In this paper the authors draw on three sequential keynote addresses that they gave at Active Learning in Engineering (ALE) workshops in Copenhagen (2012), Caixos du Sol (2014) and San Sebastian (2015). The paper reiterates themes from those keynotes, namely, the philosophical and pedagogical underpinnings of Active Learning in Engineering Education, the scholarly questions that inspire engineering educators to go on improving their practice and exemplary models designed to activate the learning of engineering students. This paper aims to uncover the bedrock of established educational philosophies and theories that define and support active learning. The paper does not claim to present any new or innovative educational theory. There is already a surfeit of them. Rather, the aim is to assist Engineering Educators who wish to research how they can best activate the learning of their students by providing a readable, reasonable and solid underpinning for best practice in this field.

Keywords: active learning; engineering education; action research, problem and project based learning.

1. Introduction

Engineering educators, who have attended our pedagogical development courses over the past few decades, often ask why the books that they are directed to read are so verbose. Some of the questions they raise include: ‘Couldn’t they have said all that in some bullet points? Why do they give so many examples? Is there any real proof that what they say will really work? Why do they not use some graphic models?’ We acknowledge that there is a significant difference in the way that educationalists and engineers conduct research and write about their results. Both groups seek to understand phenomena and solve problems connected with them. But the phenomena and problems educational researchers focus on tend to involve people, whereas the focus for engineers is more often on things and effects. A good example of an educational research topic is whether or not the use of Problem Based Learning (PBL) pedagogy versus a traditional lecture and tutorial/laboratory approach results in better understanding and application of key concepts in an engineering course. Because people (lecturers and students) are involved and because you cannot teach the course in two different ways to the same cohort of students at the same time, the variables in such research are enormous. What measure of successful understanding and application would one use? Improved grades? That would be desirable but the educational researcher cannot prove, in the way an engineer can, that x causes y. Perhaps the improved grades are due to the quality of the
teacher, the students, or the examination itself, and not the type of pedagogy used. Engineers who do research in their own particular area of expertise, on the other hand, can often control for difficult variables. For example, a mechanical engineer studying the effect that speed has on the severity of a car crash, can use a controlled experiment with a test-crash dummy instead of a real human, and provide conclusive data on the damage that occurs to both the vehicle and the dummy. Because educational researchers have so many parameters to deal with they need to ‘triangulate’ their evidence, using both qualitative and quantitative data, to convincingly argue their case. In that sense they are like barristers who try to convince a jury (made up a cross section of society) that the conclusions they have reached are correct. And like barristers, educational researchers tend to expatiate. We use big words, like ‘expatiate’, and take our time coming to the point.

The other thing that bewilders many engineering educators, who turn to people like us for guidance on how to improve the learning outcomes of their students, is that there are so many educational theories. Education, as a discipline, has been around for millennia. Educationalists have developed theories and pedagogical models throughout that time. Aristotle (384-322 BC) had a theory that people learned best when they walked. His Athenian School was called the ‘Peripatetic School’ (from the Greek work meaning to walk). Incidentally, recent neurological discoveries are providing some evidence to support this theory. Socrates (c.470-399 BC) developed a pedagogical model based on carefully formulated questioning which drew out what the students themselves instinctively knew, so they became active participants rather than passive recipients in knowledge building. For a few thousand years his model has been known as ‘Socratic Dialogue’. Today it has been rebranded in educational science as ‘Substantive Conversation’. When you Google the former term you get 241,000 hits. When you Google the latter 20,800,000 hits. Even the term ‘substantive conversation lesson’ polls 9,250,000 hits. The trend to re-badge educational philosophies, ideas and models is common today. This may not be a bad thing but it is confusing to engineers and scientists who are quite clear that in their discipline they use the scientific method, which since the 17th century, has involved the formulation, testing, and modification of hypotheses via systematic observation, measurement, and repeatable experiments. Unfortunately, in an effort to compete with more established disciplines, educational science has spawned a plethora (big Greek word) of learning theories, research methods and pedagogical models. In order to establish a scholarly basis for Active Learning in Engineering Education in this special edition, we have decided to focus on the philosophers, researchers and pedagogical experts whose contributions have stood the test of time. For Pedagogical philosophy we turn to John Dewey (1859-1952); for research to Kurt Lewin (1890-1957); for learning theories we refer to Piaget (1896-1980), Vygotsky (1896-1934) and Bruner (1915-), all of whom espoused what is known today as a ‘constructivist theory of learning’, which places the learner centre stage while the teacher becomes ‘a guide on the side’. Finally we focus on two long standing pedagogical models, namely, experiential learning (ELT) and problem/project based learning (PBL). The latter (PBL) has been used in preparing students for the medical and engineering professions since the 1960s and 70s.

2. Philosophical underpinnings

One could argue that ‘active learning’ is a tautology. It is not possible to learn unless the brain or body is active in some way or other. Learning is an action, which results
in a discernible change in what we know, or can do, or value. Evidence that learning is an activity by nature can be found in the etymological origin of the word. The etymological roots of the word ‘learning’ go back to the activity of finding a track (see: Skeat, 1993). From the moment we are born, and perhaps even in the womb (Moon, Lagercrantz and Kuhl 2013), we are learning. Small babies are practising scientists, experimenting, developing and testing hypotheses. A child in discomfort cries out, and, usually, an adult responds. A pattern is tried and tested. It will be some time before this natural instinct becomes a more conscious and reflective activity but we are, undoubtedly, natural born learners (Lowen, 1977). Nobody teaches infants how to speak or walk. They learn by themselves, often with lots of help from those around them, but fundamentally by themselves. Learning to speak provides an instructive example of active learning. We need time, we need context, we need exemplars, we need mentors and we need practice. Babies coo and babble for about nine months and speak their first word around their first birthday. This is a huge learning curve. It will take another year to communicate in words and signs and then three more before the young child speaks normally. Parallel with that process and dependent on it, is arguably the most active learning period of the young human’s life. Most parents remember the insatiable curiosity of their young children; their inventiveness, their divergent thinking and creativity. An important thing to note is that although we are all natural born learners certain types of formal educational systems can get in the way of our curiosity, our creativity and, in some respects, learning itself. This is a point Ken Robinson makes in the most watched TED talk of all time – 35 million views and still counting (Robinson 2006).

Almost a hundred years earlier John Dewey made a similar point. Dewey was concerned that schooling was not activating the scholar’s natural ability to think scientifically. He argued that ‘that the native and unspoiled attitude of childhood, marked by ardent curiosity, fertile imagination, and love of experimental inquiry, is near, very near, to the attitude of the scientific mind’ (Dewey 1910, iii). He was concerned that traditional transmission methods of teaching, strictly set subjects and topics and a tendency to teach children to rote learn ‘facts’, was an educational approach that dulled the natural propensity of young learners to inquire, think reflectively, and apply new knowledge in novel situations. Dewey’s philosophy of education is often summed up in the misquoted mantra that ‘We learn best by doing’. There is no reference to that exact quote in his various works. What Dewey did say in his book *How we think* (1910) and restated in a later revised edition (1933) was that we learn by thinking reflectively about the perplexing problems, issues and actions that we experience. He argued that there are different types of thinking, but the variety of thinking that educators need to cultivate is the natural scientific thinking that is characteristic of humans from an early age. In 1938, Dewey published another small volume called *Experience and Education*, in which he provided us with a philosophical basis for active learning that we suggest is still relevant for engineering education today.

In his preface to the book Dewey writes: ‘those who are looking ahead to a new movement in education, adapted to the existing need for a new social order, should think in terms of Education itself rather than in terms of some ‘ism about education...’ (Dewey 1934, preface). The ‘isms that Dewey was referring to were educational traditionalism versus progressivism. The dichotomy between the two are still recognizable in university engineering education today. On the one side a structured, disciplined, didactic, ‘traditional’ education, characterized by lectures, tutorials and laboratory work, often assessed by closed book, end-of-course exams...
versus, on the other side, a problem and/or project based, student centred, flexible, ‘progressive’ education assessed by a mix of more continuous, formative and summative types of testing. We argued, in our Copenhagen address, that if a student’s learning experience can be enhanced by an excellent lecture, tutorial, laboratory exercise or well designed closed-book exam then that approach could qualify as an excellent learning experience. The same would be true of a well-designed problem or project based engineering curriculum, taught in spaces designed for that approach by motivated facilitators with knowledge and training of that approach. As Dewey himself points out: ‘The belief that all genuine education comes about through experience does not mean that all experiences are genuinely or equally educative’ (Dewey 1938, 13). The key word is ‘experience’ and it is this term that forms the bedrock of Dewey’s philosophy. Dewey uses two criteria to help define a genuine ‘educative experience’. The first of these criteria is continuity. The second is interaction. The first focuses on the subjective experience of the individual learner while the second takes into account the interaction that occurs between the individual’s subjective learning experience and the external conditions under which that experience occurred.

Dewey returns to the example of a child who learns to speak to explain the above mentioned criteria. Subjective experience, he argues, leads to ‘a new facility and a new desire’ in the child but also widens the external conditions of any subsequent learning. The child’s first word, for example, and the rewards it can trigger are a powerful impetus to learning new words. But it also means that those who nurtured that extraordinary breakthrough may now need to change the way spoken language is modelled if the child is to continue to develop. The criterion of continuity is important, primarily because ‘every experience affects for better or worse the attitudes which help decide the quality of further experiences’ but also, to some degree, because it should help determine ‘the external conditions under which further experiences are had’ (Dewey 1938, 29-30). Included in the external conditions that Dewey mentions is the educator, whether it is the parent of a child or the lecturer/facilitator in charge of students in an engineering course. Boring lectures and bad problem based learning projects given by ineffective lecturers or project designers, will dull the learner’s experience, just as good ones will enhance it. Both learner and teacher have their own earlier experiences of learning to draw upon. An exception is the teaching-learning paradox, which suggests that bad teaching can motivate students to (over) compensate and consequently they learn more than expected.

However, educators should be more mature and more capable of directing the learners’ current and continuing experiences. Educators need to recognize that ‘Every experience is a moving force’ (Dewey 1934, 31) and use their greater maturity to help organize the conditions upon which effective learning depends if the learners are to get the utmost from each new educative experience. Their job as teachers is to be sensitive to the individual learners in order to help render their experiences as positive and fruitful as possible. Doing this for a single child in one’s own home can be instinctive. Doing it for a whole group of engineering students, already exposed to by many years of formal education, takes talent, training, theoretical knowledge and a love of the art and science of teaching. In summing up this section we argue that Active Learning in Engineering education can be defined as the ‘intelligently directed development of the possibilities inherent in ordinary experience’ (Dewey, 1934) and as an inquiry based education that distributes the responsibility for learning between the individual student, the group and the teacher/facilitator. We provide practical examples of how this is done when we look at models that have been evolved in line
with Dewey’s philosophical principles.

Special mention in this respect should go to the US psychologist Carl Rogers. Renowned for his contributions to psychotherapy, establishing client centred therapy, Rogers also expressed opinions on learning and education stressing the importance of personal involvement and the principle of self-directed learning. Based on his own experiences he states: “I have come to feel that the only learning which significantly influences behavior is self-discovered, self-appropriated learning.” (Rogers, 1961, p. 276). In general Rogers claims that significant, meaningful, experiential learning is self-initiated (Rogers 1969 p.4).

3. The Scholarship of Teaching and Learning (SoTL) and the use of Action Research (AR)

At the Caixos du Sol, Brazil, in early 2014 the authors used their interactive keynote session to help the ALE participants focus on ways of implementing research into their own teaching and learning practice. Participants were asked to write down an issue, problem or question related to their teaching that they wanted to investigate. They then worked in small groups to refine and categorize their research questions. In the plenary session that followed the most representative questions were addressed, the data needed to answer the questions specified, the methods of collecting that data exemplified, the methodology underpinning those methods identified, and the theoretical perspective, epistemology or philosophy that provided the basis for the whole process determined. A consensus was reached that Action Research (AR) was a simple and straightforward methodology for Engineering Educators interested in pursuing their own Scholarship of Teaching and Learning (SoTL).

It is now a quarter of a century since Earnest Boyer published his beautifully written and cogently argued special report for the Carnegie Foundation for the Advancement of Teaching. He called his report Scholarship Reconsidered. Priorities of the Professoriate (Boyer, 1990). He argued that the importance of publishing research articles in an academic’s own discipline in terms of gaining tenure and promotion had increased over time. Boyer contrasted two national surveys undertaken by the Carnegie Foundation for the Advancement of Teaching in 1969 and 1989 which asked academics in a range of different tertiary institutions to respond to a statement that read: ‘In my department it is difficult for a person to achieve tenure if he or she does not publish’. The percentages responding ‘Strongly agree’ are represented in the table below:

<table>
<thead>
<tr>
<th>Responses</th>
<th>1969</th>
<th>1989</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total faculty response across all institutions</td>
<td>21%</td>
<td>42%</td>
</tr>
<tr>
<td>Research or doctorate granting universities</td>
<td>27%</td>
<td>71%</td>
</tr>
<tr>
<td>Comprehensive university or liberal arts college</td>
<td>6%</td>
<td>42%</td>
</tr>
</tbody>
</table>

Another 25 years on, in 2014, the Higher Education Research Institute (HERI) surveyed US Faculty about ‘Differences in Scholarly Productivity by Academic Rank, Institutional Type, and Sex’. That survey showed that academics in doctorate granting
universities still valued discipline-based scholarship more than their colleagues in comprehensive universities and liberal arts college, but that the need ‘to publish or perish’ had continued to grow no matter what type of tertiary institution an academic taught in (HERI 2014, 9). The survey also showed that higher scholarly productivity was aligned with seniority in rank and male gender.

What Boyer was concerned about was the narrow definition of scholarship and the way in which academics were encouraged to separate their teaching and research duties. At Caixos du Sol we argued that despite recent rhetoric from university leadership about the equal importance of teaching and research in the pursuit of academic promotion the latter held a privileged place. The result of this was that academics often felt compelled to ‘get their teaching out of the way’ so that could concentrate on what mattered in terms of their career – publishing in what was often a very narrow field in their chosen discipline. We believed strongly that specialist studies can inform and strengthen one’s teaching but also, that the opposite was true. If academics approach their teaching and learning duties in a scholarly manner teaching can inform, broaden and benefit research and research publication. Boyer’s ground-breaking paper has changed the way that many academics view the nexus between their teaching and research and encouraged many to investigate the effectiveness of how they teach in an organised and scholarly manner. It would be over optimistic to claim that scholarly research into pedagogical aspects of a lecturer’s practice has attained the same status as discipline based scholarship or that it is rewarded in the same way by universities. Nevertheless Boyer has given SoTL visibility, credibility and academic dignity and although there are still conflicting interests at the personal and professional level that hinder its widespread adoption by university faculty, it can be used as a guiding principle and practical model for engineering educators who wish to investigate the best ways of promoting active learning in their area.

SoTL has been defined differently since Boyer’s ground breaking book. Two of the more succinct definitions are: ‘Systematic reflection on teaching and learning made public’ (McKinney, 2003) and ‘On going learning about teaching and the demonstration of such knowledge’ (Kreber and Cranton 2000). Shulman (2001) says, in the same vein, ‘SoTL shares established criteria of scholarship in general, such as that it is made public, can be reviewed critically by members of the appropriate community, and can be built upon by others to advance the field’. The following diagram gives a more detailed picture of the process.
In discipline-based research one can use a variety of different methodologies, many of them are endemic to the discipline itself. Educational researchers have a wide range to choose from whereas research in engineering often relies on the scientific method. Participants at the 2014 Caixos du Sol conference agreed on the use of AR as a suitable research model for engineering educators who wish to do research on Active Learning in Engineering Education. Action research ‘is an outgrowth of the traditions of John Dewey and Kurt Lewin’ (Argyris, Putnam, and McLainSmith 1985) although it is Kurt Lewin who is credited with naming and defining this method in his seminal article on ‘Action research and minority problems’, which was published in the 1946 edition of the *Journal of Social Issues* (Lewin 1946). Lewin had a personal interest in minority issues since he himself had been forced to flee Nazi Germany in 1933. Lewin was a socialist whose theoretical position was influenced by the Frankfurt School and critical theory. In the US he consolidated his position as a significant figure in the area of psychology by becoming one of the founders of social psychology and a pioneer of organizational development, group dynamics and force field analysis. At the time of his death in 1947 he was Professor in charge of the Research Centre for Group Dynamics at MIT. Dewey and Lewin had met on a couple of occasions and agreed on the importance of applied research and the principles of ‘progressive education’. Lewin’s motto was ‘No action without research; no research without action’ and declared that ‘Research that produces nothing but books will not suffice’ (Adelman 1993, 8).

AR research is a spiral process, where one cycle leads to another (Lewin, 1946, p 38). It is also aims at the improvement of economic and social issues (including education issues and problems) and because of that does not pretend to be completely impartial or objective as most other methodologies did in 1946. In his article Lewin argued for a type of research that compared the conditions and effects of various forms of social action, and research leading to social action’ (Lewin 1946, 42). His method gained popularity among researchers in the 1960s when government intervention made money available for social change projects. Between the 1970s and 1990s there were a number of advocates for educational action research including scholars such Argyris and Schon (1978), Stenhouse (1980), Carr and Kemmis (1986), Michael Christie & Erik de Graaff (2017) The philosophical and pedagogical underpinnings of Active Learning in Engineering Education, European Journal of Engineering Education, 42:1, 5-16, DOI: 10.1080/03043797.2016.1254160
McKinnif (1988) Fletcher (1988) and Elliott (1991). These authors argued for its inclusion as a mainstream research method. Despite the variety of action research types that exist today, the fundamental principles established by Lewin have not changed. As figure 2 below shows, AR involves a spiral of steps, where each step is composed of a cycle of planning, action, fact finding and participatory reflection or evaluation. The spiral starts with a problem or situation that needs improvement (Lewin 1946, 37) which leads to planning for change, an intervention during which data are collected followed by an evaluation where the data is analysed and recommendations for change outlined. This concludes one cycle of action research. If the changes are not completely satisfactory a new cycle can begin and the research process enters another spiral of steps (Lewin 1946, 38).

![Action research spiral](image)

Figure 2: Action research spiral (Source: Garrote, R., 2015)

Action research is collaborative by nature since actors within the situation are not only ‘objects’ of research but also the ones who will enact the new procedures that the research shows are important to improve their situation. For Lewin, who studied organizational and attitude change, active participation by both researchers and participants was a key element in his methodology. A high degree of collaboration is what more recent researchers call ‘core action research’ (Coghlan and Brannick 2010; Zuber-Skerrit and Fletcher 2007). There can be, however, varying degrees of collaboration. Action research in education, for example, has a high degree of collaboration (McNiff 1995; McNiff and Whitehead 2005; McNiff and Whitehead 2009; Whitehead and McNiff 2006).

4. The use of Learning Theories and Pedagogical Models in promoting Active Learning in Engineering Education

Although we have a similar aversion to ‘isms’ as Dewey did, one could argue that the development of learning theories over the last hundred years of can be summed up by three ‘isms’, namely, behaviourism, cognitivism and constructivism. Behavioural psychologists such as Pavlov (1849-1936), Thorndike (1874-1949), Watson (1870-1958) and Skinner (1904-1990) developed behavioural theories and Skinner’s work, in particular, was influential in educational circles. Following World War 2 cognitive psychologists built on earlier criticisms of behaviourism in order to argue that there was more to learning than stimulus and response. Jean Piaget (1896 – 1980) whose work, like that of Vygotsky (1896-1934) became known outside of their own countries from the 1960s on, are today recognised for their theories of cognitive development (Piaget) and social development (Vygotsky). Together with Jerome Bruner (1915-) they have made major crucial contributions to constructivism as an epistemology and learning theory. Piaget has highlighted that there are stages in a young learner’s development; Vygotsky stressed the importance of a socio-cultural context for learning and the degree to which learning can be facilitated with and without help from a
mentor; and Bruner, drawing on Vygotsky’s work, argues for the need to scaffold learning in well designed social settings in order to increase its effectiveness. These ideas have become important both in the preparation of teachers for primary and secondary education and in curriculum design.

Higher education has been less susceptible to change and is still largely characterized by a traditional pedagogy based on lectures, tutorials and end-of-course tests. A major problem with a poorly conceived ‘traditional’ pedagogy at the tertiary level is that it can encourage students to take a surface rather than a deep approach to their learning (Marton and Säljö 1975; Entwistle and Ramsden 1983; Marton, Hounsell, and Entwistle, 1984). If learners are encouraged to rote learn and assessed on a limited range of Bloom’s taxonomy even very intelligent learners may decide to take a surface approach if it delivers the sort of grades they are aiming at. After forty years of educational research the question of why so many students take a surface approach to their learning, according to Haggis, ‘appears to remain largely unanswered’ (Haggis, 2009, p. 378). Constructivism, which has helped shift the emphasis in formal educational systems from a focus on the teacher to various forms of student centred learning, has provided a basis for a number of pedagogical models. In this section we choose to highlight two that have had considerable impact on the promotion of active learning in Engineering Education.

The first is Experiential Learning Theory (ELT) while the second is commonly known as problem or project based learning (PBL). The main proponent of ELT is David Kolb who built on the work of Dewey, Lewin, and Piaget (Kolb 1984). Kolb argues that Dewey’s philosophical pragmatism, Lewin’s social psychology and Piaget’s developmental learning theory provide the basis for a model of learning that recognizes how learning occurs. The model is represented in the following diagram:

![Kolb's Learning Cycle Diagram](image_url)

Figure 3: Kolb’s learning cycle. Source: Kirk & Thomas, 2003.

In keeping with Dewey’s philosophical position, the model places concrete experience at the beginning of the cycle. What we have argued in our keynotes at three successive ALE conferences is that there is a tendency in engineering education to begin with abstract conceptualization. Concepts are often are ‘transmitted’ in lectures to the learners who are then expected to deepen their knowledge, understanding and skills in laboratory and tutorial work. The problem with this model is that if the lecture is not interactive lecturers have no real way of telling if students understand what they are explaining. All components of the traditional model need to be of high quality if students are expected to understand and apply the concepts presented to them (Kolb and Boyatzis 2000). Experiential learning and variations of it, such as Experience...
Based Learning (Boud, Cohen, and Walker 1993), are premised on five assumptions, namely, that (i) experience is the foundation of, and the stimulus for, learning; (ii) learners actively construct their own experience; (iii) learning is a holistic process; (iv) learning is socially and culturally constructed; and (v) learning is influenced by the socio-emotional context in which it occurs (Boud, Cohen, and Walker 1993).

The second model that we suggest as a means of activating learning in engineering education is PBL. Engineering, Medicine and Economics are rather conservative disciplines so it comes as a surprise that they have championed two of the most influential pedagogical models to have emerged in Higher Education in the last half century. Although the opportunities to transform traditional pedagogies in Higher Education have existed for some time now (Baran 2013) the lecture and tutorial system in social sciences, and lectures supported by practical laboratory work in the natural sciences, persists. High quality traditional pedagogy can deliver excellent results, especially for students who take a deep approach to their learning, but when the quality is not high and lecturers encourage surface rather than deep approaches to learning, both the system and the students within it can fail. PBL, as an alternative system, has the capacity to revitalize and enliven higher education and provide authentic assessment for real life learning. For the purposes of this paper we use the abbreviation PBL to refer to both problem and project based learning because, as we pointed out in the text of our recent keynote address, they complement and enrich one another (Christie and de Graaff 2015).

In essence these two pedagogical variations of the PBL model have been around for thousands of years. Both Confucius and Socrates (c 500 and 400 BC) believed in stimulating learning rather than transmitting information. Socrates is famous for his dialogues that began with a problem and forced students to think, question and seek solutions. Confucius gave his students one quarter of a puzzle and if his students could not come back with the other three quarters he did not go on with the lesson. One of the earliest and best known varieties of PBL is the form that was introduced in the Faculty of Health Sciences at McMaster, a Canadian University, in 1969. It was soon adopted elsewhere including the medical faculties at the University of Limburg in Maastricht, Holland, the University of Newcastle, Australia, and the University of New Mexico in the United States. About the same time Project Based Learning was developed in Roskilde and Aalborg in Denmark (Graaff and Kolmos, 2007). Today PBL is a worldwide phenomenon in higher education.

As is often the case, ‘followers’ of a new educational model can become more dogmatic about its practice than the founders (Christie 2005). In 1996, nearly thirty years after the PBL movement started, Camp was concerned that ‘true PBL’ was being watered down (Camp 1996). She insisted that unless PBL was ‘active, adult-oriented, problem-centred, student-centred, collaborative, integrated, interdisciplinary and utilized small groups operating in a clinical context’ it should not be called PBL. She did, correctly, point out that if a PBL program was ‘teacher-centred’ rather than ‘student-centred’, the heart of ‘pure’ PBL would be lost (Camp 1996). Although very few would cavil with the latter sentence there were many who objected to Camp’s ‘purist’ approach. Ranald Macdonald (2001) and Savin-Baden (2000) both argued that PBL is an approach that should be characterized by ‘flexibility and diversity in the sense that it can be implemented in a variety of ways in and across different subjects and disciplines and in diverse contexts’ (Christie 2005). Boud and Feletti (1980,) have stressed that although the main principle behind PBL is that the starting point for learning should be problem, a query or a puzzle that the learner wishes to solve, an effective PBL approach needs high quality input from the PBL facilitator. We argue,
along with Camp’s critics, that there can be a number of approaches and variations in the practice of PBL. Today a large number of disciplines use PBL, in various shapes and forms (Kolmos and Graaff, 2014).

Engineering educators who promote PBL argue, as the McMaster staff did, that good pedagogical models should emulate the way practitioners work in their own field. Doctors diagnose medical problems and try to find remedies. Engineers design, build and test products. It is the nature of PBL to adapt to different settings, cultures, curricula and circumstances. Camp did everyone a favour by clearly showing that PBL has its theoretical origins in the conceptual work of adult educators like Malcolm Knowles (1980), a constructivist epistemology (Savery and Duffy 1995) and in the psychological principles of learning (Norman and Schmidt, 1992). Having an epistemological and psychological basis for PBL is important but turning it into a dogma is dangerous. PBL should not become a straitjacket for educators. It is a practical, pedagogical paradigm, robust enough to be adapted by a range of disciplines and for a variety of purposes. Both Problem and Project Based Learning enable educators to prepare their students for their future professional life as opposed to simply being able to pass exams.

In Engineering a particular form of Project Based Learning that has gathered momentum over the last 25 years is CDIO. The abbreviation stands for Conceive, Design, Implement and Operate and started as a curriculum project at Massachusetts Institute of Technology (MIT) in 1997. Since then it has grown into a worldwide movement in Engineering Education. CDIO and has just held its 10th international conference (Barcelona, 2014) and has published a second edition of the CDIO book which outlines its principles and practice. It is now spread across a number of countries and is practised in 107 different Engineering Schools. The table below taken from the CDIO website provides a useful overview.

Figure 5: CDIO development taken from the official CDIO website.

PBL has become influential enough to affect the architectural layout of many schools. A good example is the case of Aalborg University, which has practiced Problem Based, Project Organised learning since 1974 (Graaff and Kolmois, 2007) In
Aalborg the physical layout of the learning spaces (project rooms) throughout the entire campus is suited to this particular brand of PBL. We argue that the variations of PBL, that we mention above, complement each other. Problem based learning, may begin with an issue or problem that the students need to solve or learn more about. Loosely defined problems are often selected to ensure that the scenario or case study, if that is the format, which is used, simulates real life complexities. However, in some instances students are presented with authentic problems from practice that need to be solved. Project based learning tends to focus on the creation of a product or an artefact as a goal. Some tasks require field experience in an actual workplace in other situations tasks can be simulated. Higher Education traditionally tends to default to pen and paper exams when it comes to assessment. Both problem and project based learning emphasize performance based, authentic assessment that can be reported on in a variety of ways.

5. Conclusion
A decade ago the National Engineering Education Research Colloquies, with support from the National Science Foundation, developed a blueprint for the sort of research that was necessary to prepare US engineers so that could become effective collaborators and industry leaders in a rapidly changing world. The EERC identified five research areas for what they claimed was the ‘new discipline of Engineering Education’. They were: Engineering Epistemologies; Engineering Learning Mechanisms: Engineering Learning Systems; Engineering Diversity and Inclusiveness; and, Engineering Assessment (EERC, 2006). In this paper we have revisited ideas, theories and models that we presented in a series of interactive keynote addresses at the last three ALE workshops. Our focus has been on engineering learning mechanisms and systems and our intention has been to assist engineering educators, who are already busy with teaching, research in their discipline area, administration and engagement, to become involved in the scholarship of their own teaching and learning. As social scientists, who have worked for many years in engineering universities we are aware that the gap between the sciences and humanities, which C. P. Snow spoke about his 1959 Rede Lecture, still exists to some degree. Snow had been provoked by comments about how poorly read many scientists were and responded by saying:

A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity at the illiteracy of scientists. Once or twice I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is the scientific equivalent of: Have you read a work of Shakespeare’s? (Snow, 1959)

We began this paper by emphasizing how important it was to understand that scientists and educationalists have very different ways of investigating an issue or problem. We believe that it is counter productive to burden engineering educators with a whole new ‘culture’ of methodologies and models in the scholarly investigation of their own teaching and learning. Our hope is that by providing the philosophical and pedagogical underpinnings of active learning in engineering education we will both simplify the process and encourage educators in this field, to not only carry out research into the best ways of activating learning among their own students, but also publish their results so that their colleagues can benefit from their successful

interventions. The EERC was adamant that the rapid pace of engineering innovation created a need for engineers to continually learn about and exploit the capabilities of new discoveries and, because of this, engineering education needed to be transformed. The EERC argued that ‘This implies creating formal or informal learning experiences in a variety of settings (e.g., classrooms, laboratories, exhibits, synchronous and asynchronous on-line activities) that are more motivating, more engaging, and address the needs of a diverse group of learners’ (EERC, 2006, 4). We agree wholeheartedly with their conclusion and suggest that in order to implement it engineering educators need to implement, research and publish effective ways of promoting active learning in engineering education. We hope this paper will help them do that.

References
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