in Felder, 2003b; Paulson and Faust, 2007; Bonwell and Eison, 2007; NTP, 2007; Drummond, 2007. The number of possible active learning tasks is limitless (Felder, 2003b). The activities to be used depend on the instructor and the objectives of the particular class. Some of these activities involve team work, trial and error or actual visits to industry (Keyser, 2000; Atara, Leung and Woon, *et al*., 2007). Instructors can utilize the opportunity of active learning to integrate writing activities, a key lifelong skill and reflection tool, into their teaching, in order to extend their thinking and meaning exploration. The idea is not to teach how to write but to promote writing as a tool for thinking, an essential ingredient of engineering practice (O'farrel, 2005).

Active learning has been included on a list of recommendations for teaching methods that work (Atara, Leung and Woon, *et al*., 2007; Felder, 2000; Niemi, 2002). It also has been proven to have positive effects of knowledge and skill acquisition (Felder, 2004). Felder, 2003b has suggested several techniques to make active learning as effective as possible.

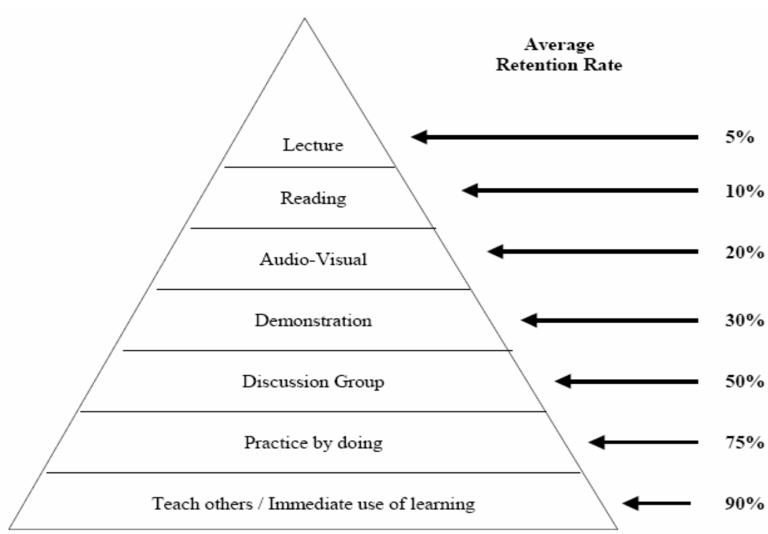

Figure 2: Learning Pyramid (*Sources: Barret, 2005*)

4.0 Consequence: The Need to Make Assessment Diagnostic

Assessment in education "describes any processes that appraise an individual's knowledge, understanding, abilities or skills" (QAA, 2006) and equates to testing in order to judge if learning has taken place (Niemi, 2002). Assessment is said to drive learning (GHEC, 2006; QAA, 2006). Traditionally, assessment may be formative or summative and uses triangulation to ensure validity and reliability (Besterfield-Sacre, 2000). There are diverse assessment practices and tools. The use of written examination is a strong traditional practice and the giving of mark is over emphasised while the giving of advice, mentoring and the learning function is de-emphasised (O'Neill and T. McMahon, 2005). Student-centred learning necessitates that assessment is more diagnostic in nature to enable the collection of data or evidence that provide educators with information they need to motivate and enhance learning. There is a shift from assessment for accountability to assessment for improvement (Cross, 1996). Instructors need to know what the students know and identify learning gaps. Classroom Assessment Techniques (CATs) (Kelly, 2005; Cross and Angelo, 1993a; Cross and Angelo, 1988), classroom research (Cross and Angelo, 1996), dynamic assessment (Mergel, 2007) and assessment of cognitive development (Wise, Lee and Litzinger *et al*., 2004), among others, provide such diagnostic data. Classroom assessment and classroom research are often used interchangeably but there are important differences between them. Classroom assessment addresses the status quo: what did students learn from the day's activities, what did they fail to understand or what did they have further questions about? Classroom research, on the other hand, attempts to answer questions having to do with understandings and attempts to provide insight into how students learn and is used to study learning (Cross, 1996).

4.1 Classroom Assessment Techniques (CATs)

CATs are teaching tools as well as assessment devices that aid the instructor to take a snapshot of the status quo and collect student feedback about their learning which helps answer the following questions (Kelly, 2005; Cross, 1996):

- What are students actually learning in the lecture / lab?
- How are the students progressing toward the learning objectives?
- Where are they having difficulties in learning?
- Have they missed any important point?
- What did they fail to understand?

The instructor is able to identify learning gaps. The most famous CAT is the Minute Paper which "requires students to stop and think about what they have learned, to synthesize and articulate an important piece of learning, to express themselves in writing, and to think actively about what they did not understand. It engages students in evaluating their own learning" (Kelly, 2005; Cross, 1996). It is simple and easy to administer and provides immediate feedback to both teachers and students about the "learning that is taking place— or not taking place — in any given classroom while it is still fresh in everyone's mind" (Kelly, 2005). The feedback of the Minute Paper is very informative. Feedback is probably the single most important ingredient in improvement (Cross, 1996; Davis, 1999). The Minute Paper is used in more than 400 classes at Harvard (Kelly, 2005). A Harvard Professor, Fred Mosteller, found it so useful he invented a version of the Minute Paper that he calls the Muddiest Point — an invitation to send a message to the instructor (Mostell, 1989). CATs afford students opportunity for self-assessment and teachers, opportunity for the development of scholarship of teaching (Kelly, 2005) (see Jarvis, Holford, and Griffin, 1950).

Other CATs tools include Background Knowledge Probe (BKP), Focused Listing (FL), Directed Paraphrase (DP), Memory Matrix (MM), Process Self-Analysis (PSA) and Diagnostic Learning Log (DLL) (Kelly, 2005). The BKP is used in probing student's prior knowledge or experience of the subject which provides information on variation in background of the class especially in a situation where a prerequisite subject is crucial. These assessment tools take a few minutes of lecture time either at the beginning or at the end. Some are more effective when done outside the class session but are all an integral part of the learning process. The frequency and type of CAT depends on the class, the subject, the learning objectives and what is to be diagnosed (Davis, 1999). The Cross and Angelo Handbooks (Cross and Angelo, 1993; Cross and Angelo, 1988) are a good reference for implementing CATs.

4.2 Student Development and Assessment of Intellectual Growth

Studies indicate that students' cognitive processes develop over time from simple black/white thinking to a more complex evaluation of alternatives as they learn (Jarvis, Holford, and Griffin, 1950). Quoting Felder (Felder and Brent, 2005), "…students enter college in what is referred to as a state of "ignorant certainty," believing that knowledge is certain, beliefs are either right or wrong only and the authorities (e.g., their professors and instructors) have all the answers and their job is to memorize those answers and repeat them on tests... As they gain experience, most (students) gradually progress toward a state of ... "intelligent confusion," in which they recognize that all knowledge is contextual, take responsibility for making their own judgments on the basis of evidence rather than relying on the word of authorities, and become relatively sophisticated at gathering and interpreting evidence from a wide range of sources. …This progression has been referred to as intellectual (cognitive or epistemological) development".

The most accepted and applied cognitive models are those by Piaget 1950 and Perry 1970. Piaget focused on child cognitive development while Perry focused on university students' cognitive development. Perry's scheme currently provides the framework for assessing cognitive development of learning. The scheme models nine developmental positions which are indicative of students' cognitive thinking and reasoning levels. Developmental assessment to probe the intellectual growth of students and provide information on the effectiveness of a subject, project or lab in promoting the intellectual growth of students. The Perry scheme has been used extensively in assessing the intellectual development of students and its application in engineering is described in a number of studies (Pavelich and Moore, 1996; Felder and Brent, 2005). A student's cognitive position is measured through an open-ended interview process and/or the use of psychometric instruments full details of which are available from The Centre for the Study of Intellectual Development and The Perry Network (http://www.perrynetwork.org/). The intellectual growth of students can be stimulated by challenges to their beliefs characterized by their current developmental levels (Felder, 2004).

5.0 A Consequence: A Paradigm Change of Instructors' Professional Profile and Strategies

The paradigm shift has extensive implications for instruction (teaching) and calls for a paradigm change of the instructors' professional profile and commensurate conception of teaching. Teaching is a skill that has to be cultivated as good grounding in the basics of one's own discipline alone does not make a good teacher. Teaching needs to be scholarly and like learning, should be collaborative, active and creative and needs to be organized around learning in order to be more learner-centred which requires "knowing" the learner (Turns, Atman and Adams, 2005). Students are said to differ in their learning styles; approaches to learning and orientations to studying; and intellectual development (Felder and Brent, 2005). There is a diversity of learning styles based on learner preferences, influenced by habits, past learning and individual strengths and weaknesses (Felder and Silverman, 1988; OPA, 2007). Different learner characteristics necessitate diversification of instructional strategies in order to achieve a high correlation between teaching and learning. Table 2 depicts restructured Felder-Silverman's (Felder and Silverman, 1988) widely cited dimensions of learning and teaching styles.

The teaching styles require different types of instructional technologies ranging from simple presentation systems to multimedia technologies and e-learning systems.

5.1 Instructional Technologies

E-learning systems and web-based and multimedia technologies offer many possibilities for innovation in teaching and have the potential to overcome the shortcomings of the traditional classroom. Instead of talking about things and allowing students use their

Table 2: Dimensions of learning and teaching styles

Preferred Learning Styles		*Corresponding Teaching Styles*	
Learning Style	*Stimulation Method*	*Teaching Style*	*Emphasis*
Sensory / Intuitive	Perception	Concrete/ Abstract	Content
Visual / Auditory	Input	Visual/Verbal	Presentation
Inductive / Deductive	Organization	Inductive/ Deductive	Organization
Active / Reflective	Processing	Active/Passive	Student Participation
Sequential / Global	understanding	Sequential/ Global	Perspective

Source: (Felder and Silverman, 1988).

imaginations, teachers use interactive animations to enhance learning. They comprise significant levels of simulation and animation that enable the teacher adopt motivating and stimulating teaching styles to cater for the diverse learning styles in order to positively meet the stipulated criteria and outcomes. They can enhance active student participation using live demos and provide mechanisms for presentation using pictures, block diagrams and simulated schematics to appeal to visual learners. The GUIs allow users to interactively change the behaviour (reconfigure) of the system to appeal to the active learner. The inductive learner has facilities to dynamically set parameter values and watch the varying results. The ability to provide an overview of large scale systems with links to detailed demonstration of underlying properties should appeal to the global and sequential learner. The sensory learner is accommodated through demonstrations and concrete examples of underlying concepts. Hence, multimedia technologies and e-learning systems provide powerful means of supplementing existing classroom instruction to address all types of learners and provide teaching styles to match any learning style.

Popular e-learning systems include SOAP, WebCT, BlackBoard and Learning Management System (LMS). There are also intelligent Tutoring Systems (ITS) that enable adaptive teaching and a number of software systems that are applicable in engineering education such as: MathCAD, MATLAB, and TK!Solver (Head and Fry, 1989; LeBlanc, 1991; Rogers, Helt and Lee, 1989; Ottia, 1996; Harbach and Wiggins, 1985). Symbolic algebra programs such as MAPLE, MACSYMA, MATHEMATICA, DERIVE and THEORIST may be used to teach calculus and may also be useful in engineering analysis and design (Baxter, 1988; Keedy, 1988; Lee and Heppler, 1990; Prudy, 1990). Computer Aided Design (CAD) programs such as ADAMS, ASPEN, NASTRAN, SPICE and pSPICE, are also tools for teaching engineering (Petouris, Humphries and Russell, 1994; Reifschneider, 2000). These programs are extremely powerful, specialized, and realistic. They can be used to work complicated problems in greater depth with reduced number of errors. However, they may be expensive to licence. A freely available e-learning system is Moodle, an Open-Source software, under the GNU public licence (McMullin, 2005). These software systems have proven to have beneficial effects on learning (Regan and Shephard, 2007; Zywno and Waalen, 2001). The extent of the use of e-learning environments in universities all over the world is difficult to determine but reports indicate that there are very significant advances in its use.

5.2 Collaborative and Creative Teaching

The educational system constitutes of interrelated or interactive parts that are handled by different educators. If every educator thinks only about his own subject or purpose, the system surfers and turns out to be a competition of parts (Good, 2003). Instructors are very good at their own disciplines, they know a lot about it but they need to understand that it's one part out of the whole system and therefore need to collaborate to integrate their thinking and efforts while being creative. Collaborative teaching "is an ongoing process whereby educators with different areas of expertise voluntarily work together to create solutions to problems that are impeding students success, as well as to carefully monitor and refine those solutions" (Flanagan, 2000). A number of Instructors take responsibility for planning, teaching, and monitoring the success of learners in a class. It is a process and not a specific service delivery model (Flanagan, 2000). Three approaches for implementing collaborative teaching have been proposed: team teaching, supportive learning activities, and complementary instruction. Complementary instruction requires that one instructor takes primary responsibility for teaching content material and the other(s) for teaching functional how-to skills so students can successfully understand and acquire skills from the content material.

Also, instructors are required to teach more creativity despite the fact that they feel they have no time to teach anything but the fundamentals and stipulated content. They can teach the stipulated content and yet be creative. They can get students to think in creative ways using mind mapping and encourage them to think by honouring and acknowledging the importance of their thinking. The "incubation model" (Good, 2002) is a good creative teaching tool. It is a three-stage model: content related observation activities; classroom fundamentals and content teaching; accommodation for the continuation of that learning, something that will connect them to additional learning or experiences in that field, or that will inspire them to pursue answers to curiosities that develop. Creative teaching can be applied anywhere and in any subject area.

5.3 Scholarship of Teaching

This is one of the emergent issues of student-centred learning which calls for a broader definition of scholarship to include the scholarship of teaching (see Benjamin, 2001; Boyer, 1990). "The current definition of scholarship is seen to be narrow and excludes areas of academic activity and productivity that are vital to the fulfilment of educational mission. According to this narrow definition, scholarship is demonstrated only by research and dissemination of new knowledge. For this reason, teachers are often not promoted if they do not engage in research" (Fincher, Simpson and Mennin, 2000). Teachers then give priority to research over teaching because teaching is not rewarded. Boyer's work (Boyer, 1990) is intended to correct this overemphasis on research and publication as the route to promotion and tenure. This rethink of the instructor reward system is in synchrony with student-centred learning and was on the priority list of about 88 percent of research universities and fifty six percent of the liberal arts colleges in America and was also a special program of the American Association of Higher Education (Kelly, 2005).

However, the questions is how to evidence, represent, evaluate, examine, publicly display, archive and reference the practice of teaching in order to conclude that a particular teaching has caused student learning to take place. How can learning be represented as an evidence of a particular effective teaching? It has to be made transparent, for public scrutiny, how learning has been made possible (Trigwell and Shale, 2004). This question is at the core of over a decade of discussions because criteria for evaluating scholarship in teaching needs to be defined before teaching can be assessed.

Evidence has to be presented to show that defined teaching standards have been met and that other related activities, such as advising, mentoring, developing curriculum and instructional materials, and educational administration have also been done in a scholarly manner (Fincher, Simpson and Mennin, 2000). The quest is to find a means of documenting and referencing teaching that is comparable to the archival functions of research (Lyons, Hyland and Ryan, 2007). Fincher, Simpson and Mennin, 2000 have proposed the kind of evidence that can be collected by educators to demonstrate if Glassick, Huber and Maeroff, 1997 scholarly criteria for instructors' roles have been met (see Table 3).

Meanwhile, teaching portfolio has become well established as the dominant form of archiving teaching and has been adopted in over 2,000 higher institutions in the US (Maclaren, 2005). The Call for changes in instructor reward system has also been stimulated in many other countries including Australia. The adoption in Irish universities was driven by seminar series and support of university administration and linkage with US universities, with emphasis on the "development of a statement of personal, individual teaching philosophy" (Maclaren, 2005). This requires self-reflection and reflective writing by teachers.

One implication of scholarship of teaching is that teachers will need to know more about how their students learn. This may require instructors to get professional qualifications in teaching and learning. Majority of engineering teachers have never had a formal course in education and the lack of necessity for it is often rationalized (Felder and Brent, 2003). This is the focus of development in the UK, with regard to scholarship of teaching, as against teaching portfolio in the US. "It is now compulsory, in most UK institutions, for new academic staff to obtain at least a postgraduate certificate in teaching and learning" (Maclaren, 2005).

6.0 Consequence: Redesign or Reform of the Curriculum

Fostering development among characteristically diverse students faced with an unprecedented choice of values, rapid changes in technology and a dynamic society with demand for new competencies presents a challenge to engineering faculties. Transforming an educational system to embrace student-centred learning in order to impact sustainable skills and thought equates to a redesign or reform of the curriculum. Redesign signifies a complete integration of the concept into the curriculum at all levels, as against "bolt-on" or "build-in", which affords an opportunity to redress problems entrenched in a content-centred, teaching-based engineering curricular (Huntzinger, 2007).

A learner-centred curriculum is intended to give students an increased sense of autonomy (O'Neill and McMahon, 2005). The overall aim is to provide a multi-dimensional curriculum that will help in developing multi-skilled individuals that can relate to the demands of their field within a dynamic social and economical environment (Kontodimopoulos, Cavouras. Kandarakis, 2004). Practice-based experiences should be integrated into every academic year of the curriculum and students recognized for their ability to work in teams to find optimal solutions to engineering design problems (see George and Catalano, 1999). The specific goals of such a curricular as highlighted in USF, 2005 and Huntzinger, 2007 will be to:

- de-emphasise the linear sequencing of courses and gradual spacing over a number of years and transform the educational experience of students.
- adapt the iterative revisiting of concepts in a "spiral" model.
- incorporate thread of process and product design concepts over the entire curriculum.
- introduce appropriate instructional methodo logical changes and assessment processes

Table 3: Kinds of evidence for the scholarship of teaching.

Criterion	Questions about an Instructor
Clear goals To what extent does the instructor . . .	• articulate clear, realistic, achievable goals/objectives that relate to the course/clerkship expectations and level of the learners? • appropriately sequence goals and objectives, and state them in the context of basic knowledge and/or important/current questions in the field?
Adequate preparation To what extent does the instructor . . .	• use accurate, current resources to develop the content of lectures? • select, synthesize, and interpret material matched to the level of the learners? • demonstrate command of basic concepts and current thinking?
Appropriate methods To what extent does the instructor . . .	• use methods that reveal the logic, organization, and relevance of the material? • match the quantity of material to audience level and allotted time? • use images, metaphors, analogies and examples that connect the subject matter to the students' experience and knowledge? • demonstrate responsiveness to learners' reactions during the presentation?
Significant results To what extent . . .	• do learners' narrative comments and ratings indicate that the lecturer achieved the goals and objectives of the presentation? • does learners' performance on comprehensive, cumulative examinations, demonstrate achievement of objectives? • does the lecturer model teaching techniques that are adopted/ adapted by other faculty members?
Effective presentation To what extent does the instructor . . .	• communicate to learners evidence of systematic application of one's intellect? • demonstrate enthusiasm and interest in the topic? • deliver the message with clarity and organization? • provide handout material matched to the goals and objectives of the presentation? • capitalize on the spontaneous occurrence of ''teachable moments'' during the presentation? • present difficult topics in ways that help students learn?
Reflective critique To what extent does the instructor . . .	• enhance his or her teaching skills through reading, discussion with colleagues, or participation in workshops? • seek and respond to feedback regarding his or her teaching?

Source: (Glassick, Huber and Maeroff, 1997) that effectively measure the progress towards educational goals. Traditional methods are not effective in measuring the new competencies, skills and intellectual development that SCL promotes.

- Address the most important challenges facing engineering education: attracting and retaining a diverse student body and providing an educational experience that builds confidence and enthusiasm in the student towards learning engineering principles and applications.

The thrust of the new curriculum will be a PBL-based structure centred on "design-build-test" experiences with focus on the experiences of the students as they progress from matriculation to graduation (USF, 2005). A major goal of such a curriculum is the preparation of students for the transition from student to practitioner. There should be clearly stated educational objectives and programme outcomes to address the educational objectives. The *program core*—"a set of courses in the program curriculum designated to address the knowledge, skills, and attitudes specified in the outcomes" (Felder and Brent, 2003) should be identified and *outcome-related course learning objectives* defined for each core. "A course learning objective is a statement of an observable student action that serves as evidence of knowledge, skills, and/or attitudes acquired in a course" (Felder and Brent, 2003). Felder and Brent, 2003 have highlighted examples of generally acceptable learning objectives. Also, outcome indicators and performance targets have to be defined.

Reforming a curriculum is not without its challenges. Student-centred roles take a time to develop and implement effectively. The increased workload for instructors and possible economic constraints of the institutions needs to be considered (George and Catalano, 1999). Also, misconceptions about the student-centred paradigm may seriously affect the curriculum reform project because of the challenge of understanding the new paradigm (George and Catalano, 1999). This understanding is necessary to guide curriculum reform. The faculty is the backbone of the reform approach. It is its duty to provide learner-centred environments (a major prerequisite), disseminate tools and methodology of the curricular and pedagogical changes to instructors and reward teaching. The student-centred curriculum reform approaches of a number of universities have been highlighted (Huntzinger, 2007).

7.0 Engineering Lab: The Virtual Lab as a Workable Alternative in Resource Constrained Environments

The value of lab experiences is widely acknowledged and physical experiments are indispensable for developing engineering skills. Basically, there are three types of labs: real lab (traditional lab), remote lab and virtual lab. All these lab types are computer mediated, the major differences being the degree of mediation and the psychology of presence (Ertrugrul, 2000). The real lab involves the physical presence of the user in the lab where all lab instruments are physically set up. The remote labs are characterized by mediated reality and are mainly for experimental monitoring and control. Throughout literature, the definition of Virtual Laboratory (VL) is inconsistent and confusing. Virtually every online teaching and learning environment is referred to as VL. However, in this context, we take VL to be software versions of the real lab where each experimental setup is implemented in software such that a personal computer can be used to take the place of an entire workbench full of measurement and test instruments. Each experiment from signal generation to experimental setup is implemented in software using a combination of objected oriented and graphical programming languages.

In a traditional engineering laboratory course, the students work through a series prescribed experiments, following instructions on equipment operation, experimentation, data collection and analysis. They then write and submit reports. This is behaviourist and not student-centred. Open ended experimental and specific objective problems that require students to take responsibility for everything from design to data analysis and interpretation/ conclusions will make the lab more student-centred with better learning results. This is assuming that students are already experienced in fundamental lab use and activities from early years (Felder and Brent, 2003).

However, it is not always possible to give students complete and genuine lab experience in situations constrained by very limited resources in the provision of laboratory hardware and infrastructure and/or where there is need for lab education, for large classes, with one laboratory stand. The research on virtual lab is focused, generally, on this great challenge: the need to give students laboratory experience that is as genuine as possible in resource constrained environments, despite the lack of physical contact with actual lab hardware and at the same time allow the teacher to use existing equipment and teaching materials. This has been demonstrated to be feasible and beneficial. A VL, based on Matlab and Simulink, for teaching power system dynamics and control at the undergraduate level was deployed for use in a number of countries in transition (Vanfreti, 2007). Favourable experiences of the use of the lab have been reported, an indication of VL as a workable alternative in resource constrained environments. There are numerous other VLs (Duarte, 2005; Ubar, Jutman and Kruus, 2006; Hakes, Zheng and Chen. 2000; Gopalan and Cartwirght, 2001) that can fulfil such a purpose. VL creation is and should be driven by need. Every implementation depends on the application, the designer and the tools used. No two implementations are exactly alike. However, the basic requirement is that every implementation should be functionally satisfying.

8.0 Conclusion

Universities have been and are still experiencing change. The paradigm shift in engineering education from lecturing to learning enhancement implies an embrace of student learning autonomy. This demands well-planned educational experiences that help all students to develop as independent thinkers and life-long learners with full cognitive maturity. A huge body of work on student learning has been developed from which we now better understand how teaching styles influence learning. We have much to add to that body of work based on which diagnostic assessment and cognitive research have given insights into the phenomenon of learning and students' intellectual development.

The level of our understanding of student learning as instructors can only be substantiated by willingness to adopt instructional practices that enhance learning. Problem-based learning (PBL) is an instructional method where real-life problems with technical and social implications are introduced at the beginning of the instruction cycle and used to provide the context and motivation for the learning. It is always active and usually collaborative. Instructors are strongly encouraged to embed more activities in their classes. The evidence and support for active learning is extensive and should stimulate faculty to think about teaching and learning in non-traditional ways.

Research efforts on enhancing student learning has seen emergence of the concept of scholarship of teaching. In reaction to this, universities are including criteria for assessing and rewarding teaching, as a scholarly endeavour, in their requirements for academic promotion. Lecturing staff are being asked to evidence and demonstrate how their teaching is scholarly. Teaching is scholarly when a teacher's work can be made public, peer-reviewed, archived and exhibit all other qualities of scholarship. This means instructors will need to change their understanding of the term and give equal priority to both student learning and research.

The international trend in student-centred curriculum reform is the writing of learning outcomes and objectives that focus on what the student will be able to do rather than content being covered by the instructor. Student-centred education, if properly implemented, yields superior outcomes compared to the traditional approach to higher education, including: increased motivation to learn, greater retention of knowledge, deeper understanding, and more positive attitudes.

However, for a proper implementation to be feasible, the basic requirements include:

- a paradigm change of the educators professional profile
- not only a pragmatic handling of decreasing resources but change in politics and organizational improvement to ensure that all stakeholders are convinced of the need for the necessary paradigm change.
- Change in personal attitude and contribution to active and collaborative intervention.

References

ABET Criteria 2000, Accreditation Board for Engineering and Technology, Baltimore, MD, http://www.abet.ba.md.gov. accessed May 12, 2007. ASEE, Washington, DC, 1990, pp 717

Atara, S., Leung, R., Woon, C. 2007, "'An Implementation of Active Learning and its Effect on the Quality of Student Learning', Innovations in Education and Teaching International", **37**(4), pp381-389.

Attia, J. O., "Teaching Electronics with MATLAB", http://fie.engrng.pitt.edu/fie96/papers/237.pdf, accessed March 24, 2007.

Barr, B. and Tagg, J. 1995, "From teaching to learning– A new paradigm for undergraduate Education". Change, Nov/Dec, 1995, pp 13–25.

Barret, T. 2005, "What is problem-Based Learning?", Emerging Issues in the Practice of University Learning and Teaching, G. O'Neill, S. Moore and B. McMullin (Eds), Dublin:AISHE, 2005, pp 55-66.

Barrow, H. and Tamblyn, R. 1980, Problem-based learning: An approach to medical education, Springer: New York.

Baxter, H. R. 1988, "Teaching electronics using an equation solver," Proceedings ASEE Annual Conference, ASEE, Washington, DC, pp 1857.

Benjamin, J. 2001, "The Scholarship of Teaching in Teams: what does it look like in practice?", Higher Educ. Research & Development, **19**(2), 200I.

Besterfield-Sacre, M. E., Shuman, L. J and Wolfe, H. 2000, "Triangulating Assessments: Multi-Source Feedback Systems and Closed Form Surveys," Proceedings, Frontiers in Education 2000, Kansas City, Missouri, October 2000.

Bonwell, C. C. and Eison, J. A. 2007, "Active Learning: Creating Excitement in the Classroom", The National Teaching & Learning Forum, http://www.ntlf.com/html/lib/bib/91-9dig.htm, accessed July 21, 2007.

Boyer, E. 1990, Scholarship Reconsidered. Priorities of the Professoriate, Carnegie Foundation for the Advancement of Teaching, Princeton, NJ.

Carlile, O. and Jordan, A. 2005, "It works in practice but will it work in theory? The theoretical underpinnings of pedagogy", Emerging Issues in the Practice of University Learning and Teaching, G. O'Neill, S. Moore and B. McMullin (Eds), AISHE, Dublin, pp 11-26.

Cross, K. and Angelo, T. 1988, Classroom Assessment Techniques: A Handbook for Faculty, Ann Arbor: National Center for Research to Improve Postsecondary Teaching and Learning, University of Michigan.

Cross, K. P. and Angelo, T. 1993, Classroom Assessment Techniques: A Handbook for College Teachers (2nd ed.), San Francisco: Jossey- Bass Publishers.

Cross, K. P. 1996, "Classroom Research: Implementing the Scholarship of Teaching", American Journal of Pharmaceutical Education, **60,** Winter 1996.

Davis, B. 1999, "Fast Feedback, In Tools for Teaching", Berkeley, California: University of California, Berkeley.

Dillenbourg, P. 1999, "What do you mean by collaborative learning?", In P. Dillenbourg (Ed) Collaborative-learning: Cognitive and Computational Approaches, Oxford: Elsevier, pp1-19.

Drummond, T. 2007, "Active Learning Strategies", Summaries of Best Practices in College Teaching.

Duarte, M. 2005, "The Intelligent Universal Laboratory (UVL)", 35th ASEE/IEEE Frontiers in Education Conf., Oct. 19-22, 2005, pp 1–6.

Elen, J., Clarebout, G., Léonard, R. 2007, "Student-centred and teacher-centred learning environments: what students think", Teaching in Higher Education, **12**(1), 105 – 117.

Ertrugrul, N. 2000, "Towards Virtual Laboratories: a survey of LabVIEW-based Teaching/Learning Tools and Future Trends", Int. J. Eng. Educ. **16**(3), 171-180.

Felder, R. and Silverman, L. 1988, "Learning and Teaching Styles In Engineering Education", Eng. Educ., **78**(7), 674–681.

Felder, R. and Brent, R. 2003, "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria"**,** J. of Eng. Educ., **92(**1), 7-25.

Felder, R. and Brent, R. 2005, "Understanding Student Differences", J. of Eng. Educ., **94**(1), 57-72.

Felder, R. 2003, "Random thoughts… Learning By Doing", Chem. Eng. Educ. **37**(4), 282-283.

Felder, R. 2000, "The Future Of Engineering Education II. Teaching Methods That Work", Chem. Engr. Education, **34**(1), 26–39.

Felder, R. 2004, "The Intellectual development of Science and Engineering Students 2. Teaching to Promote Growth", J. of Eng. Educ., **93**(4), Felder, R. 2004, "The Intellectual development of Science and Engineering Students Part 1. Models and Challenges", J. of Eng. Educ., **93**(4), pp 279–291.

Fincher, R. E., Simpson, D., Mennin, S. 2000, "Scholarship in Teaching: An Imperative for the 21st Century", Academic Medicine, **75**(9), 887-894.

Flanagan, B., "Collaborative Teaching 101", http:// www.vcld.org/pages/newsletters/ 00_01_spring/ coll_teach.htm.

George, D. and Catalano, K. 1999, "Transformation: From teacher-centred to student-centred engineering education", J. of Eng. Educ., Jan 1999.

GHEC (Gary Hargreave EIAT Consultanc Ltd) 2006, "An Introduction to Assessment", The Higher Education Academy HE in FE: Teaching and Learning, December 2006, pp2-30.

Gerdy, K. 2007, "If Socrates Only Knew: Expanding Law Class Discourse", http://www.law.byu.edu/ Lawyering_Skills/Section_9/ accessed July 20, 2007.

Glassick, C. Huber, M. and Maeroff, G. 1997, Scholarship Assessed—Evaluation of the Professoriate, San Francisco, CA: Jossey–Bass.

Good, B. 2002, "A Call for Creative Teaching and Learning: An Interview with Dr. Bee Bleedorn", J.l of Values, Issues, Experience and Collaboration, **4**.

Gopalan, P. and Cartwirght, A. N. 2001, "Java Enabled Opto-Electronic Learning Tools and a Supporting Framework", Amer. Soc. for Eng. Educ Annual Conf., 353-356.

Hakes, N., Zheng, Y., and Chen , J. 2000, "Development of an Online Analog Signal Processing Lab using LabVIEW", http:// spib.rice.edu/DSP2000/submission/SPE/papers/ paper055/paper055.pdf, accessed April 15, 2007.

Harbach J.A. and Wiggins, E. G. 1985, "TK! Solver in senior level design courses," Proceedings ASEE/IEEE Frontiers in Education Conference, IEEE, New York, 1985, pp 2.

Head, J. H. and Fry, D. W. 1989, "Solving intermediate-level classical mechanics problems using MathCAD," Proceedings ASEE Annual Conference, ASEE, Washington, DC, 1989.

Honderich, T. 1995, The Oxford Companion To Philosophy, Oxford University Press, Oxford.

Huntzinger, D. 2007, "Enabling Sustainable Thinking in Undergraduate Engineering Education", Int. J. Eng. Educ. **23**(2), 218-230.

Jarvis, P., Holford, J. and Griffin, C., The Theory and Practice of Learning, London: Kogan, 1998.

Keedy, H. F. 1988, "Introducing engineering software tools to freshman engineering students," Proceedings ASEE Annual Conference, ASEE, Washington, DC, pp 1142.

Kelly, A. 2005, "Do you know what your students are learning? (And do you care?)", In Emerging Issues in the Practice of University Learning and Teaching, G. O'Neill, S. Moore and B. McMullin (Eds), Dublin: AISHE, pp 77-86.

Keyser, M. W. 2000, "Active learning and cooperative learning: understanding the difference and using both styles effectively", Research Strategies, **17,** 35-4.

Kontodimopoulos, N. Cavouras, D., Kandarakis, I. 2004, "Upgrading the biomedical engineering undergraduate curriculum based on current trends in higher education" 26th Annual International Conference of the IEEE, **2,** 5184 – 5187.

Lave, J. 2007, "Situated Learning", http:// tip.psychology.org/lave.html, accessed July 01, 2007.

Lea, S., Stephenson, D. and Troy, J. 2003, " Higher Education Students' Attitudes to Student Centred Learning: Beyond educational bulimia", Studies in Higher Education, **28**(3), 2003, pp 321–334.

Lea, S., Stephenson, D. and Troy, J. 2003, "Higher Education Students' Attitudes to Student-centred Learning: beyond 'educational bulimia'?", Studies in Higher Education, **28**(3), 321 – 334.

Learning, http://www.city.londonmet.ac.uk/ deliberations/collab.learning/panitz2.html, Accessed July 05, 07

LeBlanc, S. E. 1991, "The use of MathCAD and Theorist in the ChE classroom," Proceedings ASEE Annual Meeting, ASEE, Washington, DC, pp 287.

Lee, T. and Heppler, G. R. 1990, "Algebra systems for enhancing the learning environment for control systems," Proceedings ASEE Annual Conference, ASEE, Washington, DC, 1990, pp 113.

Lyons, N**.,** Hyland, A. and Ryan, N. 2007, "Advancing the Scholarship of Teaching and Learning Through a Reflective Portfolio Process: The University College Cork Experience", http:/ /www.ucc.ie/ Teaching_and_Learning/, accessed

Aug. 16, 2007.

Maclaren, I. 2005, "New trends in academic staff development: Reflective journals, teaching portfolios, Accreditation and professional development", Emerging Issues in the Practice of University Learning and Teaching, G. O'Neill, S. Moore and B. McMullin (Eds), Dublin:AISHE.

McCarthy, M. and Higgs, B. 2005, "The scholarship of Teaching and its Implications for Practice", Emerging Issues in the Practice of University Learning and Teaching, G. O'Neill, S. Moore and B. McMullin (Eds), Dublin: AISHE, pp 5-10.

MCLI (Maricopa Center for Learning and Instruction) 2007, "Problem-Based Learning", http:// www.mcli.dist.maricopa.edu/pbl/ problem.html, accessed July 04, 2007.

McMullin, B. 2005, "Putting the Learning Back into Learning Technology", Emerging Issues in the Practice of University Learning and Teaching, G. O'Neill, S. Moore and B. McMullin (Eds), Dublin:AISHE, pp 55-66.

Mergel, B. 2007, "Instructional Design and Learning Theory", http://www.usask.ca/education/ coursework/802papers/mergel/mergel.pdf, accessed April 15, 2007.

Mosteller, F. 1989, "The Muddiest Point in the Lecture as a Feedback Device on Teaching and Learning", Harvard University, Derek Bok Center for Teaching and Learning, 1989. http:// bokcenter.fas.harvard.edu/docs/mosteller.html Accessed July 09, 2007.

Niemi, H. 2002, "Active learning—a cultural change needed in teacher education and schools", Teaching and Teacher Education, **18,** 763–780.

NTP (National Training Partnership) 2007, "Active Learning Strategies", http://www2.edc.org/NTP/ trainingdesign_activelearningstrategies.htm, accessed July 21, 2007.

O'farrel, C. 2005, "The Write Approach: Integrating Writing Activities into your Teaching, pp149- 157.

O'Neill, G. and McMahon, T. 2005, "Student-Centred Learning: What does it mean for students and lecturers?", Emerging Issues in the Practice of University Learning and Teaching, G. O'Neill, S. Moore and B. McMullin (Eds), Dublin: AISHE, pp 5-10.

O'Sullivan, M. 2003, "The reconceptualisation of learner-centred approaches: A Nambian case study", Int. J. of Educ. Development

OPA (On Purpose Associates) 2007, "Funderstanding: Behaviorism", http:// www.funderstanding.com/ behaviorism.cfm, accessed July 04, 2007.

Panitz, T. 2007, "A Definition of Collaborative vs Cooperative, http://www.city.londonmet.ac.uk/ deliberations/collab.learning/wiersema.html, Accessed July 12, 2007.

Paulson, D. R. and Faust, J. L. 2007, "Active Learning For The College Classroom", http:// www.calstatela.edu/dept/chem/chem2/Active/, July 21, 2007.

Pavelich, M. and Moore, W. 1996, "Measuring the effect of Experiential Education Using the Perry Model", J. of Eng. Educ., pp 287-292.

Perry Network, http://www.perrynetwork.org/

Perry, W. 1970, Forms of Intellectual and Ethical Development in the College Years, Holt, Rinehart and Winston, Inc., New York.

Petouris, P., Humphries, J. and Russell, P. 1994, "Computer aided design for teaching modern optics to electronic engineering undergraduates", Science, Measurement and Technology, IEE Proceedings, **141**(3), 171 – 176.

Piaget, J. 1950, The Psychology of Intelligence, Harcourt and Brace, New York.

Prince, M. 2004, "Does Active Learning Work? A Review of the Research", J. of Eng. Educ., **93**(3), 223-231.

Prudy, D. J. 1990, "Symbolic algebra in mechanical engineering," Proceedings, ASEE Annual Conference,

QAA (Quality Assurance Agency), Gloucester, UK. http://www.qaa.ac.uk , accessed May 12, 2007.

Regan, M. and Shepard, S. 2007, "Interactive Multimedia Courseware and Hands-on Learning Experience: An assessment Study", http://www-adl.stanford.edu/images/viamm.pdf, accessed April, 2, 2007.

Reifschneider, L. 2000, "Teaching Design for Manufacturability with Desktop Computer-Aided Analysis", J. of Industrial Technology, **16**(3), http://www.nait.org/jit/Articles/reif050300.pdf, accessed June, 18, 2007.

Rogers, D. A. Helt, J. L. and Lee, D. J. 1989, "Using "MathCAD" in introductory antenna analysis," Proceedings ASEE Annual Conference, ASEE, Washington, DC, pp 903.

Simon, B. 2005, Why no pedagogy in England? In

G. O'Neill and T. McMahon, "Student-Centred Learning: What does it mean for students and lecturers?", Emerging Issues in the Practice of University Learning and Teaching, G. O'Neill, S. Moore and B. McMullin (Eds), Dublin: AISHE, pp 5-10.

SIUMS (Southern Illinois University Medical School), http://www.pbli.org.

Trigwell, K. and Shale, S. 2004, "Student learning and the scholarship of university teaching", Studies in Higher Education, **29**(4), 523 – 536.

Turns, J., Atman, C. J. and Adams, R. S. 2005, "Research on Engineering Student Knowing: Trends and Opportunities", J. of Eng. Educ., Jan. 2005, pp27-40.

Ubar, R. Jutman, A. and Kruus, M., 2006, "Applets for Learning Digital Design and Test", IMCL Conf., April 19 – 21, Amman, Jordan, 2006, http://www.pld.ttu.ee/~kruus/ Applets_06.pdf, accessed April 15, 2007.

USF (University of South Florida) 2005, Chemical Engineering dept.

Vanfreti, L. 2007, "A comprehensive Virtual Laboratory for Teaching Power Systems Dynamics and Control at Undergraduate Level", http://www.ecse.rpi.edu, accessed March 17, 2007.

Wankat, P. and Oreovicz, F. 1993, Teaching Engineering, McGraw-Hill, (e-book), https://engineering.purdue.edu/ChE/ News_and_Events/ Publications/ teaching_engineering/index.html, Accessed June, 28, 2007.

Wiersema, N. 2000, "How does Collaborative Learning actually work in a classroom and how do students react to it?: A Brief Reflection", Mexico City, http:// northonline.sccd.ctc.edu/ eceprog/ bstprac.html#active, accessed July 21, 2007.

Wimmer, M. 2005, "Schooling in the Knowledge Society", Catalyst Conf., 15-17 Sept., 2005, Liverpool, Manchester, UK. http://www.catalystconference.co.uk/creative-teaching-and-learning, accessed July 10, 2007.

Wise, J. C., Lee, S. H. and Litzinger, T. 2004, "A Report on a Four-Year Longitudinal Study of Intellectual Development of Engineering Undergraduates", J. of Adult Development, **11**(2), 103-110.

Zywno, M. S. and Waalen, J.K. 2001, "Student Outcomes and Attitudes in Technology-enabled and Traditional Education: a Case Study", Global J. of Eng. Educ., **5**(1), 2001.