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A FRAMEWORK TO DEVELOP LIFELONG LEARNING AND TRANSFERABLE SKILLS IN AN ENGINEERING PROGRAMME

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Abstract: Engineering programmes have a strong reputation in the delivery of technical knowledge and skills. Graduates need equally high levels of competence in personal and professional skills to not only meet the existing requirements of employers and professional bodies but to also help them manage the inevitable changes that society is facing in an increasingly populated world. The need to move from traditional to student-centred learning is discussed in the context of engineering education. The use of group-based, problem driven learning facilitates high integration of technical and non-technical knowledge and skills and requires more engagement with the programme from today's student. Personal skills should be developed from a low base in a progressive, structured manner over the entire programme. A framework is presented to help those in curriculum design to develop learning, teaching and assessment methods that are in alignment with the delivery of all the intended learning outcomes in an accredited engineering programme. Through the use of group-based pedagogies, the student is required to develop a basic understanding of group collaboration skills and self-directed learning in the first year. As these are enhanced in the subsequent years, increasing attention is paid to other personal knowledge and skills such as critical thinking, creativity and awareness of ethics. High levels of direction from the tutor fade over time as the students become more competent at managing learning.

Keywords; symposium, engineering education, transformation, unsustainable, society, international.

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1. INTRODUCTION

"The world we live in demands self-starting, self-directing citizens capable of independent action. The world is changing so fast we cannot hope to teach each person what he/she will need to know in twenty years. Our only hope to meet the demands of the future is the production of intelligent, independent people" (Combs 1972 as cited in Candy, 1991).

The changes in society and environment since the industrial revolution are remarkable in scale and pace. The improvements in healthcare, education and lifestyle, predominantly for those in the western world, are an amazing achievement but have come at a price. A peak in the supply of oil that helped facilitate this transformation during the last century is imminent. Air pollution, global warming, groundwater shortages and contamination are major international problems. Yet world population and the demand for food and water continue to grow. Change, either forced or desired, is inevitable. How will these scenarios eventually play out? Engineers have always been key players in facilitating change but the model for the past may not be appropriate for the future. Can they use their creativity to treat both the causes and symptoms of global warming while retaining the benefits gained in the past? Can they communicate with and influence change in society even though many fail to comprehend what is required to resolve issues such as greenhouse gas emissions (Sterman & Sweeney, 2007)? To facilitate a move to strong sustainability, engineers will need a more holistic approach to design and development in which the entire footprint of the project is considered from many points of view through critical thinking.

For example, irrigation in farming can become the focus of creativity and brainstorming to find solutions that harness rain water instead of pumps in a move to sustainable farming. This requires critical thinking driven by an holistic view of agricultural practice. The engineer must then communicate with the farming community to agree and teach new methods. The use of many personal skills such as creativity, critical thinking, communication and people management are required, based on a set of ethics that is complementary with strong sustainability.

These personal skills are also demanded by employers and the accrediting professional bodies. Employers want innovative, self-starting graduates who can work in a team in different settings, display initiative, critical thinking and can undertake self-directed lifelong learning. Society needs these graduates to have well balanced set of ethics so they can influence policy at many levels. The Irish professional body is Engineers Ireland whose criteria (Engineers Ireland, 2007) include a wide range of non-technical skills that are compatible with the development of the above aims. Government agencies, concerned about national competitiveness and employment, can also provide input to this debate. An example in an Irish context is a recent national skills needs report which called for the development of creativity and innovation and increased use of problem and project-based learning during the third level educational experience (Expert Group on Future Skills Needs, 2009).

How should we best prepare our forthcoming engineering graduates for this new world which demands a high level of personal skills and competences? Which learning and teaching methods are now appropriate to meet a changed set of requirements for our graduates? Can we develop a curriculum that can deliver strongly on both technical and non-technical skills and knowledge? These are the issues that are being explored by staff in the School of Electrical Engineering Systems in the Dublin Institute of Technology (DIT). Our undergraduate programmes include a Bachelor of Engineering and a Bachelor of Engineering Technology in Electrical Engineering. These contain a diverse group of students including school leavers, international students and mature students with trade qualifications. An increase in the use of group-based pedagogies is being implemented to enhance the development of personal skills and competences. A framework is being developed to facilitate the coordination of these modules so the students experience a steady, progressive development of non-technical skills throughout the programme.

2. ENGINEERING EDUCATION

Constructive alignment requires the selection of learning, teaching and assessment methods that are compatible with and facilitate the achievement of the intended learning outcomes (Biggs

2003). The challenge for curriculum design in engineering education is to provide methods that are aligned with the attainment of the wide range of knowledge and skills, both technical and non-technical, that both employers and professional bodies expect a graduate engineer to possess. In many instances, however, the status quo is a teacher-centred approach to education with facilitation of learning through lectures and structured laboratories. This is the traditional approach to engineering education. Although learning can and does happen in this environment it has many limitations. Only a minority of students are sufficiently engaged with it, surface learning is sufficient and development of non-technical skills is not required. It does not provide alignment with the full range of intended learning outcomes.

In the traditional approach, students who are naturally highly engaged tend to do very well, those who are not struggle to pass, yet the former are often in the minority. Even for those, misconceptions remain unchecked (Halloun & Hestenes, 1985; Wieman & Perkins, 2005) and the passive role of the student does not lead to the development of personal competences that, combined with good technical understanding, constitute a good engineer. Technical competence alone is not sufficient; an excellent chef plus an incompetent waiter gets a bad review. Employability and key skills are often addressed by the provision of one module that specifically targets these issues but in isolation to discipline content. Such ‘professional engineering’, or similarly titled, modules can pay lip service to the wide and complex range of non-technical skills and continue to isolate technical and non-technical competences as if they are mutually exclusive and should be split apart. This does not reflect the real world.

In contrast, student-centred approaches pay more attention to the learner’s needs and abilities, achieve higher levels of engagement and thinking (Biggs & Tang 2007) and require the concurrent development of technical and non-technical knowledge and skills. Student-centred approaches include problem-based learning (PBL), enquiry learning, project-based learning, discovery learning, case-based teaching and just-in-time teaching. A review of these learning and teaching methods concluded that they encourage deep approaches to learning, improve critical thinking and self-directed learning and are based on an established understanding of how the brain functions and theories of learning (Prince & Felder, 2006). The unifying theme is that they are inductive, the problem or project is presented first and this drives the learning so that students develop questions before seeking answers. It is argued here that these methods, particularly those that use group-based pedagogies, are highly suited to engineering education. By learning through a group-based and project driven approach the students are *required* to concurrently develop technical and non-technical knowledge and skills. In this case, learning, teaching and assessment are aligned with the delivery of all outcomes, technical and non-technical. In one study, employers rated graduates from a student-centred institute much higher on a range of non-technical skills than their counter parts from a traditional institute (Moesby, 2005).

In the group-based project or problem driven approach students work in small groups of 3 to 6 members on a problem or project that is consistent with their prior knowledge. The groups follow a repeated cycle of brainstorming, self-directed learning and reporting. In the brainstorming phase, the group discusses the problem, suggests possible solutions or paths to investigate and members probe each other for current understanding. A chairperson can manage this meeting. A scribe or minute taker records any tasks or learning goals that must be addressed and these are delegated to the members before the meeting finishes. Each member then follows up on her/his task in the self-directed phase. This is the opportunity to develop self-directed learning and information literacy skills and is the equivalent of homework in other contexts. In this case, the homework is written by the student and the strategy for completing it is decided by the student. The group then meets again to allow each member to report back on new findings or information. Each member should explain in her/his own words what s/he has learnt. This is an opportunity for members to teach and question each other to enhance learning and practice communication, negotiation and conflict resolution. They are required to do so. Having addressed some or all of the issues from the last meeting, the group then starts the cycle again by identifying what must be done next, delegating the tasks and so on. The tutor is present for the meetings and observes each student's behaviour and input. The tutor receives feedback on the self-directed phase at the reporting meeting and can assess how much effort each student has made to complete her/his task. This describes the behaviour of a well functioning group. Novices do not behave in this way - time is needed to develop these skills.

3. PROGRESSIVE DEVELOPMENT AND THE ROLE OF REFLECTION

The progressive development of technical knowledge and skills has always been well defined in engineering programmes. Students are introduced to the basics in year one, the fundamental sciences that engineers apply in their disciplines. Years two, three and four deal with progressively more complex applications and uses of this knowledge. The level of maths becomes progressively more difficult, new methods continuously added. By the end of the programme, the engineering education produces a graduate who has high technical competences in the wide range of subjects associated with her/his chosen discipline.

It is argued here that the same approach should be taken for the development of the wide range of non-technical knowledge and skills. If ability to work in a team is low at the start it should be advanced by graduation. The students should progress from weak to strong communicators, team players, managers, self-directed learners, creative and critical thinkers and continually develop an awareness of ethics. These personal competences should be steadily developed throughout the programme in a progressive, structured way.

Students enter engineering programmes, at least in the Irish system, with a perception of learning that was formed during a teacher-centred secondary education. Their demand for authority is high; they expect the lecturer or the internet to be the source of all knowledge and tend not to look to themselves or each other for answers. They are weak in their abilities to work in a group, deliver a quality presentation, manage a team and so on. A modification is required for student-centred approaches to be successful but the change in behaviour takes time. It is difficult to fully assess all skills at the same time. Learning in this environment is most effective if the students have at least a basic level of group collaboration and self-directed learning. These should therefore be the initial focus of the tutor's attention. Attention can then be shifted to other skills such as creativity, critical thinking and awareness of ethics and sustainability. Figure 1 illustrates this idea but is not intended to give specific direction on exactly when, and by how much, each skill is developed. The important point is that a foundation of group collaboration and self-directed learning is laid before giving significant attention to the many other skills.

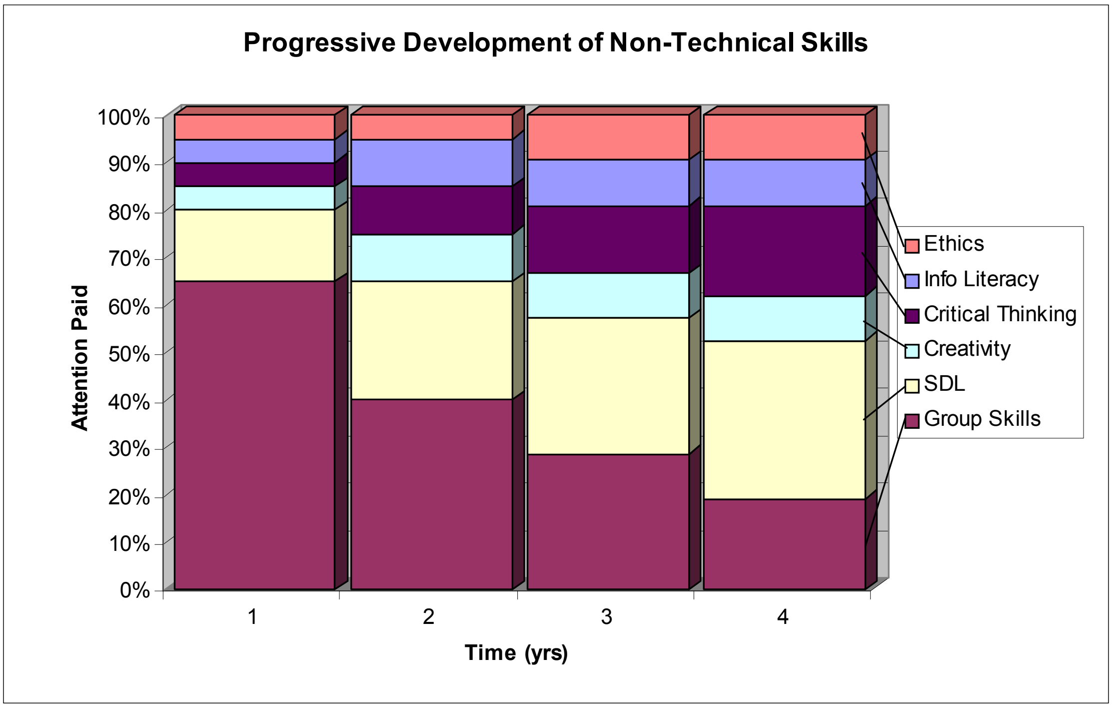

Figure 1. Change in focus on a selection of personal skills during a programme (SDL = self-directed learning)

Schön (1991) used the term 'reflective practitioner' to describe effective professionals who use reflection to cope with new challenges and situations. To be guided in this direction, student must develop a reflective practice. Reflection has a number of functions in group-based learning. It helps to improve retention of knowledge and allows the student to critically appraise her/his approach to learning with a view to improving the learning cycle (Kolb, 1984). It can intrinsically facilitate a modification in any personal competence and is therefore appropriate for the development of non-technical skills. For example, by reflecting on her/his performance in the group, a student learns to give an accurate description of how s/he behaved, analyse and evaluate this behaviour against a set of criteria and then suggest how s/he can improve in the future. For learning groups to grow in autonomy and members to improve self-management in learning, the extrinsic motivation supplied by the tutor at the start must fade and be gradually replaced by an intrinsic desire to learn in this way. This development can be facilitated through a reflective practice and requires the student to not only acknowledge strengths and weaknesses in all personal competences but to also decide how to improve. This reflective practice should also be progressively developed with criteria provided by the tutor at the beginning being gradually replaced by criteria decided by the student (Loacker 2000).

4. A FRAMEWORK FOR PROGRESSIVE DEVELOPMENT

For engineering graduates to score highly on all skills, each programme team must choose an appropriate suite of learning, teaching and assessment activities that are aligned with the attainment of these criteria. The framework presented here provides general advice on curriculum design which can then be transferred to specific learning, teaching and assessment activities by a programme team. The view of the team in the School of Electrical Engineering

Systems in the DIT is that at least one group-based project driven module in each semester of the programme is required to give sustained attention to the development of non-technical skills. A module in this case is worth five points in the European Credit Transfer System (ECTS) and approximates to 100 hours of learning, including class time. Under the ECTS system, a bachelor of engineering is equal to 240 points. It is planned, therefore, to devote 40 points to group-based learning on a continuous basis.

An important feature of this framework is the emphasis on the learning process at the beginning so students are required to work effectively in a group and manage self-directed tasks; this is faded over time as these skills are developed. This is illustrated in Figure 2.

5.1 Years 1 to 2 – 'Laying the foundation', Group collaboration, communication, learning to learn, starting reflection, problem solving

Students have difficulty working in a group at the beginning. The lack of interaction that is a common problem in small group teaching (Tiberius, 1999) must be quickly addressed. Training on group collaboration should be provided as is common in PBL in medical education (Schmidt, Loyens, van Gog, & Paas, 2007); an initial workshop is a good starting point but practice and improvement by the student is the primary objective at this stage. Groups are formed and students get a feel for group work. Assessment by and feedback from the tutor should focus on individual contribution to the group process. For it to be effective feedback should be formative and frequent and should be simple to understand; for example, tell the student one good point and one point for improvement. Students must be *required* to contribute to the group discussion, question others, offer ideas, complete tasks and report back. Tutors need a clear understanding of the learning process and self-directed learning to avoid confusion on the student's part and withdrawal from the group process (Miflin, Campbell, & Price, 1999).

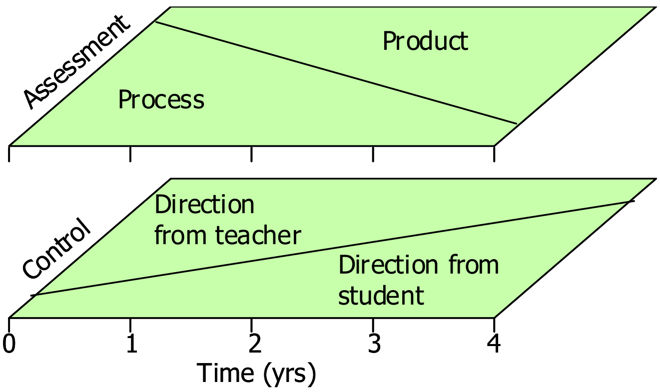

Figure 2. The change in control and assessment of learning over time (Candy, 1991; Miflin, Campbell, & Price, 2000).

Each student should reflect on learning style. For example, some students prefer to learn by doing but need to change so they also give time to improve theoretical understanding. A workshop on reflective writing should be provided in which a reflective model such as 'What?, So what?, Now what?' (Rolfe, Freshwater, & Jasper, 2001) is presented. This should be provided a few weeks into the first semester after the initial adjustment to the group environment. Reflective activities should then focus on individual performance in the group and the self-directed phase. Information literacy skills should be drawn out based on the model provided by The Society of College, National and University Libraries, UK (SCONUL, 1999) or equivalent. The goal by the end of year one is to instil some level of intrinsic motivation in the student combined with a basic level of group and self-directed learning skills to allow the motivation to have effect.

5.2 Years 2, 3 and 4 – 'Enhancing all skills', Management, communication, self-directed lifelong learning, self-awareness, ethics, creativity, critical thinking

Projects or problems should grow progressively more complex over time as groups become more effective at managing their work and members improve their personal skills. The tutor should start to observe that group meetings are being effectively managed by the students. The tutor is now fading from the central role occupied at the beginning. Improvements continue to be made. The skill of chairing a group discussion, if not introduced in year one, could be introduced now. A more defined structure can be imposed on meetings. The role of scribe, or minute-taker can also be introduced and assessed. The chair and scribe are assessed differently which can cause confusion at the beginning of year one. The students should also experience a reduction in the provision of resources by the tutor to support the problems or projects. These can be further reduced in years three and four. This requires the student to continually improve information literacy and take greater control of learning.

Making well justified decisions requires the use of critical thinking and application of creativity. Once the groups are working reasonably well, feedback on group collaboration can be replaced with feedback on critical thinking skills and the use of creativity. A workshop on these skills can be provided and the application of them subsequently assessed. The open ended nature of project or problem driven learning always requires choices to be made by individuals and the group. As students become more professional in their approach more open-ended problems can be considered such as engineering projects taken from the community. These have a real customer and help develop awareness of beliefs and values. Project management concepts and skills can also be accommodated in this model by focusing on their development with a suitable project that is not isolated from but integrated with discipline content.

5. CONCLUSIONS

Attainment of non-technical or personal skill to a high level by engineering students requires continuous attention and coordination over the entire programme through the use of constructively aligned learning, teaching and assessment methods. Group-based pedagogies, in which the problems or projects drive the learning and are set in the context of the discipline content provide true integration of all skills and the opportunity to score highly on all accreditation criteria. Personal skills should be developed in a progressive structure throughout the programme. Over time, students should become progressively more independent, problems more complex, and groups more effective so the graduate who emerges at the end is attractive to employers and has a set of beliefs and values that will help reshape society and environment.

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