

**ENVISIONING
ENGINEERING EDUCATION
IMPROVEMENT**

**Thesis submitted for the degree Master of Engineering in Development and
Management
at the North-West University**

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**April 2006
Potchefstroom Campus**

ABSTRACT

Can engineers be educated more effectively, and if so, how would it be done, was the question at the heart of this study. The research investigated alternative ways of educating engineers, compared them with the current way of educating engineers at the North-West University Faculty of Engineering, and envisions a more effective way of educating engineers. It also recommends an improvement strategy based on business improvement principles, as an Engineering faculty is seen as a business with its core process being the education of engineers. An engineering education process model was developed to use as a measuring and comparison tool, and to give structure to the transformation vision. To achieve improvement of engineering education in the faculty, it is recommended that the further work be defined and managed as a business reengineering project, using project management and Business Process Reengineering methodology, supported by change management strategies.

PREFACE

It is with a glad heart that I submit this thesis. It has been an opportunity seized and enjoyed to finally do the research I have always wanted to do for the past twelve years! Fulfilling many roles and having many different responsibilities while also trying to be a student was at times a challenge, but everything is possible for those who believe. Thank you very much My Father in Heaven for giving the light needed every step of the way. Thank you Prof. Johan Fick, for being the five personality you had to be in supporting this effort as my study leader. Thank you for providing the vision and direction when the prospects were cloudy, and thank you for always retaining a sense of humour when this scatterbrain could not think clearly and wanted a 'perfect answer' in a grey context. Thank you Dr. Susan Coetzee-Van Rooy for providing an educationist's point of view with the necessary criticism of style as well. Thank you Prof. Albert Helberg, for being my informal mentor and friend when I just had to speak to somebody for understanding, direction and encouragement. Thank you, Theunis, for your support as a loving husband in allowing me this time and especially helping out with the children when necessary. Lastly – thank you everybody at the Faculty of Engineering for taking part in this study and being honest and sceptical at the same time.

*What lies behind us and
what lies ahead of us
are tiny matters compared to
what lies inside of us*

- Ralph Waldo Emerson

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1 Research problem

1.1 Problem Identification

"Is our education about producing critical professionals who can take up a stance toward knowledge, or is it just about providing them with prefabricated bricks of knowledge that they will find difficulty arguing against?" (Savin-Baden, 2003). In the engineering profession this question is crucial, as engineers are supposed to work with knowledge as a means of achieving innovative designs, applications and the like for improving society. At an Engineering department in Belgium the faculty's disappointment with what their engineering education process was achieving increased as a result of the following: "low student motivation, high drop-out rate, shallow mastery of material, low retention rate, little demonstration of higher order skills, too little initiative or autonomy and low competence even after years of study" (Raucent, 2004). Raucent (2004) also found that in trying to comprehend the essence of their actual business as an engineering education department, "very few of them had actually tried to understand what learning is all about." These statements reflect what faculty members at the North-West University (NWU) Faculty of Engineering are saying and wanting to address. They believe that there must be more effective ways to educate engineers than the current system. The research questions to address were therefore:

- Are there more effective ways of educating engineers?
- What do more effective ways of educating engineers entail?
- What strategy can be used to successfully implement a more effective system or process of educating engineers?

Pressures on and changes to the higher education system as a whole within the South African environment force one to rethink the effectiveness of one's education. This is confirmed as the South African Department of Education has identified deficiencies in higher education, with one concern being, "the chronic mismatch between the output of higher education and the needs of a modernizing economy, in particular the shortage of highly trained graduates in fields such as science, engineering, technology and commerce" (Department of Education, 1997). To address this, a better understanding of and more information on the engineering education process are needed, as well as available options and methodologies to improve the process. This research project was launched to address this problem by investigating and recommending more effective ways. The study was therefore an open-ended problem with many possible answers and should be read in this context.

With outcomes-based education (OBE) introduced in South Africa since 1998, a paradigm shift is required for the educational model in general, of which engineering education forms a logical part. "The reengineering of the learning system towards the outcomes based approach is a major attempt to build the country into becoming an international role-player. Outcomes based learning reflects the notion that the best way to get where you want to be is to first determine what you want to achieve. Once the end goal is defined the strategies, techniques and other ways and means can be defined to achieve the goal" (Olivier, 1998). This end-goal of outcomes is exactly what the Engineering Council of South Africa (ECSA) has defined for a graduate engineering degree, taking into account current trends and expectations of the industry. For details of these outcomes see the document: *PE-61 Whole qualification standard for Bachelor of Science in Engineering (BSc(Eng))/Bachelors of Engineering (BEng): NQF level 7* available on the ECSA website [www.ecsa.co.za]. In an OBE educational context learners accomplish more than remembering or mastering skills and knowledge. In the OBE context, quality *teaching* is "the facilitation of learning so that outcomes are achieved by learners" and quality *learning* is "the active involvement of learners in the learning process that results in the ability of learners to demonstrate the outcomes they achieved" (Coetzee-Van Rooy, 2002).

The purpose of education is after all to prepare learners for life in society and for performing a job well. The difference between content based learning and outcomes-based learning are described as follows: With a content focus the learner masters a syllabus, whilst hopefully developing thinking and reasoning skills. The teaching process is planned to 'get through the content' (Hanrahan, 1997). Assessment is done at the end of

a period, with summative evaluation on content mastery and recollection within a pure content focus. Scoring is thus done on the learners' ability to remember and recall. With an outcomes-based focus the objective is to evaluate the learner's *mastery of the learning processes*, including contextualised knowledge and skills, (Olivier, 1998) thus what a person can do and not just knowledge reproduction. Outcomes based education has caused us to realise that our current way of educating engineers is not as effective as it could or should be, and therefore the faculty needs to do something about it. Outcomes-based education necessitates a paradigm shift towards the curricular process and how learning should empower the learner. The goal is obviously to improve the quality of real learning and as with an implementation of Total Quality Management (TQM) it *changes the organisational culture*.

1.2 Research objectives

The main objective was to **envision a more effective model for engineering education**, and to recommend a strategy for improvement.

Achievement of the above required:

1. Research on various engineering education *improvement initiatives* and/or models.
2. Development of an engineering education *process model*.
3. *Comparison* of the current process model elements with the models of engineering education of some other universities who are known for their effective engineering education.
4. Research on relevant *business improvement strategies* or methodologies.

The following diagram indicates the relationship between the objectives:

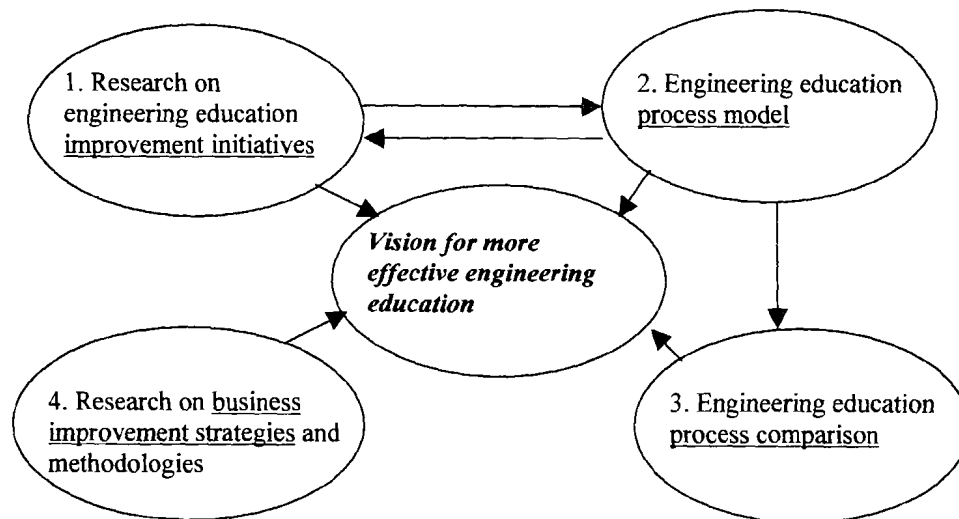


FIGURE 1 – STRUCTURED APPROACH TO RESEARCH STUDY

1.3 Research investigation process

Following the structured approach above, the following research activities were employed to reach the objectives:

<i>Research objectives</i>	<i>Activities to achieve objectives</i>
To research various engineering education improvement initiatives.	A comprehensive <u>literature study</u> was carried out and <u>visits</u> paid to some universities who have implemented improvement initiatives.
To model the current engineering education process at the NWU Faculty of Engineering.	A <u>process model</u> of the engineering education process was developed as a means of interpreting the literature studied and to serve as a basis for measuring the current status.
To compare the NWU's current engineering education process to other models from Europe.	A <u>research visit</u> took place, including the researcher and the dean of the faculty, to five European universities. From interviews with selected personnel and documentation made available, a comparison was made with the NWU's current process.
To research business improvement strategies or methodologies.	A <u>literature study</u> was carried out and the <u>research visit</u> to the European universities took place.
To recommend an improvement strategy.	All of the above activities provided the input to a recommended improvement strategy for improving engineering education at NWU Faculty of Engineering.

2 Contextualisation

The context of the study is illustrated by answering the following questions:

- What does engineering education involve?
- What research on engineering education is currently taking place?

The following paragraphs address these questions.

2.1 Engineering education defined

To define engineering education adequately, engineering itself must first be defined. The following quotes were selected to represent the definition of engineering as it is to be interpreted for the purpose of this study.

- According to Watson (1994), "engineering is the art of developing and executing a *practical application* of scientific knowledge to the design of product or process. It differs from the pure science in that it seeks an implementation of knowledge, not knowledge purely for its own sake. Engineers design and manage intricate enterprises and operations using the tools of information technology to help them apply scientific principles more clearly to the task of business."
- Clough (2004) states that engineering is becoming more *interdisciplinary* or even multidisciplinary than in the past, as illustrated by the following quote: "The lines between engineering disciplines are becoming increasingly interwoven and the time-honoured definition of engineering as a whole is becoming less distinct. It is no longer clear where science stops and engineering starts or even where engineering stops and business begins. The education we provide engineers must prepare them to move beyond merely fulfilling a technological function and become leaders in making wise decisions about technology and setting policies that foster innovation. The future will need engineers who are creative and ingenious with strong analytical and teamwork skills, who see themselves as global citizens with enhanced communications skills with the larger public and government." (Clough, 2004)
- "Engineering is about *design, development* and manufacturing, but it is also about marketing and selling. Engineering is about designing and manufacturing products of the right quality at the right price." (Kubie, 2003)

It is thus clear that engineering education cannot be focused on teaching science and technology only, although science and technology should still form the basis of the engineering curriculum. Engineers of the future should be well-rounded i.t.o. knowledge and skills related to business as a whole, and cannot function in isolation anymore. Engineers need to interact, communicate and work with other disciplines in business and research environments. The nature of new research fields in engineering already supports these concepts i.e. nanotechnology (engineering and physics) and bioengineering (engineering and medicine). Therefore their education should prepare them for this bigger interdisciplinary scope and function. The fact that information and knowledge about things are continuously growing is another reason that an engineering education can no longer focus on providing content scope only. The process of learning any content or knowledge should be the primary outcome of an engineer's education.

2.2 Current research on engineering education

Engineers will continue to play a crucial role in developing technology/systems/processes for improving society's needs. Research on engineering education is a continuing quest. Engineers will be required in a future with the following characteristics as predicted by Pretorius (1998):

- Rapid communication between countries concerning information and events;
- internationalisation of practices and services;
- a migrating world population;
- a shift from industrial communities towards service communities;
- a new do-it-yourself era; and

- the need for entrepreneurship.

Many organisations are involved with research on engineering education. A few of these organisations include:

- The American Society for Engineering Education (ASEE);
- the National Academy of Engineering (NAE);
- the Laboratory for Innovative Technology and Engineering Education (LITEE);
- the Transferable Integrated Design Engineering Education (TIDEE) consortium;
- the Canadian Academy of Engineering; and
- the Centre for Research on Engineering Education (CREE) locally.

Below follows a few questions provided in context to highlight the aim of this study.

The question "Is engineering education in South Africa going the way it should?", was asked a number of years ago by Van Vuuren and Pouris (1992). They found that in general, industry does not seem to be satisfied with the quality of engineers being delivered by tertiary institutions. More than a decade has passed and can we now answer the question, *'Is industry satisfied with our delivery of engineers today?'*

Some industries reported a lack of "problem-solving abilities, innovative and lateral thinking, initiative, decision-making and communication abilities" (Van Vuuren and Pouris, 1992). The average engineer needs to have more managerial skills from the start, including "human resource development, industrial relations, business and finance management and project management skills". The investigation also showed that the curriculum should be made more appropriate to meet industry needs. *'Has the curriculum been made appropriate to industry needs or has it remained the same for more than a decade?'*

Projects like "The Engineer of 2020" (Clough, 2004) indicate that the future nature of the engineering professional look different than the outcomes envisaged some years ago. Industry leaders complain that "graduating students, while technically adept, lacked many abilities required in real-world engineering situations." (Gaidi, 2003). *'Is that not the feedback we also get from industry in South Africa?'*

The CDIO initiative attributes the current low quality of engineering education to "engineering education becoming disassociated from engineering practice, because fewer faculty members have actually worked as engineers and therefore engineering science has become the dominant element in the culture of engineering schools" instead of real engineering where the "focus is on solving tangible problems, conceptualizing and designing products and systems" for the benefit of society (Gaidi, 2003). *'Is that true in our South African academic engineering environment as well?'* The CDIO model/concept/framework will be explained further in chapter 4.1.1.

Informal feedback from members of industry says they are not complaining about engineering students' technical ability, but technical ability is not the only skill needed to be an effective engineer in industry, and this is where the real issue seems to be. It is believed that all of the above research has a common theme, which is to approach engineering education more holistically. It is also believed that more research needs to be done on the process, method and style of engineering education as the problem is not with content but with what engineers really learn in the process. This study therefore aims to be part of global research done on engineering education with the objective of improving the NWU's own engineering education process and contributing to the knowledge of engineering education improvement.

3 Engineering education improvement initiatives – literature survey

The purpose of the literature survey is to gain more information on different approaches and/or initiatives for improving engineering education in order to interpret them better and to enable the development of a strategy for improvement. Different concepts have been investigated and are presented. This literature survey was not intended to include a review of all basic educational philosophies and responses of engineering educators to previously implemented program designs which moved away from inputs to outputs.

3.1 Examples of engineering education improvement initiatives

One may find a variety of terms in the literature used to describe a spectrum of activities that may improve the current process of education. These may vary from the addition of just one new module or project (classified as minor improvement) to an existing programme/course to changing the whole process to interdisciplinary problem-based learning principles (classified as major improvement).

Examples of some minor improvement initiatives:

- In the Project Based Learning in Engineering (PBLE) Guide, as developed by a consortium working on the PBLE project with the aim of promoting and facilitating the use of Project Based Learning, the following case studies are all mentioned as initiatives to improve engineering education:(FDTL, 2003):
 - Aston University – Facilitating Collaborative Design through *Information and Communications Technology (ICT)*.
 - University of Derby – Fostering *Progressive Learning* through Scenario-Based Assessment.
 - Loughborough University – Running Team Projects in *Co-operation with Industry* as well as Widening the *Project Based Learning* Experience with Student Mentors.
 - University of Manchester – Teaching Engineering through *Problem Based Learning*.
 - University of Plymouth – Learning Through Competition.
 - University of Sheffield – Enhancing Teamwork in *Group Projects* through Pre-project Training Exercises as well as *Introducing Business and Enterprise* to Civil Engineering Students.
 - University of Strathclyde – An Innovative *Design Class* for First Year Mechanical Engineers.

Examples of some major improvement initiatives:

- Penn State University College of Engineering implemented *cross-disciplinary problem-based learning*, which brought more design experience into the curricula by collaboration with the Colleges of Business. A *physical work space* was created where the necessary tools for collaboration, design, construction and testing were available. Most of the design projects were *industry sponsored* (Sathianathan, 2002).
- Youngstone State University are taking major steps in improving the quality of their programme ranging from the introduction of a *freshman engineering programme* to *co-operative education with industry* (Cala & Patel, 2003).
- At Plymouth University's Faculty of Technology an *interdisciplinary project programme* (between the civil, mechanical and electrical engineering schools) was implemented for the final year students, where the main objective was to provide the students with the significant intellectual challenge of doing an engineering design project, gaining a broader insight into problem-solving and

dealing with uncertainty – all comprising the essence of engineering. Part of this initiative included equipping a *purpose-designed facility* for the students to work in (Skates, 2003).

- Massachusetts Institute of Technology (MIT) have transformed their Mechanical Engineering department by *redefining* what mechanical engineering entails, and bringing other disciplines such as biology and information technology into the department. They have also *renovated the facilities* and *initiated research in new areas* such as bio-instrumentation and nanotechnology (Suh, 2003).
- At the University of Pretoria (UP), a Learning Management System (LMS) called *WebCT (World Wide Web Courseware Tools)* has been implemented as part of its Education Innovation initiative at the Industrial Engineering department, with a distance learning, student-controlled environment supporting the learning process (Van Dyk, 2003).
- *Project-based learning* and *ICT* have had positive benefits for the four-year Industrial Engineering degree programme at the National University of Ireland (Gibson, 2003 and 2002).
- At the University of Hong Kong, an *interactive multimedia e-learning system* (IMELS), adopting problem-based learning, has been implemented in their industrial engineering department, which delivers realistic case problems using interactive multimedia technology over the World Wide Web (Lau & Mak, 2004).
- The implementation of *Conceive-Design-Implement-Operate (CDIO)* as the context for engineering education include adoption of the CDIO syllabus, an introduction of Design-Build experiences, the introduction of more active learning as teaching strategy and the upgrading of facilities. CDIO is being implemented at the Massachusetts Institute of Technology (MIT) Department of Aeronautics and Astronautics (Crawley, 2001), as well as at three Swedish Universities i.e. Chalmers University of Technology, Royal Institute of Technology (KTH) and Linköping University, taking the initiative and with more than 10 other universities worldwide following.
- The development of *Design-Based Learning (DBL)* at the Technische Universiteit Eindhoven (Tu/E). DBL is defined as an educational model in which a major part of both the curriculum and the study programme is aimed at learning to design (Van de Wouw, 2004). It is similar to Problem-Based Learning (PBL), where the process of learning is more important than content, with different forms of work such as group work and assessment such as peer review as part of the model (Perrenet, Bouhuijs & Smits, 2000).
- At the University of Twente in the Netherlands, the implementation of *Project-Led Engineering Education (PLEE)* has led to many positive effects. Lecturers feel they have a greater insight into their students' capabilities, there is an integration of courses with research projects and the majority of students are motivated to work harder (Powell & Grunefeld, 1999).

The above list demonstrates that research into engineering education differs in scope, purpose and implementation. The list is not intended to be exhaustive but rather to be illustrative of the fact that faculties and departments of engineering all over the world are continuously doing things to improve, whether only on a minor scale such as improving individual courses, or on a major scale involving faculty-wide programme redesign.

3.2 Curriculum or syllabus improvement

Curriculum improvement is often seen as the most important option to improve engineering education. However, it is not the way radical improvements to the engineering education process are achieved. As Glasgow (1997) suggested "we must begin to look at the real world that is an integrated, interdisciplinary, multidisciplinary place for real problems, projects and challenges, as a starting point for curriculum planning."

A curriculum is defined as the set of courses for a programme. A curriculum therefore does not define the outcomes achieved by the programme, nor the requirements set by the standards-regulating body. However, the curriculum should be designed, planned and developed with the objective of achieving the outcomes and/or requirements given. According to Glasgow (1997) many current curricula in education institutions are based on the teacher's past experience, input from textbook manufacturers, discipline frameworks, standards and information from peers. Teachers hope that their curricula and style of teaching will meet the needs of the students they face each day. It does not necessarily connect to reality. It is estimated that 95%

of the classroom curriculum comes from textbooks. Most textbooks contain nothing more than a compendium of facts not necessarily relevant outside the classroom. Filling students' intellectual toolboxes with techniques, tools and small bits of today's information and knowledge does not reflect what successful people are required to be able to do in today's "learn-and-relearn-as-you-go" world. Many current curricula do not enhance the student's judgment and capacity to act intelligently and confidently in new situations.

Most curriculum planning is like trying to build a car in the middle of a junkyard. Pieces from here and there are added as different lecturers add their different disciplines. Different voices give instructions on how best to build the car. Some pieces fit, others do not. Most of the time it is not a strategic, effective or productive process. Often improvement to the engineering education process is viewed as being only a question of improving the curriculum. Many hours of debate result from trying to decide what to include and what to exclude from a particular curriculum. This process wastes valuable time where the effort could have been put into designing a curriculum with the real objective of delivering effective engineers in mind. As part of this study an engineering education process model was developed with the aim of bringing attention to the improvement of the total process, and not only curriculum improvement.

3.3 CDIO as a 'new model for engineering education'

With support from the Wallenberg foundation, the Royal Institute of Technology (KTH), Linköping University, Chalmers University of Technology and Massachusetts Institute of Technology (MIT) formed an international collaboration during October 2000 with the aim of doing research on improving engineering education. The project became known as the CDIO initiative – CDIO being the acronym for Conceive-Design-Implement-Operate. The strategy to implement CDIO has four themes:

1. Curriculum reform to ensure that students have opportunities to develop the knowledge, skills and attitudes to conceive and design complex systems and products.
2. Improved level of teaching and learning necessary for deep understanding of technical information and skills.
3. Experiential learning environments provided by laboratories and workshops.
4. Effective assessment methods to determine quality and improve the learning process.

CDIO provides a *comprehensive framework* for adopting activities and ideas to improve engineering education. The advantage of adopting CDIO is that benchmarking examples are readily available to learn from. CDIO takes a holistic approach to improving the process by having the four themes interrelate to each other. If a faculty decides to adopt the CDIO framework, a list of CDIO standards is available against which a faculty may evaluate itself. These standards explain the improvement objectives of CDIO.

The following quotation demonstrates the origin of CDIO at MIT (Crawley, 2001):

In contemporary undergraduate engineering education, there is a seemingly irreconcilable *tension* between two growing needs. On one hand, there is the ever increasing body of technical knowledge that it is felt that graduating students must command. On the other hand, there is a growing recognition that young engineers must possess a wide array of personal, interpersonal, and system building knowledge and skills that will allow them to function in real engineering teams and to produce real products and systems. In order to resolve these seemingly irreconcilable needs, we must develop a new vision and concept for undergraduate education. At MIT we are developing this new educational concept by applying the engineering problem solving paradigm. This entails first developing and codifying a comprehensive definition of the skills needed by the contemporary engineer. Next we are developing new approaches to enable and enhance the learning of these skills. Simultaneously we are exploring new systems to assess technical learning, and to utilise this assessment information to improve our educational process. Collectively these activities comprise the CDIO programme at MIT.

It is believed that in South Africa, this tension is also felt, and we thus agree that we also need a new vision and concept for engineering education. The development of this new vision and concept are at the heart of this study.

CDIO proposes an improved syllabus incorporating a variety of skills engineers must possess as expected by industry, it proposes a more active learning environment, as well as the adoption of appropriate assessment methods in this active learning environment. It is also proposing the building of appropriate facilities in order for engineers to execute the product life cycle process as the context for engineering education. Their vision is as follows (Soderholm et al., 2005):

...to provide students with an education that stresses the fundamentals of engineering, and is set in the context of conceiving, designing, implementing, and operating real-world systems and products. This new educational model will be more integrated, with disciplines interwoven and mutually supporting. Students will learn from their own experience through a rich offering of team-based design-build-operate projects, both in modern classrooms and in a workshop/laboratory. By developing a set of authentic personal technical experiences, the students will not only learn about system building, but will also better master the vital deeper working knowledge of the fundamentals of engineering.

From its start, the initiative's product was designed as open architecture. It would be freely available to all schools that offer undergraduate engineering education to take CDIO methodologies, products and templates and readily adapt and adopt them to their own programmes (Berggren et al., 2003).¹

3.4 Industry collaboration or co-operative education

Another initiative taken by some institutions specifically to improve the education of their engineers are industry collaboration or co-operative education as part of the undergraduate programmes. The term co-operative education implies that the supplier (being an education institution) are working in partnership with the market (industry) receiving the engineers in designing the programme or individual courses, or even supplying projects for students to work on as part of their programme. Industry, engineers and academic institution should be working together, especially when courses with the objective of teaching application skills are presented. It makes sense to collaborate with and involve industry in the design of these type of courses. In any course offering project work, the option to make the projects 'real' lies in communication and involving industry. Some examples are explained below.

Robotics is a subject that is often taught with the only outcome being engineers who merely know about the subject, but who have no application skills. Gippsland School of Engineering has taken a different route in the development of their *Robotics Systems* course (Ibrahim, 1998). They have liaised with industry to allow team projects to work on real-life, unstructured, industrial automation projects, where they had to apply the knowledge and skills gained through the ordinary lectures, tutorials and laboratory sessions. This approach led to the achievement of knowledge, skills and a *confident attitude* of a graduate engineer to enter industry and tackle real problems. Industry's involvement was simple: They were responsible for offering real projects, providing a contact person to liaise with the student team working on the project and to play an active role in the assessment process of the outcome. They found that this approach helped not only in achieving the educational objectives, but also in motivating the students and in alerting industry to the ability of an academic institution to solve some of their problems. It strengthened the weak link between industry and education.

In the teaching of project management at the Department of Management and Entrepreneurship at Xavier University (Kloppenborg, 2003), all their projects are real organisation problems taken from the community's businesses, and especially from non-profit organisations. Teams are also formed to work on the projects, and the pedagogical approach they use is problem-based learning (described below). Again industry's involvement is to define and offer projects, to be available for consultation, provide information as needed and be involved in the assessment process.

¹ For anyone interested in further reading, comprehensive literature is available from the CDIO website (www.cdio.org) of which the article "*CDIO: An international initiative for reforming engineering education*" provides the necessary summary background information. Also available are reports and other articles providing valuable information to use when adopting CDIO, of which some are referred to in this study.

Some of the many advantages of co-operative education programmes are:

- To provide the student with the experience of a real-world situation to improve his/her confidence to enter the workplace;
- to prepare students better in terms of knowledge, skills and values for the real world; and
- to improve students' chances of employment after graduation.

However, working with industry is not that easy, and careful consideration must be given to exactly what is expected from them. They must take up their responsibility during projects, especially with regard to the time frame. It may also help to have the necessary co-ordinating role fulfilled by a dedicated person or organisation even, as is the case at Xavier University, with a volunteer managing the co-ordination of projects for them (Kloppenborg, 2003).

3.5 Pedagogical models

The most common examples of rather radically improving engineering education has been the description of changes made to the 'way' engineers are educated. I call these changes, pedagogical models collectively and will describe active learning, problem based learning, design-based learning and project based learning as four approaches investigated. In education the trend has been to move away from teacher/subject-centred learning to student/topic-centred learning.

3.5.1 Active learning

Active learning is recognised as a teaching strategy where the learning taking place is more effective. This is supported by ample research done on the best ways students learn (Campbell, 1999). It is also a fact that tertiary education lecturers worldwide have shown great interest in teaching methods grouped under the term active learning (Hall et al., 2002). Active learning is a student-centred approach where the focus is on engaging and involving students through well-designed active learning experiences, while the teacher fulfils a facilitating role, in contrast with a teacher-centred approach where the teacher is seen as transmitter of knowledge. Active learning has many benefits (Campbell, 1999 and Hall et al., 2002):

- It achieves learning objectives related to content, even complex and substantial content;
- it develops communication abilities and leadership skills;
- it develops decision-making skills;
- it increases motivation and attendance;
- it values student input;
- it is very effective at developing higher order critical thinking skills like analysis, synthesis and evaluation, which are particularly important skills in the engineering education environment;
- it enables students to apply the information and skills learnt in new settings; and
- it can inspire students to become self-directed, lifelong learners.

In their Unified Engineering course at the MIT Department of Aeronautics and Astronautics (Hall et al., 2002), a strategic move towards implementing active learning techniques faculty-wide proved to improve learning even though it was not an easy change to achieve.

Active learning approaches include a variety of strategies from writing assignments, concept tests, in-class small-group discussions, group work, debates, role-playing, simulations, problem-solving, students using technology better, case studies, co-operative learning, and so forth. Co-operative learning is also an active learning approach where students work together in groups to learn, explain and support each other. A reason to use this strategy according to Johnson et al. (1990) is that it is important for senior students to leave skilled in teaching material to peers, listening with understanding, knowing how to build trust in relationships and providing leadership in groups. This is a very important outcome to achieve if we want to honestly claim that we have prepared students for the real world where co-ordination of effort is key to solving any real problems. Co-operative learning may be incorporated in courses through the use of informal or formal learning groups where they are usually working together towards achieving some common goal. It is therefore relatively easy to introduce more active learning strategies into the traditional

and often ineffective lecture-only class.

In his interesting article, Kubie (2003) calls for more active learning in engineering programmes to make engineering education exciting so that more students are attracted to enter engineering programmes. He also states that engineering programmes must:

- encourage experimentation and modelling, and learning from failures;
- be relevant to real life and real engineering situations;
- demonstrate its relevance in the education process;
- give students significant control over what they do to learn (e.g. project and design work);
- fully explore the social, economic and communication aspects of engineering. (group work); and
- encourage entrepreneurship and risk taking.

All of the above require an active learning approach to the curriculum design process.

When considering implementation of active learning, it must be recognised that there will be barriers to overcome. Bonwell and Sutherland, (as mentioned in Hall et al., 2002) have identified some:

- The 'coverage' problem;
- increased class preparation time;
- limited or a lack of resources;
- support; and
- large classes.

3.5.2 Problem-based learning

Problem-based learning (PBL) is a widespread teaching method or active learning approach in disciplines where students must learn to apply knowledge and not just acquire it. It was developed in response to criticism that professionals (trained in medicine and engineering) failed to equip graduates with the necessary skills to solve problems effectively. Problem-based learning focuses on problem solving in conjunction with problem formulation (Brodeur, 2002). It may also be regarded as an active learning approach or teaching method since it derives from the theory that learning is a process in which the learner actively constructs knowledge. PBL is a model which could be applied particularly in the engineering education environment since problem solving is an essential skill to be learnt by students. "Engineering programmes must be based on problem-based learning and discovery" since "engineers solve relevant problems and they solve them economically and timeously. Engineers experiment and model and learn from failures" (Kubie, 2003). Problem solving is also specifically stated as an outcome to be achieved by international standards such as ABET EC2000, as well as nationally by the ECSA exit level outcomes for graduate engineers.

"The expanding knowledge base of most professions means that it is impossible to include all knowledge that is required for the beginning practitioner in the pre-service curriculum. It is important for students to be able to learn quickly and effectively and independently when they need it" (Boud, 1996). This statement makes one wonder if the current lecture approach is effective in producing real professional engineers. It relies too much on the "student's capacity to memorize" (Engel, 1996). The introduction of critical cross-field outcomes in South Africa as part of the outcomes an engineering programme must achieve is a step towards improving this weakness.

The question remains "Do we produce engineers without enquiring minds, who are not curious and seek to understand but only act on some set of reflexes with tools from a toolbox?" (Engel, 1996).

Problem-based learning defined:

The process of problem-based learning is described logically by Perrenet et al (2000) as follows: In its original form problem-based learning is delivered as a set of problems which provides the starting point for the learning process. It is a cyclic process consisting of three phases: Students first encounter problems instead of facts and theories as phase one. During a group session with the help of a tutor, learning

objectives or issues are identified. Phase two is individual self-directed study then applied to address/research these learning issues. The last phase is co-operative group work where the newly gained knowledge is applied in order to solve the problem. The last phase also includes summarising what has been learnt. Lectures may help the process but ideally the self-directed learning activity of the students is the core focus of the process. Assessment is done by means of different methods, some of which are tutors' written reports on individual students, observation of workshops conducted, modified essay questions, oral exams, portfolios, etc. (Norman, 1996) The roles of teachers change from those of dispensers of knowledge to providers of structure, support and connections to the resources the students need to solve problems. Teachers create the vision, set the tone for performance and define the quality expectations (Glasgow, 1997).

Problem-oriented curricula can be presented in an entirely traditional manner, but then it will not really be problem-based learning as it should not be confused with problem-solving learning or 'teaching with problems' (Savin-Baden, 2000). The traditional approach assumes that students have to have the knowledge required to approach a problem before they can start work on such problem, whereas in the problem-based learning approach the knowledge arises from the problem. Students work on the problem and identify and search for the knowledge to solve the problem themselves. This turns the traditional approach on its head.

Another way to define the problem based learning process is typically as follows: (Ross, 1996)

- The design team selects a problem;
- this is used to define the area of knowledge to be covered;
- the team selects an event as derived from the problem to place before the students;
- the students (in groups) then define the problem from the event;
- the students express the problem as a question or set of questions, or as learning objectives/issues in order to solve the problem;
- the students then define the resources needed for research to get the appropriate knowledge or skills to solve the problem;
- the students then collect and apply these to the problem until solved; and
- finally the students review their learning objectives and summarise their work.

Problem-based learning as a challenge:

This problem-based learning approach calls for another type of curriculum, a different role for the lecturer and even a change in the organisational structure. As Engel (1996) also stated "The full potential of problem based learning as an educational approach is dependent on the quality of the educational environment, and the design of the curriculum. Implementation requires subject centred groups to *relinquish some of their power*. A central education committee will need to plan and implement the overall curriculum, and it should not be staffed on the basis of subject representation. Principles and concepts are studied in relation to the agreed progression of problems." (italics added) This implies that a major paradigm shift is needed in order for PBL to be fully appreciated and implemented. This is confirmed by Barron (1998) when he states that "a major hurdle in implementing problem based learning is that it requires simultaneous changes in curriculum, instruction method and assessment practices." When looking at case studies of implementations (see various case studies in Boud, 1996) one can also see that even a change in facilities may be required when implementing problem-based learning.

Margetson (1996) states that one's own view of, or paradigm concerning, education/teaching/learning will be how one views problem-based learning as either positive or negative. He argues that problem-based learning evokes strong emotions for several reasons e.g. dislike/disbelief of the claimed benefits of problem-based learning, anxiety that the outcomes might not be that tangible, a disruption of the habitual comfort patterns of work and a general fear of change. But the most significant reason, he explains, has to do with the notion of expertise in the professional environment. He writes that "on a subject-based conception, expertise tends to be seen in terms of content – to be an expert is to know a lot of content, it is to have covered much in one's learning. An alternative definition of expertise may be put this way: Expertise is an ability to make sound judgments as to what is problematic about a situation, to identify the most important problems, and to know how to go about solving them. Dealing with problems presupposes propositional knowledge but does not equate expertise with it, as subject-based views tend to do. Problem

based learning requires a much greater integration of knowing than with knowing how." Again there is the suggestion that problem-based learning is not just a minor adjustment but a significant change to the traditional education process.

This notion is confirmed when one looks at the characteristics of problem-based learning as defined by Margetson (1996), with comments on how it may be perceived in brackets:

1. It encourages open-minded, reflective, critical and active learning. (This may be perceived as a threat to teachers who like control and who will see the loss of control in the classroom as a loss of personal power.)
2. It is morally defensible in that it pays due respect to both student and teacher as persons with knowledge, understanding, feelings and interests who come together in a shared education process. (This can be a threat to those who conceive of education as a one-way process.)
3. It reflects the nature of knowledge – knowledge that is complex and changes. (This can be a threat to those viewing knowledge simply as bodies of information, teaching as being only the transmission of information and learning as merely information absorption.)

If one looks at implementing problem-based learning as a pedagogical model, the dilemma will be how to persuade colleagues to change their focus from **efficient teaching** to **effective learning**. It is thus worth noting that a great effort should be put into change management in preparation for a move towards a teaching model such as problem-based learning. But this can be seen as an opportunity to provide leadership in curriculum research and development to the advantage of the engineering education community as a whole. Many references to problem-based learning implementations exist in the literature from which one can learn.

In a "Position paper on Problem-Based Learning" (Menning et al., 2003) lessons learned are listed as follows:

- There is a big risk of compromising the benefits of problem-based learning when it is blended, hybridised, or otherwise placed in competition or juxtaposition with more traditional approaches to education.
- Learning in small groups is much more difficult, with a little problem-based learning and a lot of traditional pedagogy.
- In curricula that combine problem-based learning and more traditional methods, students may view problem-based learning as secondary to more traditional aspects of the curriculum if assessment strategies do not reflect tutorial skills and content in a significant way.
- There is a continuing necessity for well-trained teachers who can conduct small-group problem-based learning sessions skilfully. This is an obvious problem when most academics are recruited on the basis of their specialist knowledge and not their teaching skills. Training needs to continue and be iterative over time beyond a short single introductory session.
- Assessment methods for students in problem-based learning programmes need to be consistent with how students learn.

Those considering problem-based learning implementation must also reconcile numerous tensions when planning and designing problem-based learning activities. "Tensions such as the debate over depth vs breadth of curriculum, higher-order thinking vs factual knowledge acquisition, long-term effects vs immediate learning outcomes, traditional roles of professors vs the roles of problem based learning tutors and student's discomfort vs their positive attitudes" (Hung et al., 2003).

There are those that are critical of problem-based learning, and even those practising it are acutely aware of the realities as reflected in the following excerpt where problem-based learning was implemented in the School of Nursing at the University of Salford, United Kingdom (Wray et al., 2004):

We have, together and separately, experienced that for some students and lecturers in nursing it is possible to be merely a passenger and non-compliant within the problem based learning process. Furthermore, that this position can be sustained for the totality of a three year nursing programme. In particular we have noticed a number of distinct and familiar features over the past three years of doing problem based learning, both as a facilitator and as students. The level

of engagement in problem based learning is extremely variable, across and within cohorts and the small problem based learning groups. In addition, a vast amount of energy is required, both physically and emotionally, to undertake problem based learning. In other words it is very labour intensive, potentially rewarding and consistently draining. The interactive and participative nature of problem based learning requires crafted skills in communication, evaluation, debate and analysis from the facilitator, ideally with practitioners and in practice. From our experience this can be a tall order for practitioners, student nurses and nurse lecturers and can be at odds with student nurses' main methods of learning, which is practice based".

Many arguments have been raised against problem-based learning, which may seem daunting. Some of these are:

- "Foundational knowledge are a precursor to problem solving", "problem based learning is a scam for poor teaching" (Knowlton, 2003).
- "It is a good idea but it will never work", "It is too much work", "I do not know the content enough to be a tutor". Some of these comments may have validity, but they may also be resistance to change and fear of the unknown.
- De Camargo Rubeiro (2005) found student feedback in general to be very positive although it was interesting to note that the monotony of repeating the same process over and over again resulted in a decrease in motivation.

In spite of this the value-adding possibilities of problem-based learning is worth investigating as a new teaching model for improving engineering education.

Problem-based learning's applicability to engineering education:

Problem-based learning has been investigated to determine its suitability for engineering education specifically (Perrenet et al., 2000). It has been implemented with success as an adapted form (called Design-Based Learning – DBL) in the Mechanical Engineering programme of the Technische Universiteit Eindhoven (Tu/E) in the Netherlands. They concluded that an adapted form of problem-based learning can be successfully applied in engineering programmes. However, the accent will be more on application and integration of knowledge than on acquisition of knowledge only. In engineering some topics are characterised by a hierarchic knowledge structure and complex problem solving. These topics cannot be approached without risk in a problem-based learning setting and therefore separate direct instruction and supervised practice are needed in different forms such as direct instruction of outlines, demonstration of expert problem solving, teacher-guided discussions and problem-solving tutorials with specially structured group work. They have also made a comparison of what they call their partial problem-based learning strategy at Tu/E with the overall problem-based learning strategy implemented in the medical programme at Maastricht University.

The comparison is summarised in Table 1:

<i>PBL in Maastricht</i>	<i>PBL (partial) in Eindhoven</i>
Knowledge acquisition	Knowledge application and integration
A case takes two sessions	A case takes about five sessions
A case is done in seven steps	Most steps within a case are repeated
A case has no concrete product	A case results in a report or a presentation
Moderate coaching in choice of literature	Strong coaching in choice of literature
The tutor has mainly a coaching role	The tutor has an assessing role too
Assessment is on an individual base	There is individual and group assessment
Self-study generally means reading	Self-study means a variety of activities
There are no separate subject courses	There are separate subject courses
There are few lectures	Courses have lectures and tutorials
Lectures support PBL	Courses are not directly related to PBL
Skills training is related to PBL	Skills training is embedded in PBL

Table 1 - Problem-based learning compared

3.5.3 Design-based learning

Perrenet, Bouhuijs and Smits (2000) showed that an adapted form of the well-known Problem- Based Learning (PBL) model may be the ideal model to apply in an engineering education environment. This is what has become the design-based learning (DBL) model at the Technische Universiteit Eindhoven (Tu/E) in the Netherlands. Tu/E has 5500 students and its eight departments offer 12 study programmes in engineering, including Mathematical Engineering. In its Institutional Plan for 1998 to 2001, the TU/e announced that it would develop a single university-wide educational philosophy for university-based training of engineers referred to as DBL.

The main motives for introducing design based learning were the following, namely to:

- improve the quality of education;
- increase the level of competence orientation;
- reinforce the coherence between education and research;
- strengthen cohesion and coherence within the TU/e; and
- achieve innovation of technical systems.

"Conforming to the needs of employers, the field knowledge of TU/e engineers has to go hand in hand with the ability to critically apply that knowledge in an industrial setting and in multidisciplinary teams of designers. The activity of designing is a central activity of professional engineers which occurs in many variations, such as designing products, processes, models, systems, structures, etc. It depends on the specific engineering discipline whether one should view designing more as creating, collaborating and integrating, making procedures or problem solving" (Perrenet, 2002). DBL can best be conceived of as a type of education with an emphasis on products, as well as the underlying process that are created within the framework of education (Van de Wouw, 2004).

The DBL model has the following six primary characteristics:(Van de Wouw, 2004):

- It is activating (active learning focus);
- it is co-operative (fostering teamwork);
- it is innovative and enhancing creativity;
- it is integrative (of theory to practice);
- it is multidisciplinary; and
- it leads to professionalism.

The DBL model also has the following educational process characteristics distinguished from the traditional chalk-and-talk, content focus way:(adapted from Gibson, 2003):

- Course curriculum – theory and applications are integrated, theory is introduced in the context of real engineering problems.
- Course structure – subjects are not compartmentalised anymore, but integrated across disciplines, especially when multidisciplinary design projects are done.
- Course emphasis – less focus on content delivery only, but a problem-solving approach to the design challenge.
- Course content and assessment – the learning outcomes determine the form of assessment e.g. presentations, meetings, portfolios, etc.
- Teaching style – from lecturing only to a student-active learning environment where group work, collaboration and the learning process are important.
- Student involvement – from a passive uninvolved individual student to an active learner and team player.
- Facilities – from a lecture room only to places where group work and collaboration for design interaction can take place, including appropriate facilities providing the necessary technological support needed.

On differentiating design-based learning from problem-based learning the following argument is presented: "To design is to solve problems, thus designing is a problem solving process" (Nelson, 2003). Whether design is thus perceived as a type of problem or whether any problem requires design activity is debatable

but not relevant to the development of improved pedagogical models. Designing and problem solving has the common goal of changing an existing 'something' or an existing 'situation' into a preferred one. Thus both designing and problem solving requires systematic processes that should lead to purposeful and practical outcomes. What is important is that both design and problem-solving competencies are required from graduate engineers (ECSA, 2004). Davis (1998) says:

Design experiences require students to move fluently among linguistic, visual and computational modes of thought in the solution of problems for which there are many right answers. Among those competencies developed when designing are the use and manipulation of information, the use and allocation of available resources, use of technology and systems, and use of interpersonal skills. Design activities develop the ability to enhance and transform ideas through the visualization, manipulation, and application of data to problem solving. Through design projects, students learn to reveal meaning in facts, to view the same information from many viewpoints, and to expose various dimensions of data through alternative forms of presentation. The role technology plays in that manipulation and application of data is increasingly important to work, but so is the development of technology itself. Design projects encourage the invention of new ways of doing work more efficiently and effectively, as well as the critical evaluation of technology in the service of ideas. Design activities provide a valuable tool for bridging the gap between theory and application.

Gibson (2003) also noted that "there has been an increasing emphasis on design activities within engineering education". Some universities actually call it "Engineering Design", teach it as a subject, and regard it as a very important skill the graduate engineer should possess, since "**design is at the heart of engineering** and is the activity which gives all other engineering tasks their meaning" (Thomas & Izatt, 2003).

At Tu/e the implementation of design based learning took place by the introduction of projects ranging from in-course projects to multidisciplinary projects across more than one department. This idea of projects being the process by which design activities happen most frequently leads to the next model investigated, namely project-based learning.

3.5.4 Project-based learning

One can have an interesting debate over the real differences between problem-based learning, design-based learning and project-based learning. One can argue that a project is always a problem in any case and will require design of some sort, or that any problem-solving goal is a project in itself even if it does not require design as such to solve the problem. From the literature surveyed there was no formal definition of project-based learning as a separate model. However, it is clear that project-based learning is *based on and thus very similar to problem-based learning* (Gibson, 2003). "Project-based learning is an ideal methodology for use in the engineering environment, since most 'real-world' engineering development is long-term project oriented" (Heckendorn, 2002). Any design activity can be viewed as a 'mini-project' in itself and therefore also supports the context for engineering application. Another differentiation is offered as follows: Problem-based learning focused on the process of inquiry and research, whereas in project-based learning an end product is usually the organising centre of the learning goal. This then results in differences in teaching and assessment strategies. Joe Oakey (FDTL, 2003), who has been described by some as "the father of Project-Based Learning in California", puts it this way: "Why should we care what we call it? Are the two the same? If we can develop a meaningful way for anyone, any age, to be challenged and to learn useful skills and knowledge as they answer the challenge, why should we care if it is called project-based, problem-based, or circus-based? We should be expending our energy on more useful questions."

The most enlightening literature found on the topic was the **Guide to Learning Engineering through Projects** (FDTL, 2003), where project-based learning is fully explained and described, and case studies and examples are provided, with the purpose being "to help those involved (especially the individual lecturer) in the teaching of engineering to implement or improve the use of projects in their work with students" (FDTL, 2003). The PBLE project's aims were to enhance engineering education by promoting and facilitating the use of project-based learning. PBLE was a consortium project, involving engineering academics from the

engineering faculties of the University of Nottingham, Loughborough University and Nottingham Trent University in the United Kingdom.

In the guide it is shown that projects used as a basis for implementing or using project-based learning can take many and varied forms, including design-and-build type projects, environmental impact assessments, production of a tender document, product analysis, etc. Projects differ and therefore different processes may be required to implement and use them.

Learning through projects requires:

- Support for the theory, the content and the *process skills* that are developed through a project. This variety of skills developed within a project should be supported through a diverse range of mechanisms.
- Support within projects from peers, project tutor(s) and students is critical to progress effectively and with the appropriate focus on both project and product outcome.
- The appropriate selection and structuring of groups (in the case of group projects it is essential).
- Effective work spaces are critical in order to make project-based learning effective. Some examples are project rooms that are studio environments, containing screen dividers, conference tables, swivel chairs and core project resources such as PCs and poster boards.

Throughout the case studies it is clear that, as with problem-based learning, the preparation and planning required from the lecturer's side are much more than with conventional teaching methods. Current engineering and technology degrees tend to be highly structured, with programmes biased towards the acquisition of knowledge. Project-based learning can enable students to develop inquiring and creative minds so that application, integration and deep learning take place.

3.6 E-learning

It is necessary to investigate the support information technology can give to the engineering education process, as one often reads how information technology has positively affected business processes in general. The education process (as a business process) can thus also be affected positively by the Internet, web-based education and information and communications technology (ICT). These concepts all encompass the principle of e-learning as investigated.

"What students learn must be related to what is required in the workplace" (Gibson et al., 2002). The content of what students learn as well as the **process by which they learn** can and should be workplace-related, or else the whole purpose of education will vanish, namely to place effectively functioning people in the workplace. ICT can serve the purpose of being the delivery strategy where the students are exposed to technologies that help them to be comfortable with the use of technology. It can also be the means by which they learn technology that is used practically in the workplace. ICT has up to now been used mostly for putting "lecture notes on the web to be available for students" (Gibson et al., 2002). This is definitely not the optimal use of IT in support of the education process. And as Sjoer et al. (2003) observed, "using an ICT platform does not necessarily imply educational renewal and improvements."

The Internet can provide a cost-effective and efficient learning environment, after the initial setup costs. It enhances project-based learning by saving both time, for students as well as lecturers, and the required resources to implement project-based learning. One of the greatest advantages of using technology is that there is no constraint on when one does the work. One underlying assumption that the implementation of ICT makes is that students are taking "responsibility for their own learning process and are considered to be knowledge and information intensive workers, and not just passive consumers of information." (Sjoer et al., 2003) At the Faculty of Technology, Policy and Management (TPM) at Delft University of Technology in the Netherlands, the uses of the e-learning environment include university-wide scheduling software, digital study guides, online assessment tools called Etude, tools and techniques for collaborative learning, even on an international collaboration project, and a document management system for project-based learning documents. In Korea a web-based, interactive virtual laboratory has been developed and implemented for use in the Chemical Engineering department of Seoul University to complement the physical laboratory

experiences as part of engineering education (Shin et al., 2002). Electronic mentoring programmes with the benefit of independence from time and geographic constraints are yet another example of the possibilities that exist for ICT to support the education process (Mueller, 2004).

Although some may regard on-line higher education as becoming a "Virtual University which supplies all the services of a conventional university but is supported and interfaced through Web- and Internet-based technologies" (Shin et al., 2002), the real value added by IT to education is still developing slowly. The National University of Ireland (NUI) in Galway (O'Sullivan, 2003) has designed and developed a unique infrastructure, or what they call pedagogical approach, in one of their courses appropriately called *Innovation Management*. They view it as 'project-based learning online'.

The approach makes use of a number of *online supporting elements*. The course has keynote seminars where the slides from such a seminar are put online to be available to all. Course notes are also available online. The lecturer is always available via email as the Online advisor, and there are case studies providing appropriate templates for use by students. Group work is done physically as well as via online collaboration. Lastly it is clear that assessment takes many forms, where online assessment is done of their case studies in progress, as well as oral and written assessment.

At TPM Delft University a survey was done to classify the different stakeholders' reasons for why they support certain tools. The stakeholders included students, teachers and support staff. It is interesting to note that the different stakeholders have different reasons for using different tools, but all agree that ICT can be of benefit to the education process. This is summarised below in Table 2.

<i>Tool</i>	<i>Students</i>	<i>Teachers</i>	<i>Support staff</i>
Online feedback system	It makes the assessments more uniform and transparent	It saves grading time and it will help enhance the uniformity of assessment among teachers	
Knowledge management system	It makes students less dependent on the teacher and gives opportunities for self-directed learning	It decreases the time that is needed to answer the same questions over and over, and fraud can be detected more easily	It is a possibility for making the knowledge base of the faculty more visible and less dependent on the coming and going of personnel
Electronic portfolio	Students do not directly feel a need to reflect on their own development or to show their achievements to others (unless assessed)	It gives insight to the entrance level of students and the development of students during the module. It can also aid in assessment processes	It enhances the visibility of project-based learning in the curriculum and the attention to student development
Electronic form for assessment of group processes	Students are sceptical towards review of group processes	It gives insight into the group processes, and it saves time in calculating individual scores	
Software to track fraud	Not interested	Teachers will be interested if this is possible	

Table 2 – Group reasons for using ICT analysed at TPM Delft University of Technology

An ICT-based assessment system is where the biggest possible benefit is for the lecturer. A well-designed assessment strategy can motivate students, and help teachers and institutions to support deep learning. For teachers, assessment is a key element of the didactic process, providing a mechanism for feedback and a means to encourage the practice of skills and techniques. Traditional grading and feedback are time-consuming activities. ICT systems can aid in grading and feedback activities to radically decrease time spent. However, it is crucial to design assessment activities to match the mode and purpose of learning (Heap et al., 2004).

Recommendations from literature when implementing ICT include:

- Remember/know that setting up an e-learning system is not a simple task. There are major challenges, including the development of course notes, online applications, and managing and supporting the online environment.
- Technical support is essential, but luckily most technical support staff will be glad to be involved and see this task as an interesting and valuable challenge.

-
- Once the environment has been created the benefits for academic staff and students are *significant*.
 - The assessment process is continuous and multifaceted and includes the opportunity to review student effort through a simple web browser. Online assessment can be carried out both regularly and at random.
 - Most universities have the technical infrastructure necessary for such project-based online assignments. What remains is the need for lecturers to see the learning opportunities that the Internet can bring – not only for campus-based students but clearly also for students based at home and work.
 - A key imperative for implementing ICT will be continued technical support for web-based technologies along the lines of the accepted need for technical support in traditional laboratories and workshops.
 - The implementation of ICT-supported innovations requires the full support of and substantial effort by academic professionals. This is not an easy process and requires a definite implementation strategy to achieve the desired results. Professional workers like to be involved in a process and will not change unless the change is seen to be imperative and to their advantage.
 - Substantial support and facilitation will be good, such as funding and technical support.
 - Thinking differently and reassessing one's teaching habits is not easy.
 - Tools are more easily developed than pedagogical content (Forte, 2005).
 - Getting started is a long and painful process and skilled people will be an asset (Forte, 2005).

Thus it is clear that information technology *can and should be used to effectively support* a project-based, or even problem-based, learning environment.

4 An engineering education process model

4.1 Business process modelling explained

The research was approached from the basis that an engineering faculty is a business with engineering education as its core business process. Thus a model of the engineering process was developed to define the elements of this process. The model also served as the basis for identifying improvement opportunities. "Understanding how processes work is essential to ensuring competitiveness of a company" (Chase et al., 2003).

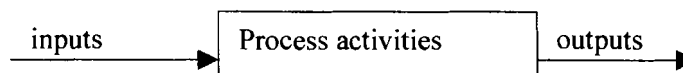
What is a process?

A key concept in business improvement initiatives is process improvement. However, it is a concept that is not readily understood by managers in general, since managers are focused on tasks, people, jobs, structures and outputs, but generally not on processes. A process can be defined as "the collection of activities that takes one or more kinds of input and creates an output that is of value to the customer" (Hammer & Champy, 1993). It is thus "a specific ordering of work activities across time and place with a beginning and an end and clearly identified inputs and outputs and structure for action" (Davenport, 1993).

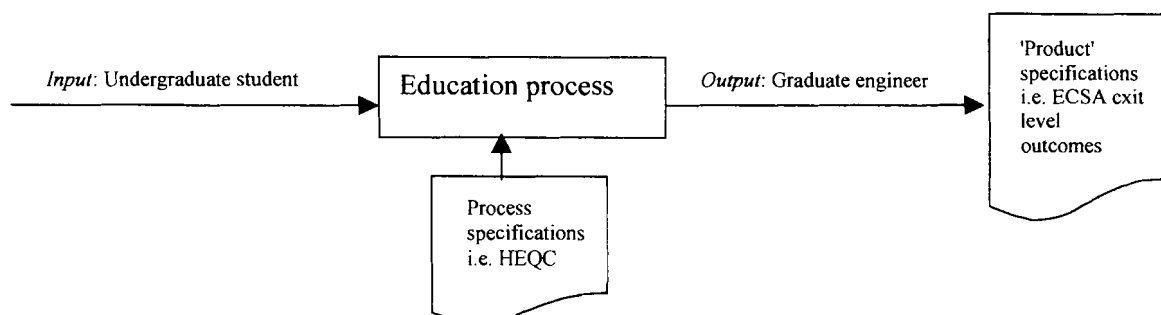
Modelling a process

A process can be modelled in different forms, of which flow charts and the like are well-known. The most important aspect of a model is not the technique used, but the fact that it is documented and visible to all who need and want to give input. A process model's goal should be to "facilitate understanding and never just to do problem analysis. It is better to present it simple than complex, with less detail than too much detail. As the conceptualization of a process develops so will the opportunities for improvement" (Institute of Industrial Engineers, 1994). Detailed information on processes can always be added as it is needed for better comprehension but care must be taken not to overanalyse the process just for the sake of it.

In its simplest form a process can be modelled as follows:



In a production environment the output or product must meet certain product specifications and the process must conform to process specifications. This analogy is translated and modelled simply for the engineering education process as follows:²



² The author wishes to acknowledge that other disciplines i.e. the educationalist viewpoint defines input in another manner. This model has been developed from a production process model perspective where all the inputs an educationalist will look for are included in the detailed definition of the process.

The Engineering Council of South Africa (ECSA) graduate engineer's exit-level outcomes as defined in the standard numbered PE-61 is the specification of what the NWU output (namely graduate engineers) should meet. On the other hand the Higher Education Quality Council (HEQC) provides a specification for programme accreditation that one can interpret to be the specification the education process should meet. With this as a basis, the model was developed further, as explained in the following paragraphs.

4.2 An engineering education process model

Like any other process, the engineering education process is in need of proper definition and understanding to enable analysis and improvement. The model was developed with the goal of a common interpretation of the logic of process activities. It was not the intention to develop a comprehensive detailed model indicating all possible activities.

No relevant model for the engineering education process was found in the literature surveyed. The proposed model was developed by using input from the literature and the principle of keeping it simple. The literature provided conceptual input. The reason for developing the model was that "by mapping a process it is possible to apply self-assessment tools" in order to measure the quality, effectiveness and opportunities for improvement of the process (Du Toit, 2001). The model was validated by discussing it with education experts and advisors from the university's academic support services group. It was also shared with the faculty's management group, consisting of the dean, department managers and programme managers. The model went through one iteration after a discussion workshop with faculty management. The initial proposed model for the engineering education process is shown in Figure 2. The model was restructured according to the three main categories under which the educational process can be clustered namely – educator, learner and programme. This condensed model as agreed upon after discussion with the faculty management, is shown in Figure 3. The model elements are briefly explained after the model diagrams.

This model or diagram enables one to understand the different aspects or *elements of the whole "system" or process of engineering education*. Customers may include the students, their parents, the university senior management, industry, government and society at large. In this model the main customer receiving graduate/postgraduate engineers has been seen as the industry, and therefore it should be the party consulted when determining the requirements or specifications for engineering education. It is assumed that the Engineering Council of South Africa (ECSA) is responsible for negotiations with industry, government and other relevant parties to determine what knowledge, skills and attitudes a graduate engineer should have upon completion of degree. The ECSA standards document [PE-61] can be found on their website (www.ecsa.co.za).

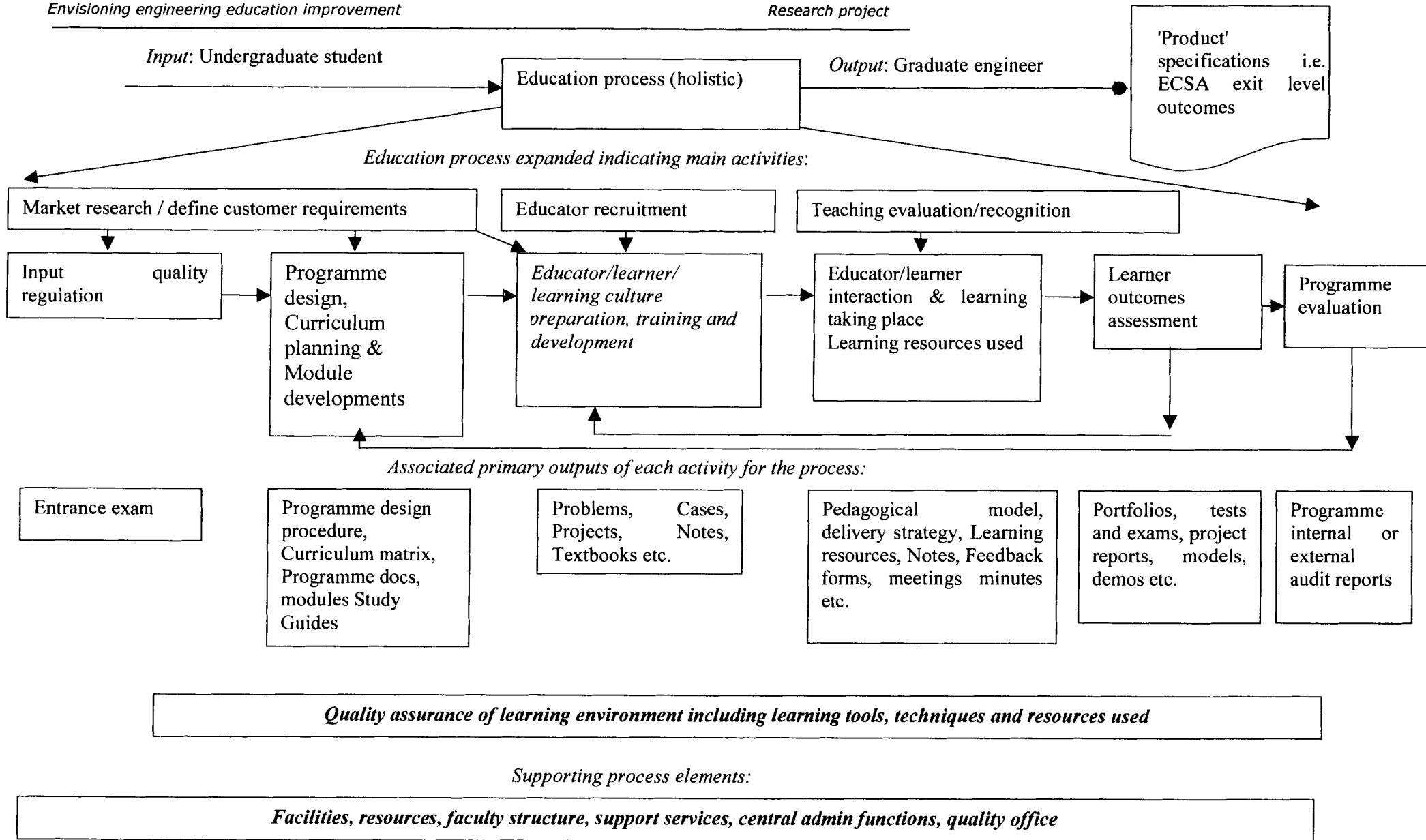


FIGURE 2 – INITIAL MODEL OF ENGINEERING EDUCATION PROCESS

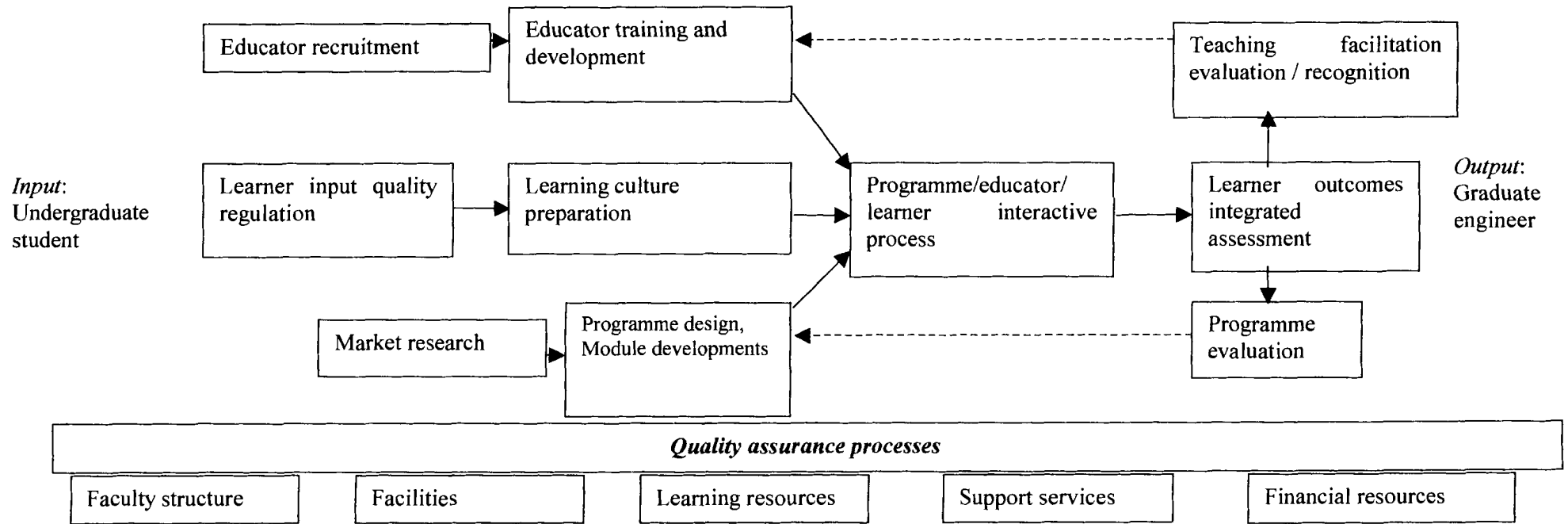


FIGURE 3 – AGREED MODEL FOR ENGINEERING EDUCATION PROCESS

The engineering education process consists of three lines of processes (educators' line, learners' line, programme line) interacting at one point (educator/learner/programme interactive process), where learning should be taking place. This implies that engineering education can only take place as long as there are educators, learners and a programme present, with no one element being more important than the other. The input is seen as the undergraduate engineer taking part in the learner line and when assessed and found to have achieved the learning outcomes, being granted the status of graduate engineer.

The quality assurance process should continuously engage with all the processes. The elements supporting the core process are the faculty structure, the facilities, the learning resources, support services and financial resources.

A more detailed description of the model elements and interactions is given below:

Market research – the process of getting information from the market receiving/employing graduate engineers where the intention is to understand our customers' needs and requirements better. ECSA acts as a negotiator between industry and government, and therefore liaison with ECSA is also an important aspect of market research. Market research includes getting feedback from employers on how NWU graduates are performing to act as input in the NWU's continuous improvement process.

Educator recruitment – the formal process describing the policies and procedures for recruiting and appointing lecturers (educator is the generic term used).

Learner input quality regulation – the process for assuring the quality of the entry learners into the programme, including policies on entry requirements and different entry routes.

Educator training and development – the processes for training the educators in their educating responsibility as well as for developing their capacity to fulfil their educating role. It is assumed that most educators in an engineering faculty are usually trained as engineers and not as educators, and therefore need training and development in this respect.

Learning culture preparation – the process of preparing learners for the higher education environment which is most likely different from what they are used to in secondary school. This includes supporting the learners in the learning environment, with special reference to supporting learners who are not adequately prepared.

Programme design and module developments – the process of designing and redesigning the programme continuously to improve according to changing circumstances and needs. At the highest level a programme is designed to meet the ECSA exit level outcomes as previously described. Thereafter the modules are developed on a more detailed level as a logical outflow of the programme outcomes.

Programme/educator/learner interactive process – the core activity or process where learning is taking place. This process include all interaction activity, such as lecture contact time, practicum, laboratory work, project work and even the learner interacting with the learning material in his/her self-study.

Teaching facilitation evaluation – the process of evaluating how effectively the educator creates a learning environment so that optimal learning can take place. It specifically does not refer to evaluation of a lecturer only.

Learner outcomes integrated assessment – the process(es) describing all the activities to assess the learning outcomes achieved by the learners as a result of the learning process. Integration of outcomes assessment is important in the outcomes-based education context, and implies the assessment of multiple outcomes in one integrated assessment activity.

Programme evaluation – the process of evaluating the programme against its objectives for continuous improvement purposes.

Quality assurance processes – the policies and procedures describing the quality assurance processes for the programme.

Faculty structure – refers to the organisational structure of the faculty and how it specifically supports the education of engineers process.

Facilities – refers to all physical spaces, lecture rooms, laboratories, study rooms and spaces available, including information technology support.

Learning resources – refers to all resources used during learning including study guides, textbooks, notes, feedback forms and software as needed.

Support services – refers to the administrative support given to the education process in the form of university-wide central services, such as class scheduling services and examination procedures, as well as faculty administrative support and advice on teaching and learning matters.

Financial resources – refers to the financial support provided to the education process.

The model shown in figure 3 served as the basis for communicating the process as well as forming the basis for analysis of the current process.

4.3 Current status of engineering education process

"Opportunities for improvement arise out of the detailed analysis of *current process operations*, and problems experienced" (Davenport, 1993). In order to analyse and improve a process Davenport (1993) (adapted) suggests the following activities in order to prepare for process innovation or analysis:

- Identify processes and determine boundaries.
- Describe/model current process and indicate relevant policies, attributes and characteristics (the status quo).
- Assess the strategic relevance of the process.
- Qualify the process culture and current problems.

This research study included all the above-mentioned activities. In the description of each model element for the current state, relevant policies, procedures, characteristics and problems within the faculty are referred to. The input was received from the North-West University Faculty of Engineering programme managers who took part in facilitated workshops to determine the current status of each element related to engineering education. Questions were asked relating to each model element to determine the status and identify opportunities for improvement.

"A common mistake is to undertake analysis at an inappropriate level of detail e.g. too little or too much. A process analysis' goal should be to enable processes to be understood, to be communicated and shared. A redesigned process should be vision-led. People also have a tendency to drown in details of 'what-is' and then become bogged down with incremental improvements at the expense of creatively thinking about wider issues and alternatives" (Coulson-Thomas, 1996). Thus the objective must always be born in mind when conducting an analysis. The purpose of the process analysis at North-West University Faculty of Engineering was to agree on the status of the current situation, process activities, problems and culture. The purpose was not a detailed statistical analysis and should be understood as being subjective and qualitative in nature.

In this section the current status as perceived and summarised by the researcher is described. The engineering education process model was used as the basis for structuring the measurement of the current status. The results are presented in groups per engineering education process model element.

4.3.1 Market research

Current status of model element

Process description: There are no formal processes for determining market needs in the faculty. None of the current interaction opportunities with industry are utilised effectively to capture market needs. It is assumed that ECSA liaises with the general market for engineers in South Africa, and will therefore provide input as needed, but formal contact with ECSA (also being a customer) is only done by way of the 5-year external audit cycle.

Policies and/or procedures: No formal procedures exist for capturing market information. Informal input is received on market needs by faculty who are involved in external industry work.

General comments:

- The market is not clearly defined.
- The concept of the engineering education process customer is interpreted in a variety of ways.
- Since most faculty members are involved with industry in some way, market research could be done relatively easily. Feedback from industry can also be received during final year projects to capture their needs, requirements, feedback, etc.
- Compulsory holiday work for students can also serve as a valuable source of input, but is currently not utilised.
- There is currently relatively low contact with alumni, also a potential source of input for market research information.

4.3.2 Educator recruitment

Current status of model element

Process description: The current recruiting policy focuses on recruiting professional engineers with academic or industry experience. Teaching experience is not regarded as essential or even necessary.

Policies and procedures: There is no formal procedure within the faculty describing the recruitment policies and/or processes for full-time and part-time appointments.

General comments:

- The status of professorship is currently awarded based on the university's central policy, which focuses on research output and not on development of teaching capacity.
- In general the current educators are all qualified engineers with both industry and academic experience.

4.3.3 Learner input quality regulation

Current status of model element

Process description: Current entry into the engineering programmes is based on matriculation grades only, specifically in Mathematics and Science. Within the faculty there are no explicit processes addressing learner quality issues once allowed to the university.

Policies and procedures: In the annually revised prospectus, admission requirements to an engineering programme are described.

General comments:

- The general perception in the faculty is that learner quality is low.
- Students have poor communication skills and language proficiency even on advanced level, where it is assumed that language will no longer be a problem. This is ironical in light of the fact that the university's admissions office requires a language proficiency test to be taken on initial entry into the university. If a student fails this test, he/she must take a specific course to address this problem.
- It would appear therefore that the support provided to address this problem is not adequate.
- The faculty has a programme that specifically supports previously disadvantaged learners who enter the programme. The faculty doubts the effectiveness of the programme.

4.3.4 Educator training and development

Current status of model element

Process description: The current definition of educator training and development includes:

- 1) The voluntary attendance of training workshops, apart from the workshop for new lecturers, presented by central Academic Support Services. These are not often attended by the Faculty of Engineering.
- 2) The attendance of conferences, seminars or workshops in specialised fields of knowledge, often outside the institutional structure. These are attended regularly by most faculty members.

Policies and procedures: There is no formal documentation describing policies and procedures to address educator training and development. There seems to be no co-ordinated effort to record faculty and/or individual staff training. Formal teacher training is not obligatory.

General comments:

- The quality of the training offered by Academic Support Services (as the education expertise central office function) is perceived not to be value-adding enough to motivate faculty members to attend.
- Academic Support Services offer support to individual educators as needed on an individual basis, but this service is not utilised effectively.
- Any research on engineering education improvement is done only on an individual basis out of personal interest, and in general is not encouraged.
- An attempt to improve communication and development are faculty colloquiums where individual research activities are discussed. These seem to focus on technical research only and do not include discussions on engineering education.
- Most educators see their role as that of being the teacher, with the main teaching activity being to give a lecture. There is no evidence of an internalised understanding of the principles of outcomes-based education, or learning theory.
- The current perception of the faculty's engineering education effectiveness is positive, with only a few individuals truly interested in improving the effectiveness of educating engineers.

4.3.5 Learning culture preparation

Current status of model element

Process description: There is a centrally co-ordinated compulsory "Learning and Reading" module in the first year with the purpose of equipping students with necessary learning/studying skills. Students are generally not appreciative of this module, and often report that it is a waste of time.

The first year module, Introduction to Engineering, does not appear to be effective in motivating students for engineering or even giving them a clear understanding of what engineering is about.

Policies and procedures: No formal documentation exists describing learning culture preparation.

General comments:

- No specific effort is put into attuning students to ECSA exit level outcomes as being the objectives of their study, and to brief them in what will be expected of them during the programme.
- ECSA exit-level outcomes are part of the study guides handed out to students, but faculty members complain that students do not read their study guides.
- There are no study counselling services within the faculty.
- Mentors (appointed from amongst faculty members) are available per year group to handle problems and issues as necessary.

4.3.6 Programme design and module developments

Current status of model element

Process description: Small changes are made on an ad hoc basis as the need is perceived by the programme manager.

Policies and procedures: There is no strategic, systematic or co-ordinated programme design process evident. There is no formal scheduled forum for discussing programme design or improvement.

General comments:

- There is no clear vision of the aims to be achieved with the programmes.
- There is no evidence of a real interpretation of the outcomes-based education objectives as specified by ECSA.
- Programmes are generally overloaded with module credits, especially when compared to ECSA requirements.
- Programmes are not focused on achieving ECSA exit level outcomes holistically.
- Modules are not integrated or designed to form a holistic programme and are not designed to achieve programme outcomes.
- The responsibility for module design is completely in the hands of individual lecturers, resulting in an unco-ordinated achievement of the programme objectives. This is very ineffective.
- The focuses of modules are on individual disciplines, with no multi- or interdisciplinary co-ordination evident.
- Some modules overlap in outcomes and even content.

Jawitz (1999) found that ECSA experienced similar problems in their earlier accreditation audits. They found that institutions failed "to address the issues around [achieving] assessment of programme outcomes", as well as around "producing quality assurance evidence". "Little evidence of a shift away from a focus on content to that of outcomes" was also found as "most faculties chose to only modify their existing programmes rather than redesign their curricula" when new accreditation processes were established that required faculties to provide evidence of quality assurance mechanisms (Jawitz, 1999). Programmes are still overloaded with content and modules/courses are still taught as individual topics in isolation from each other as a result of ineffective programme design processes. The programme lacks a big picture and it is clear that integration of skills is not planned effectively.

4.3.7 Programme/educator/learner interaction

Current status of model element

Process description: Currently the main interaction point is the traditional lecture, with the teacher at the centre of the interaction process. Laboratory and practical work are included in the programmes. These are pre-planned. The other main interaction of the learner with the programme is during self-study hours (all calculated as part of the module credits in study guides.) Some modules have group work included as part of contact time.

Policies and procedures: The study guides of all the modules describe the calculation of and logic behind credits and contact hours.

General comments:

- Class attendance is good in general.
- It is interesting to note that the final year project module is experienced as the biggest learning event during the programme, where no lectures are given, more one-on-one consultation with lecturers takes place and more practical work is done by the students themselves.
- Students tend to put more effort into this project than into any other module.
- A concern is the fact that educators are not aware of their colleagues' work, and generally work in isolation from each other.
- Apart from the scheduled hours per module, educators are in principle available to students for consultation.

4.3.8 Teaching facilitation evaluation

Current status of model element

Process description: The only formal process currently is the university-wide Teaching Excellence award made to teachers receiving a certain rating based on an evaluation by a panel as arranged by Academic Support Services. The intention of this prestigious award is to improve the quality of teaching at the university.

Policies and procedures: Within the faculty there is no formal reward or recognition for improving teaching excellence. However, it is faculty policy for teachers to volunteer for the Teaching Excellence award every three years.

General comments:

- A standard form is completed by the students at the end of every module to evaluate the teaching.
- This process is perceived to be ineffective in providing feedback to educators, as the feedback is standard and does not give specific information for improvement.
- The feedback is also usually given to the lecturer long after a module has been completed, and this is only done in instances of very negative feedback being received.
- Educators and management do not evaluate each others' performance.

4.3.9 Learner outcomes integrated assessment

Current status of model element

Process description: Assessment of modules takes place primarily via class tests, a written semester test and a written final exam. Practical laboratory work is also assessed. Grades are assigned with specific percentages (0%-100%). The pass grade for all modules is 50%. The final-year project is the only module where alternative assessment includes the measurement of milestones as stipulated in the study guide.

Policies and procedures: The study guides for all the modules specify the assessment methods for the individual module.

General comments:

- The required ECSA exit-level outcomes are not interpreted for the programme as a whole or even on module level, and are therefore difficult to assess on an individual module basis.
- Assessment criteria per module outcome are not clearly defined for all modules.
- There is no evidence of integrated assessment that is obvious, except in the final-year project.

4.3.10 Programme evaluation

Current status of model element

Process description: The current programme evaluation is done informally, only as required and usually to address only certain aspects of the programme. It is not a coordinated effort or part of an improvement strategy.

Policies and procedures: No policies or procedures exist for programme evaluation within the faculty.

General comments:

- Individual modules are usually evaluated in detail, but not the programme as a whole.

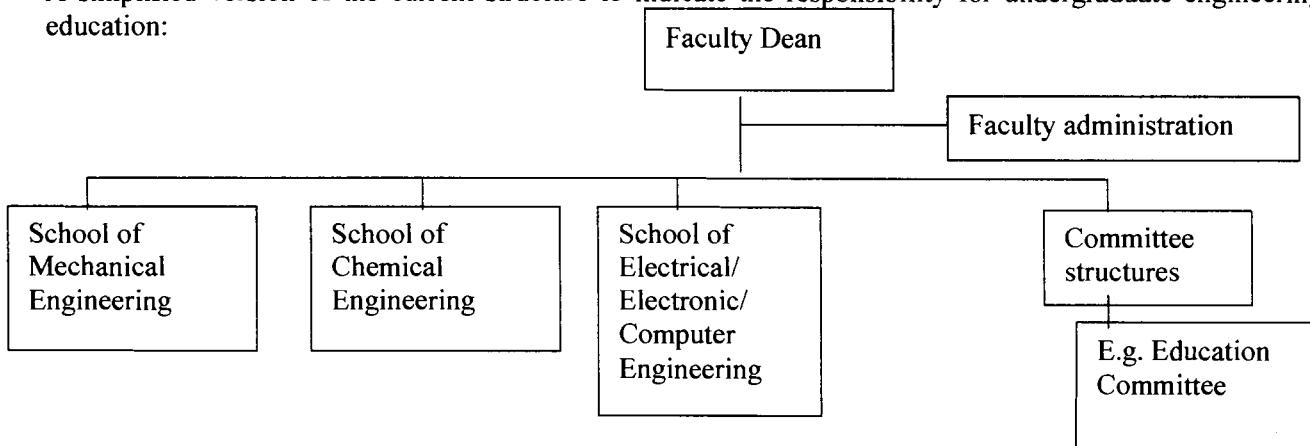
4.3.11 A quality system for the faculty

<p>Current status of model element</p> <p><i>Process description:</i> The current definition of quality as part of education only entails assuring the quality of the examination papers. For this process, internal and external examiners are appointed with the responsibility to provide feedback on the examination papers for every module presented every year. On programme level, ECSA conducts the formal external quality audit once every five years.</p> <p><i>Policies and procedures:</i> There are no formal quality system policies and procedures for the undergraduate engineering education process within the faculty. Informal quality processes exist for module examination evaluations.</p> <p><i>General comments:</i></p> <ul style="list-style-type: none"> • The set of ECSA quality standards are not interpreted fully enough to reflect implementation of quality assurance objectives for the programme as a whole. • On university level there is a central quality office function co-ordinating self-evaluation processes per programme every four years. • This is subordinate to the ECSA audit process.
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4.3.12 Faculty structure

<p>Current status of model element</p> <ul style="list-style-type: none"> • The current structure reflects a decentralised professional bureaucracy with departments (named schools) and ad hoc committees for project work. • Three schools are arranged according to traditional engineering disciplines i.e. Mechanical, Electrical and Chemical Engineering schools. Schools have a director responsible for managing the school's administration, human resources (average 12-15 people) and finances. • Directors also function as programme managers, researchers and educators and therefore experience workload pressure. • An organisation structured according to schools does not encourage cross-disciplinary work.

A simplified version of the current structure to indicate the responsibility for undergraduate engineering education:



4.3.13 Facilities

<p>Current status of model element</p> <ul style="list-style-type: none"> • In general the lecture halls and facilities are adequate and well equipped. • Laboratories are perceived by faculty members to need more equipment for improved practical work. • There are no suitable venues for collaborative design and group work. There is no space available to create such venues either. • The current electronic networking and software facilities are adequate to support the current process.

4.3.14 Learning resources

<i>Current status of model element</i>
<ul style="list-style-type: none"> • All modules have study guides in which module outcomes are defined in terms of knowledge, skills and values. • The development and improvement of study guides is a formal process co-ordinated by a central Academic Support Services function. Continuous improvement of study guides is the responsibility of the individual lecturer. • Many learners report that the current study guides are of little use. Some do not even bother to collect them from the study guide depot. • The learning resources per module mostly include a textbook(s), notes from the lecturer and references to other material.

4.3.15 Support services

<i>Current status of model element</i>
<ul style="list-style-type: none"> • Support services for all faculties include central administration support provided by the university in the form of module registration, scheduling and managing the grading system. • All schools have administration support in the form of a secretarial function. • The dean's office also provides some central administrative functions in support of the schools.

4.4 Investigation of selected European engineering education processes

With the background on engineering education improvement initiatives and a concept of the current status of the faculty's education process, a research visit was planned to investigate the engineering education process of selected European universities. The intention was to learn from others who have already made improvements to their engineering education effectiveness.

The main objective of the visit was to investigate other models or processes of engineering education with the specific focus on getting more information on *improvement implementation strategies*. The visit confirmed that learner-centred strategies have been implemented with success.

The following universities were visited:

<i>University name and country</i>	<i>Improvement initiative implemented</i>
Chalmers University of Technology (Gothenburg, Sweden)	Implemented CDIO as an engineering education improvement model. Investigated their facilities for active learning and first-year Design-Build course (integrated multidisciplinary team projects)
Royal Institute of Technology (Stockholm, Sweden)	Implemented CDIO as engineering education improvement model. Investigated their facilities for active learning and final-year Design-Build course (integrated, multi-disciplinary team projects)
Technische Universiteit Eindhoven (Eindhoven, the Netherlands)	Implemented Design-Based Learning (DBL) as pedagogical model for engineering education. DBL is based on the problem-based learning model.
University of Twente (Enschede, Netherlands) Faculty of Engineering Technology	Implemented ICT in support of their successfully implemented Project-Led Engineering Education (PLEE) for their engineering education
Delft University of Technology (Delft, the Netherlands) Faculty of Mechanical, Maritime and Materials Engineering	Implemented e-learning in a project-based learning environment -- electronic learning environments

Table 3 – European universities visited as part of research

The universities were chosen on the basis of a number of factors:

- A conference on CDIO provided motivation to visit universities who have implemented CDIO in Sweden.
- The geographical location of the universities in the Netherlands near to Sweden included them on the list.
- The availability and response of contacts.
- The relationship of the North-West University to some of the universities in the Netherlands.

In retrospect, it is felt that the universities visited were a good selection, providing enough input for the purpose of this study.

Some general comments regarding the visit:

- The standard European programme for attaining an engineering degree was a five-year programme consisting of a three-year preparatory phase followed by a two-year master's programme, resulting in a Master of Engineering degree obtained by all students completing the programme. With the introduction of the Bologna agreement in Europe, the degree will now be split into a three-year Bachelor's Programme followed by a two-year master's programme. Most students complete the master's degree even though it is not compulsory.
- In Sweden, all education is free.
- In both Sweden and the Netherlands, universities of technology specialise in delivery of engineering education. The higher education institutions responsible for educating technicians are called polytechnics, similar to South Africa's universities of technology (former technikons).
- The University of Twente has implemented an engineering education process model most suited for adaptation to the NWU's circumstances. Their model, known as Project-Led Engineering Education (PLEE), has been in operation since 1995. It is a form of student-centred active learning with specific focus on using projects as a basis in the design of the programme.
- Although much information was received on programmes, modules and quality assurance procedures, documented information on implementation strategies was not adequately available. Most of the information on implementation strategies was received verbally from interviewed staff members.

Again the engineering education process model elements will be used to structure the summary findings.

4.4.1 Market research

Status: Europe

Process description: No formal market research activities were evident. The interviewees said that they continuously received input to improve their programmes via an active informal network with industry and alumni, as they are involved in research activities.

An advisory board serves the purpose of providing input to the programmes (at all Dutch universities). This board consists of faculty members, other disciplines' faculty members, alumni and industry representatives.

General comments:

- In Europe there is no statutory body regulating professional standards of education for the engineering profession, or serving the purpose of liaising with industry on behalf of education institutions.

4.4.2 Educator recruitment

Status: Europe

Process description: In Sweden a new law requires that criteria for the appointment of tertiary educators must include teaching experience (a minimum of 10 weeks) before an appointment can be made. This brings about a new focus on the importance of teaching status, and not only professional status, in the engineering educator profession's recruitment policies.

General comments:

- The policy regarding recruitment of educators is similar to our policy of recruiting.

4.4.3 Learner input quality regulation

Status: Europe

Process description: In both Sweden and the Netherlands the requirements for entering the technical universities are a certain level of mathematics, science **and English** as secondary language. They do not experience problems in language proficiency, as all their bachelor's programmes are offered in their home language.

General comments:

- Their programmes are structured such that early termination of learners who under-perform can already take place during the first year.
- This process is formal in that a student receives a letter advising him/her to investigate other education opportunities. Agreements exist with the local polytechnics to allow such student to continue their studies immediately.
- This ensures that higher-quality learners are retained, and throughput is increased as a result.

4.4.4 Educator training and development

Status: Europe

Process description: All universities had a similar service centre at a central position delivering academic/education/teaching services in support of teaching staff. One is called the "Learning Lab" (KTH) and was the only centre doing specific research on engineering education. These service groups were always a respected part of the implementation of a new pedagogical model and provided significant support to the change towards a new model.

General comments:

- All educators are **continually** trained by the service centres in specific skills as needed to support the pedagogical models such as Design-Based Learning (DBL) or Project-Led Engineering Education (PLEE). This training is compulsory.
- The general attitude of the educators to this training is extremely positive, as they have obviously experienced value-adding training and development.
- Continuous upgrading/adjustment of these courses take place.
- Tutors or teaching assistants (who are not only postgraduate students but also lecturers) are abundantly used everywhere and are essential to the implementation of DBL or PLE. Tutors are also continuously trained by the support centre as well. The training often counts as credits toward an education qualification.
- Research on engineering education is not done formally (except for the Learning Lab). Research on improving engineering education is done on a personal interest basis by faculty members.
- All interviewees mentioned that in changing to a new model, there were difficulties encountered with educators having a difficult time changing into their new roles as tutors.
- All advised that providing them with adequate training and development support would be critical in changing to a new model.

The Learning Lab's 30 hour course (over 10 weeks) for lecturers is very practically oriented, as it is designed to enable a redesign of the module the lecturer is responsible for.

4.4.5 Learning culture preparation

Status: Europe

Process description: They have a very active student association that provides induction to new students within the engineering programmes. A central student centre provides some of the general training necessary to support the project-based learning models.

General comments:

- At Chalmers University, "Introduction to Engineering" is a very prominent module where the intention is to prepare the students for the learning environment, where it will be expected from them to design and build products, and to work in groups as part of their projects. This module is applauded for its successful preparation of students for the academic process of the following years.
- General support for students to cope in the pedagogical model is provided in the form of contact time with lecturers, tutor roles and study counsellors.
- Lecturers are available daily as most of them are not involved in industry work outside campus.
- Tutors include senior students providing more personal support to students on a needs basis.
- Study counsellors are available fulltime for students to support them with respect to emotional, psychological and personal needs. These counsellors are associated with specific faculties.

The Introductory course at Chalmers University of Technology has the following objectives:

- To provide a clear overview of the different fields of engineering (or a specific discipline like mechanical engineering). It should also aim at least to explain integration of disciplines.
- To introduce the essence of engineering work.
- To teach the processes of design and development of new technological products.
- To give students confidence in handling basic tools and theories that will follow.
- To motivate and excite students about the field of engineering.
- To increase students' awareness of the importance and necessity of analysis for finding optimal solutions for engineering problems.
- To acquaint students with the faculty or department.
- To familiarise students with different aspects of engineering expertise.
- To provide the context or big picture overview of the engineering curriculum.

Additional reading material is available if the reader wishes to learn more.³

A interesting phenomenon is that special attention is always given to first-year students by having well-trained and *experienced tutors* assisting the first year groups. These tutors guide the development of the students' process skills (how to do a project, how to work in a group, handling conflict) by having a weekly meeting with their own group, typically only 5-8 people. So the tutors get to know the students well. Apart from these tutors every year group has a study counsellor as well to consult in case of emotional, stress or other psychological problems. Tutors are expected to help students make appropriate career decisions after the first semester, for example to rather go to a polytechnic if the student's progress has been inadequate. Such a recommendation is taken seriously and confirmed by a formal letter from the university administration. The attention given to first-year students is quite radical but rewarded in the benefits gained further along the course. At Twente it is believed that a student must be exposed to a different mode of working from day one in order to develop the self-discipline necessary for further study success, thus they treat the students as responsible adults from day one. Thus, the group project students in the first semester are allowed to choose their own group members.

³ Literature providing more detail is available e.g. *Towards a new model for first-year introductory courses in engineering education programmes* (Gustafsson et al., 2002), *Implementing the project based learning approach in an academic engineering course* (Frank et al., 2003), *Experiences from the transformation of an engineering education introductory project design course into a project design-build-test course* (Gustafsson, 2004) and *What kind of project in the basic year of an engineering curriculum* (Raucent, 2004). The report on *Recommendations to address barriers in CDIO project-based courses* (Soderholm et al., 2005) also provides a valuable checklist to use in development of project-based courses.

4.4.6 Programme design and module developments

<p>Status: Europe</p> <p><i>Process description:</i> Their bachelor's programmes are very foundational with a strong focus on mathematics and basic engineering sciences only. Quite often the programme entails only two or a maximum of four courses running concurrently during a semester. (This is very different to the NWU faculty's five to six courses running concurrently during a semester). The specialisation knowledge and skills are part of the masters programme.</p> <p><i>General comments:</i></p> <ul style="list-style-type: none"> • Programme design is a prominent activity and the responsibility of the Programme Director (or Director of Education) is a position with a high status. • The Programme director has a detailed knowledge of every course within the programme and provides strong leadership in the programme design activities. Often (s)he is the person responsible for making changes, and this responsibility is seldom delegated to individual lecturers. • This function also acts as the chairman of meetings where individual courses are discussed. • Project-based learning is implemented complimentary to basic discipline courses, as big project themes where students are usually designing, building and testing a product of some kind. • The variety of cross-disciplinary specialisation fields available at faculties were of particular interest, as often these provided ideas for projects and problems used in the programme. • The credits or points used in the programmes to calculate work effort per module compared well with the NWU faculty's total credits per semester. • A programme board consisting of the Director of Education and faculty members meet weekly with programme improvement as the core agenda. • As a result of these regular meetings, modules are therefore seldom developed separately from each other as the process is seen to be interactive and co-ordinated.

All the universities mentioned in this study had been visited by the American Board for Engineering and Technology (ABET) to audit their international comparability. All were found to be on standard.

A very important recommendation from one programme director was that programme design is a critical success factor in a successful implementation of project-based learning. The effort needed for an effective programme design should not be underestimated. Project theme leaders co-ordinate projects across programmes and across year groups, to enable the programme director to focus on his/her primary responsibility of programme design and improvement.

4.4.7 Programme/educator/learner interaction

<p>Status: Europe</p> <p><i>Process description:</i> Most of the programmes still have a strong lecture-based focus on the basic (e.g. Mathematics) courses. The exception to this is the University of Twente, where traditional course work comprises 40% of the programme and the other 60% consists of projects.</p> <p><i>General comments:</i></p> <ul style="list-style-type: none"> • Most of the programmes observed included definite active learning components. • Often courses are designed as complete projects, and these courses run every year from the first to final year.
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It is a fact that the "developing and running of project courses (especially if it includes elements of design, build and test activities) is more complex than course development alone" (Malqmvist et al., 2004).

The final-year project is one of the most important courses presented during a programme and should have at least the following objectives:

- To enable integrated assessment of some exit-level outcomes.
- To be the culminating design experience, preferably as industry-inspired big projects (Raucent, 2004)
- "Project work in the senior year should be used as a means of teaching research methodology and as a means of doing research" (Kgaphola, 1999)

4.4.8 Teaching facilitation evaluation

<p>Status: Europe</p> <p><i>Process description:</i> Formal questionnaires are submitted to students to complete at the end of every course. They have found that interviews are more effective and that at most of the universities the interview process is preferred to get feedback from students. Often these interviews are held during the course presentation to change or improve the course for that specific group, and not only afterwards.</p> <p><i>General comments:</i></p> <ul style="list-style-type: none"> • At Chalmers University students form their own groups for evaluation purposes. This group has a formal meeting to discuss the course, then they write up a formal report that goes to the lecturer, programme director and dean of the department. • Evaluation reports are filed and actions to improve followed up.

4.4.9 Learner outcomes integrated assessment

<p>Status: Europe</p> <p><i>Process description:</i> Assessment includes tests and examinations for the traditional lectured courses. For the project courses, a variety of assessment methods are used, such as project management required documentation and a technical report, together with the working product or deliverable as built by learners themselves. As these projects are usually of an interdisciplinary group work nature, integrated assessment is easier.</p> <p><i>General comments:</i></p> <ul style="list-style-type: none"> • In a number of courses, the students are presented with the outcomes at the beginning of the course. It is then expected of them to understand these goals of the programme and they are responsible to build up enough evidence themselves to prove they have met the outcomes during assessment sessions. • In some cases the students themselves define the outcomes, the assessment criteria and the grading system for a specific course (KTH). This method of defining their own assessment criteria is also encouraged in group evaluations. • In the project courses, an evaluation always includes grades (or marks) from a lecturer, the group members and often also self-evaluation grades. • The grading systems used are simple, with usually only a pass or conditional pass or fail grades. Sometimes these are translated to a grade A–E or 0–10, but none have a percentage grading system.
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4.4.10 Programme evaluation

<p>Status: Europe</p> <p><i>Process description:</i> At all the universities there are weekly meetings between the programme director or Director of Education, study counsellors and students to ensure that problems are addressed during the programme. A formal annual evaluation is done at Chalmers University, where all educators involved in a programme go away for two days to discuss and improve the programme. This meeting also serves a team-building purpose.</p> <p><i>General comments:</i></p> <ul style="list-style-type: none"> • A strong sense of continuous improvement is apparent amongst the lecturers spoken to.

A very interesting observation was how the faculty at Twente involves students in almost everything they do that has to do with evaluating, improving or changing the programme. This indicates a lot of trust in the students' capacity to add value, and it is also a good example of how they perceive the students to be their primary 'customer'.

4.4.11 A quality system for the faculty

Status: Europe

Process description: The University of Twente has a formal quality assurance system, describing policies and procedures for ensuring quality within courses and of the programme as a whole. In the other universities visited no evidence of a formal quality system existed. An informal system of peer review in the matters of both programme and module improvement was obvious. There are a number of forums where peer input are gained, i.e. programme management meetings, module development meetings and learning areas meetings.

General comments:

- The responsibility for quality assurance at Twente is with an individual working closely with the programme director.
- At the other universities, the colleagues take up their responsibility in peer review functions when meeting to discuss programme and module development.

4.4.12 Faculty structure**Status: Europe**

- The most important observation was that a very formal function with programme management responsibility exists within the structure.
- The position and status of programme director or director (or even dean) of education, is very obvious in the organisational structure. This indicates that programme management receives priority attention.
- The faculty structure supports the core processes of a typical faculty such as research and education.
- Lecturers are part of theme/subject-related groups, each with a group leader who reports to the programme director.
- Subject group meetings are held weekly and together with formal programme meetings also serve as a forum to discuss programme design.
- All directors of education are engineers by profession, with the exception of Kees Ruijters at Twente, who has exceptional personal experience in the field of teaching and adds tremendous value to the maintenance and real implementation of Project-Led Engineering Education at the University of Twente. This factor was perceived to be critical to a successful implementation of a different pedagogical model.

4.4.13 Facilities**Status: Europe**

- Facilities are critical to the support of the students' group work, project work and design and build type projects.
- The facilities most utilised by the students do not entail high investment (such as laboratory equipment), but rather suitable spaces to encourage them to work on campus.
- Facilities observed included computer labs (where laptops were not used), plug points, coffee/food counters, leisure lounges, lockers for laptops, with power supply, enough spaces to get together and work, including movable tables, chairs, whiteboards and screens.
- The use of laptops by all students at University of Twente was definitely an eye-opener to the benefit and support that information technology can give to the engineering education process. The students buy the laptops from the university, resulting in an effectively smaller capital investment for the institutions than expected.
- The design of the University of Twente's wireless area network with access to the web provides a new dimension to learning as one sees how the students work together informally.
- Extensive use of the internet to provide the central one-stop facility for learning resources (as provided by lecturers online) have been obvious.
- At one university, lectures are videotaped and the lecture then put onto the web for review purposes.
- All agreed that the implementation of ICT was critical to the success of the project-based learning models in the support it provides to students. However, it is not the primary delivery mode of learning.

It was most enlightening to observe how many students were continuously around the campus actually working because the facilities were there for them to work at. Students were sitting in project group rooms,

multifunctional rooms and even in the cafeteria on their own, working on a project or course work. Twente stated it was their goal to have students working 8 hours per day 5 days per week, and this seems to be achieved.

4.4.14 Learning resources

<p>Status: Europe</p> <ul style="list-style-type: none"> • At all the universities visited, learning materials and study guides are put onto electronic 'study portals' or Learning Management Systems (LMS). • Students can enter these portals anytime and the information is kept updated with lecturer notes, messages and/or learning material. • Study guides are usually not distributed as printed copies but are only available electronically, therefore students use the internet extensively in learning.

4.4.15 Support services

<p>Status: Europe</p> <p>Since most of the European universities of technology are providing only technically related degrees, the concept of faculty differs from the South African definition. Their faculties are specialised areas of expertise offering specialised degrees. Within each of these faculties, departments are provided with financial and administrative support services. This gives the impression that they have more than enough support services available to run the programmes effectively.</p>

4.5 A vision to improve engineering education

This study has thus far defined the current status of engineering education at NWU and provided an investigation within the context of selected European universities. The formulation of a vision for improved engineering education at the NWU will be dealt with in this section. Again the engineering education process model elements provide the structure. Conceptually the vision will include implementation of a form of student-centred active learning to suit the NWU's own unique circumstances to improve engineering education at NWU. In an engineering education environment, this may result in being a form of project based learning.

4.5.1 Market research

<p>End status vision</p> <p><i>Vision statement:</i> Faculty programme management is provided with sufficient market information. This enables management to plan programmes strategically in order to meet the needs of the market effectively.</p> <p><i>Supporting statements:</i></p> <ul style="list-style-type: none"> • The market information is provided following market research procedures with a system to effectively capture, organise and analyse the information received. • The creation of an industry co-operation group within the structure, with the specific function of obtaining market information supporting the market research process. • This group's primary function is research work with industry, with an added responsibility for liaison with ECSA. • This group has close contact with real engineering issues, providing valuable input to projects for a project based learning environment. • Market information provides input for curricula and programme development. • The market research process makes provision for obtaining input from students and alumni on programme effectiveness. • An industry co-operation and market research team in the faculty organisational structure allows formal and effective processes leading to a better understanding of the NWU's customers and their
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requirements.

4.5.2 Educator recruitment

End status vision

Vision statement: Educator recruitment is based on both professional skills and teaching skills, combined with a willingness to learn.

Supporting statements:

- Recruitment policy and process are defined as part of the quality manual.
- In a new model, good tutors (as coaches/mentors and guides) are more important than good teachers (with expert content knowledge) thus the required knowledge, skills and experience for future positions may change.
- Within the national framework, employment equity goals will also have to be taken into account in developing recruitment policies.

4.5.3 Learner input quality regulation

End status vision

Vision statement: Programme admission requirements are defined more widely than scholastic performance in Mathematics and Science, including language proficiency and engineering aptitude.

Supporting statements:

- Special support is given to students who are not sufficiently prepared, focusing on also enabling language proficiency and not only technical competence.
- More effective processes are in place for identifying, supporting or counselling learners who are not performing according to expectations as early as possible in the programme.

Popular opinion is that language proficiency is critical for the education process, as well as for a successful career in engineering. Entry exams may be investigated as an option to screen admissions. This might become necessary, since it is believed that the value of a matriculation certificate (Further Training and Education Certificate as from 2009) will become of lesser importance in future (De Vries, 2004), thus necessitating another test of knowledge and skill than the matriculation examinations. According to Park (2003) the secondary school sector's performance is not helping the tertiary education sector with their low performance, forcing tertiary education to become all the more involved in supporting the school sector with appropriate academic support processes for candidates not sufficiently prepared. In addition to this, the numbers of candidates suitable for entry into engineering programmes are generally very low, thus making the challenge of ensuring high input quality all the more difficult.

4.5.4 Educator training and development

End status vision

Vision statement: Faculty members are trained and developed to fulfil their responsibilities in both research and teaching more effectively.

Supporting statements:

- Respected training is provided, which successfully equips educators to fulfil possible roles as tutors/guides.
- Ongoing training and development are provided to ensure continuous improvement as well as to ensure high-quality curriculum study guides and assessment techniques. This training should focus on helping faculty members internalise outcomes-based education.
- Research and publication on engineering education are a formal requirement for faculty members.
- Effective training and development are reflected when educators view and execute their roles as 'facilitators' of the education process, rather than 'knowledge experts' only.

Major paradigm shifts will have to be made by faculty members to fit into their new roles as tutors in a new organisation structure. Knowledge will have to be gained, by self-learning, from workshops, training sessions and from input by support services. Mentoring support will play an important role in the changes people need to make when implementing the new model. A dedicated education consultant to the faculty might be considered in the new structure. At the University of Cape Town Faculty of Engineering their education development officers act as catalysts for change in their curriculum reform project (Fraser, 1999). At University of Twente their education consultant provided continuous training and assistance for two years during their implementation of project-oriented education (Ruijter, 2002).

The true impact of a new model of teaching-learning should not be underestimated. It will be necessary for faculty members to truly acquaint themselves with the National Qualifications Framework (NQF) terminology, outcomes-based education (OBE) principles, teaching and learning philosophies, CDIO strategies and details, and the principles, techniques and tools of active learning. This will require time and effort and will require the willingness to change. As Jawitz (1999) pointed out, "difficulties associated with assessment, workload and personal assistance to students to achieve mastery levels in learning outcomes should not be underestimated."

4.5.5 Learning culture preparation

End status vision

Vision statement: Learners are effectively prepared for a learning environment in which they will take responsibility for their own learning

Supporting statements:

- Learners will most probably not be enabled to take responsibility for their own learning, and therefore the support that students will need should not be underestimated.
- Tutors (who may be senior students) as well as mentors will fulfil a critical role in supporting students, especially during the first years.
- The first-year, first semester "Introduction to Engineering" course will have been adapted to stimulate a hard-working attitude, motivation to continue and will incorporate a real hands-on design-build-test project experience.
- This course will be taught to all first-year engineering students.
- This first project will be perceived as being difficult, challenging and not easy to pass, as this should serve as an induction to the 'world of engineering' as well as the 'world of learning about engineering'.

Changing to a new pedagogical model has a big impact on students, and will be a big factor in determining the successful implementation thereof. It is therefore recommended that it should be ensured that students are prepared and equipped for their role in taking responsibility for their own learning in a new pedagogical model by induction, orientation, training sessions and the like on topics like active learning, time management, teamwork and project management.

4.5.6 Programme design and module developments

End status vision

Vision statement: Strategic, co-ordinated and effective programme design and development take place continuously, resulting in a clear understanding of the programme goals, focus and objectives by all stakeholders involved, especially students. The programme outcomes continuously drive the curriculating and improvement processes.

Supporting statements:

- The outcome of a programme design process is reflected in relevant, updated programme documents that include all information on exit level outcomes and the logic or rationale of the programme design as well as indicate relationships among courses.

- In terms of the model envisioned **problems** and **projects** are driving the 'modules'/themes and not isolated knowledge concepts.
- The programme is simplified to focus on the core sciences necessary to meet ECSA exit-level outcomes with additional courses on 'learning the process' more than 'learning a body of knowledge' or content focus.
- Meetings or forums are held to discuss programmes and/or modules, both formally and interactively, so that duplication and overlap will be minimised, and cross-training achieved.

The most critical change to the NWU's current process will be the implementation of a more effective programme design process. Pearce (1997) recommended a "*radical restructuring*" of an engineering curriculum to enable flexibility as South Africa's future will be met by diversity, not uniformity. To simplify the programme a major curriculum review/redesign exercise of all current programmes will have to be done. Envisioned is a curriculum focusing on "transferable skills and conceptual knowledge and on process rather than detailed content" (Pearce, 1997), as well as "a multitude of student projects, a pedagogic model that supports active, experiential and group learning, a varied learning environment with classrooms, workshops and the outside world as well as a continuous improvement process" (Gustafsson et al., 2002).

It is recognised that most current curricula are inherited, making it is nearly impossible to really think creatively about a new curriculum. A top-down programme design process (as if starting a new engineering programme) may add value to explore potential improvement opportunities. To drive the process top-down the ECSA's exit-level outcomes should be the starting point, but then these outcomes should be clearly understood by all faculty members and interpreted within modules. These outcomes are defined in its *Whole Qualification Standard for Bachelor of Science or Bachelor of Engineering programmes*. (ECSA, 2004). Modules/courses should follow from these outcomes. A 'blank page' design process is recommended. Within a project based learning model **multidisciplinary problems, designs** and **projects** should serve as the starting point for the 'modules'/blocks of the curriculum, thus the challenge will be to develop these problems and projects. The content-focused subjects should be done away with, especially loose-standing subjects not contributing towards achievement of the exit-level outcomes. The design of the project sizes and themes will be crucial and need to be interactively developed between teaching and research groups (Ruijter, 2002).

In agreement with Kubie (2003), engineering does not entail knowledge and skills related to technology only, but in order to be successful in engineering, emphasis must be placed explicitly on the social, economic and communication skills as well. This must be taken into account during programme design. Traylor et al. (2003) argued for the need to integrate constituent pieces of a curriculum in a coherent whole. Relevance and connections between modules should be clear to students or else they will not be able to assimilate these 'islands of knowledge', to the detriment of their educational experience. This need for integration and integrated assessment is very important and should also be taken into account during programme design.

4.5.7 Programme/educator/learner interaction

End status vision

Vision statement: Within an engineering environment, the programme is designed from a project perspective, with more than half of the learning occurring in a project environment. This is valid for all the years of study with integrated learning and the development towards a number of ECSA exit-level outcomes being achieved through project work.

Supporting statements:

- Projects are done every semester in all the years.
- These projects are active, learner-centred, with the purpose to design and build/create something.
- The projects require focus and co-ordinated group work (in case of group projects).
- Group work constitutes an important part (although not the only part) of the programme, with tutors regularly interacting with the students.
- Lecture-based courses with the traditional practical work may still be present.

The positive results of introducing active learning approaches are confirmed by a number of experiences:

- By implementing problem-based learning "the course helped to develop their engineering thinking....increased motivation to study....and made them feel like responsible collaborators in the learning process" (Frank et al., 2003).
- Including a hands-on build (manufacture) element improved students' general application of the theory of product development, its tools and the necessity of planning with production factors in mind, and it combined theoretical and practical work, it also enabled students to verify their designs by having to produce something that "works". The course definitely "met with the learning expectations", and students' experiences were positive (Gustafsson, 2004).

In the new model, the role of the 'teacher' and learner will be significantly different. The tutor's role will be to guide, mentor and lead the learners to questioning/reflecting on their own learning. New roles will require changed paradigms by both faculty members and students. The importance of providing enough support in the initial phases must not be underestimated.

4.5.8 Teaching facilitation evaluation

End status vision

Vision statement: Teaching facilitation excellence is recognised as an important part of a lecturer's performance, and is taken into account during performance management processes. Teaching excellence is measured by students, colleagues and external services such as Academic support services by using appropriate measurement techniques.

Supporting statements:

- The process for making 'Teaching excellence' awards is applied.
- An interview-based course feedback system where students give their feedback during and immediately after each course, is implemented.
- Halfway feedback during courses helps identify and rectify problems as necessary during the progress of the course.
- Students are trusted to arrange and conduct feedback interviews, and provide formal documentation as the outcome of the process.
- Valuable input is received from colleagues attending each other's classes with the objective of learning from them and giving feedback.

Important to note is that the basis of a teaching evaluation should change since within a project based learning model the teacher's role as tutor is different from a traditional teaching role.

4.5.9 Learner outcomes integrated assessment

End status vision

Vision statement: An assessment system, which effectively and accurately measures the achievement of the ECSA exit-level outcomes by every student, is in place, understood and implemented by all faculty members.

Supporting statements:

- A portfolio-based assessment system is implemented where the responsibility for collecting, organising and presenting the evidence that all outcomes have been achieved rests with the student.
- The programme objective to achieve exit-level outcomes is communicated to learners at the start of the programme. This is critical if professional portfolios are to be expected as the outcome.
- Learning outcomes and assessment criteria are properly defined per individual module.
- A simplified grading system is implemented that allows for only pass/conditional pass/fail grades and no longer any specific percentage grades. This system will be more effective in deciding whether a learner is meeting outcomes or not.
- The final assessment of a number of exit-level outcomes is done by an improved final-year project that is strategically planned as being a multidisciplinary *integrated* project.

The implementation of a portfolio assessment system to assess students' achievement of outcomes will be beneficial. Portfolios are defined as a purposeful collection of student work (from start to finish) to demonstrate mastery of specific learning outcomes, which serves as a personal reflective tool for self-assessment. Two major advantages of a portfolio is that it documents the progress of learning experiences and it can illustrate the processes of integration that have occurred (Brodeur, 2002). Portfolios can include drawings, designs, test results, video presentations, written material and anything else to demonstrate achievement of outcomes. The portfolio can be completed by the instructors or the students. However, the advantage of having students complete their own portfolios is that "it transfers the responsibility of demonstrating achievement of learning outcomes from the instructor to the student" (Brodeur, 2002). Creation of a portfolio by students is in itself a demonstration of a mastery of organisational skills, synthesising and effective communication skills. Portfolios can be paper-based or electronically based. But in all formats the student portfolio should be a creative personalised package, clearly organised to demonstrate/communicate achievement of outcomes. Portfolios can be handed in for assessment, but can also be defended in front of a panel, if required. However, implementing a portfolio system will entail a mini-project in itself if the vision is to truly use it as the measuring system to determine student competence and readiness to enter a profession, as in other programmes, e.g. the arts environment.

4.5.10 Programme evaluation

End status vision

Vision statement: As part of the faculty's quality assurance system, continuous improvement of the programme is effectively planned, scheduled and executed.

Supporting statements:

- In order to achieve continuous improvement, a formal programme assessment process is defined and performed annually.
- Input to this process includes market research information, alumni feedback, information gained from exit interviews with graduates, and feedback from students currently in the process.

4.5.11 A quality management system for the faculty

End status vision

Vision statement: A simple yet effective quality management system is implemented which addresses all critical success factors to achieve the faculty's primary objective of educating engineers.

Supporting statements:

- The quality system includes all necessary policies, procedures and documents for assuring the quality of the engineering education process.
- Internal audit or self-evaluation processes are performed regularly to achieve continuous improvement to the quality system for the faculty.
- A quality assurance function is part of the organisational structure.
- This function takes responsibility for co-ordinating, training and consultation on quality assurance matters within the faculty structure.

4.5.12 Faculty structure

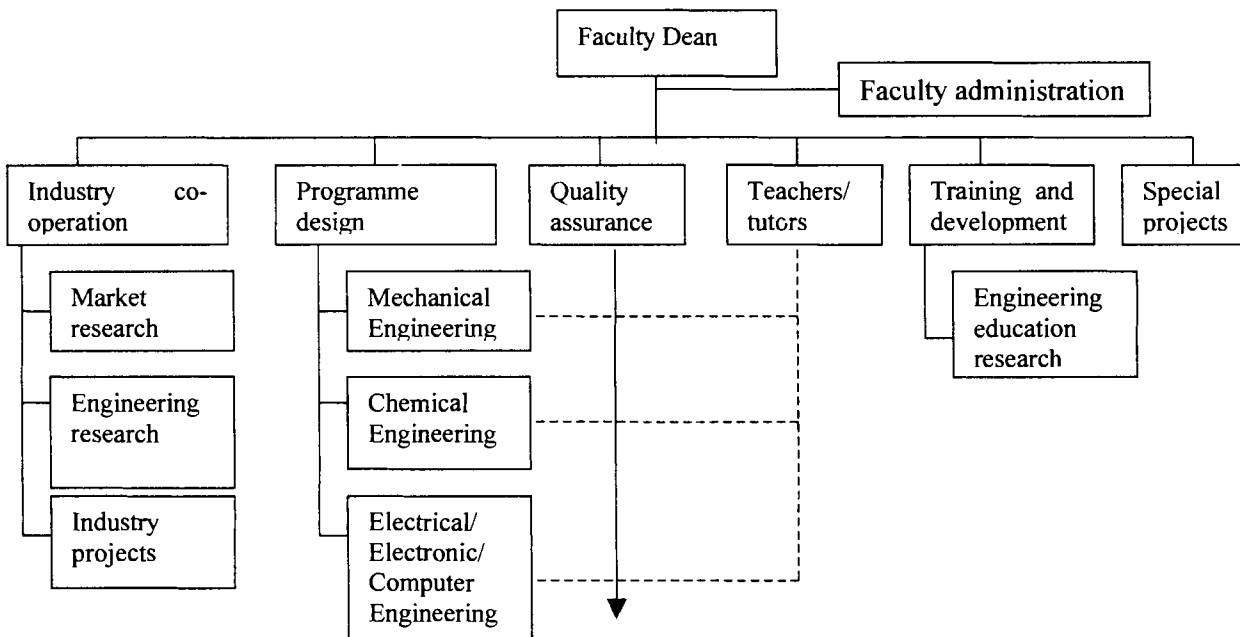
End status vision

Vision statement: An organisational structure more aligned to core process activities is implemented, where programme management is a critically important function within the structure.

Supporting statements:

- Reorganisation of the faculty structure is a critical success factor in achieving successful implementation since performance management criteria will have to change.

An interesting recommendation made by Coetzee-Van Rooy (2002) is to split the faculty structure to enable focused activity for different faculty members. This includes for example to allow some to focus on research, some on curriculum development, some on being the primary facilitators of learning, some on quality system issues and others on technology applications. This is supported by the fact that during the process analysis it became clear that faculty members all have multiple roles to fulfil, which is not necessarily the most effective division of effort. Jawitz (1999) remarks that "a system of rewarding contributions to curriculum development may encourage staff members to participate in the process". However, in a new structure not everybody will be required to do that since not everybody has the necessary passion for it. A very radical change to the traditional way of managing a faculty and to the current structure will require a challenging mind shift, with an appropriate shift in positions, titles and performance expectations. A proposed functional structure is presented in the following diagram:



This structure aims to achieve a more focused effort by individuals in their respective roles. The inclusion of research on engineering education as a separate group is motivated by the fact that at UCT it was found that "educational research undertaken was very effective in promoting change, providing a credible and sound platform for educational reform of current thinking on teaching and learning" (Fraser, 1999).

4.5.13 Facilities

End status vision

Vision statement: Facilities suitable for supporting active learning are available. Facilities that encourage students to work collaboratively and individually are available on campus.

Supporting statements:

- Facilities are available, including project rooms, multi-functional open rooms with movable tables, chairs, whiteboards, plug points and appropriate technology to encourage student presence.
- Other facilities available include design studios and equipped laboratories to enable design-build experiences.
- Facilities are utilised effectively by both lecturers and students.
- A wireless network environment exists where engineering students all have laptops and are all comfortable using them as part of their learning processes.

4.5.14 Learning resources

End status vision

Vision statement: Learning resources are designed effectively to support the learning process, especially as it relates to a different learning process.

Supporting statements:

- Electronic learning resources are designed effectively to support the learning process to encourage learners to utilise technology so as to save time and effort. It is not just a matter of providing the lecture notes electronically.
- Faculty is creative in their use of learning resources other than textbooks.

4.5.15 Support services

End status vision

Vision statement: Effective support services are provided to the engineering education process for both faculty members and learners.

Supporting statements:

- A workload and needs analysis is done to identify support service needs across faculty.
- Support service staff is appointed to fulfil the needs as identified.
- Central administration services provide realistic support to faculty administration processes.

Having stated a new vision of future engineering education in this section, the next question is that of implementation. In the next section the application of business improvement strategies and methodologies to the case in point is explored.

5 Business improvement strategies/ methodologies

Business transformation, with improvement as the obvious aim, is stated to be "the **central management challenge** and the primary, if not sole, task of business leaders" (Gouillart, 1995). Change can be achieved in small steps over time, or as a breakthrough in a short time. Quality programmes such as Total Quality Management (TQM) ensures improvement by introducing small incremental changes over time. A business transformation strategy, such as Business Process Reengineering (BPR), seeks to radically improve the business because it requires a fundamental change to the current processes or operations. This leads one to conclude that although reengineering is not the same as quality improvement or TQM, it does share a number of common themes such as recognition of the importance of processes. Both acknowledge the importance of the customer's voice and both seek to improve business.

But it does differ fundamentally in that quality programmes usually work within the current framework (structure and processes) of business and seek to enhance and continuously improve by implementing incremental improvement activities, whereas business process reengineering seeks breakthrough improvement and redesign of processes to achieve that. It may also be a result of the technology considering that the scope of change will be radical and not incremental. The "contrast between continuous improvement and reengineering lies in where you start, where you want to go, what you want to achieve and the magnitude of the resulting changes" (Hiatt, 1998). "Reengineering seeks to begin again with a clean sheet of paper" (Hammer & Champy, 1993), whereas continuous improvement starts with the status quo. One can also argue that the two philosophies complement each other and therefore do not need to be regarded as opposites all the time, but it still approaches change management differently.

When looking at the challenges of implementing project-based learning (as a form of student-centred active learning) as a new pedagogical model, it is clear that radical changes are envisioned. The changes required to implement the model have the characteristics of a reengineering effort since it requires simultaneous changes to different aspects of the education process. Therefore TQM has been excluded from the literature survey since a project to achieve radical change will not be achieved by implementation of TQM. Business process reengineering as a field of study was included in the literature surveyed.

Improvement to the engineering education process will result in change, therefore change management as a field of study was included in the literature survey as well. Engineering faculty members are professional people who require a special approach regarding change initiatives. Mintzberg (1979) described a professional as a person who "identify more with his profession than with the organisation where he practices it. A professional's power lies in the fact that his work is usually too complex to be supervised and managed and his/her services is typically in great demand." This makes management of professionals a challenging matter. Thus Mintzberg advises the professional bureaucracy's top management to be 'subtle' in achieving changes that are necessary. "The strong manager of professionals (a professional himself) will be able to play a major role in changing the business' strategies when approaching the change cooperatively" (Mintzberg, 1979).

The following section therefore explains the concepts of strategic change management, project management and business reengineering, as background to the improvement strategy recommended in the next section.

5.1 Strategic change management

Systematically orchestrating change is challenging and underestimating the rigorous nature of change can doom a programme even before it starts. Any effort to change should expect resistance as a result of insecurity, fear, loss of status or authority, loss of responsibility, comparison with others and critique from others. Different quotes illustrate this:

- "Facilitating change is both an art and a science. Do not underestimate the sophisticated and complex issues involved. It is both frustrating and rewarding – sometimes at the same time! Be prepared !" (Glasgow, 1997).

- "Change is a dynamic process which needs to be anticipated, shaped and controlled" (Grundy, 1993).
- "When you make a major change, you create a kind of corporate vacuum while employees wait to see what happens. The trick is to fill that vacuum with positive ideas before others fill it with negative ones" (Gibbons in Bennis & Mische, 1995).

If one's project is so large that its failure means the whole organisation fails, it is known as a strategic project. **Change management** is then a critical success factor in this type of project and needs to be understood and prepared for effectively. It is important to manage change in any big transformation because it involves pain. People are not just machines that can easily be reconstructed, redesigned or reprogrammed to work differently. People are complex beings with a natural resistance to change to overcome, paradigms to shift, attitudes to change and new skills to be learned in a transformation project. A process redesign project is transformational in nature, therefore a strategy for change management needs to be investigated and planned for effective project implementation. One doesn't have to be afraid of change though, one should be confident (Gewirtz, 1996). Improvement will not happen without change.

To ensure the necessary support for change, Watson (1994) describes a set of conditions that can make change effective:

- Managers must be sensitive to the feelings and emotions of their workforce.
- Managers must encourage continuously.
- Managers must communicate effectively.
- People should be involved in the change process.
- Implementation should be carefully planned.

To classify the type of change one is planning, Van der Waldt (1998) suggests different categories of change that will aid in understanding the process to be followed:

- Planned change.
- Reactive change.
- Developmental change.
- Transitional change.
- Transformational change.
- Change as a paradigm shift – when pressure is applied for a relatively long period to the core of the paradigm, a paradigm shift may take place.

The need for change in the faculty may be a combination of these categories. Assuming the classification is that of a planned change, the process can be *simplified* as a three- step model (Van der Waldt, 1998):

1. Unfreezing phase – including all activities preparing for change
2. Transition or change – including the change activities as planned (note that rapid change not preceded by enough unfreezing cause resistance to change)
3. Refreezing – including activities to maintain the momentum of change

More details of these steps are provided in the next section.

5.1.1 Process for managing change

Change management is not something that will happen automatically. Change management can be planned beforehand. A **suggested process for managing change** includes the following activities associated with each of the three phases of the three-step model (adapted and combined from Van der Waldt, 1998 and Kirkpatrick, 2001):

Unfreezing phase:

- Analyse the current circumstances (as-is state) to determine the need for change and ensure a clear definition of the problem.
- Develop and communicate the business' vision and mission (who are we, who are we doing it for, what are we doing..., why, etc.), including long-term objectives (define the required state) with specific objectives (measurable results).
- Define strategies to achieve the objectives, including the change management strategy. (This step might also include analysis of the probable reactions to change.)
- Define structures and channels of authority and communication during the change process.
- Clarify systems and policies applicable to the change initiative.
- Plan the transformation project, including communications activities on a detail level.

Transition phase:

- Execute the transformation activities as planned while doing the following:
 - Maintaining the support of key authority figures.
 - Communicating as per plan.
 - Monitoring progress.
 - Providing feedback.

Freezing phase:

- Stabilise the situation.

These activities might look easy, but it is common to make mistakes, as described below.

5.1.2 Eight common errors made while involved in change management

In his book "Leading Change" by Kotter (1996) eight common errors organisations make in organisational change efforts are explained, and he describes their consequences:

Error 1 – Allowing too much complacency i.e. there is no sense of urgency, it is underestimated how hard it is to drive people out of their comfort zones.

Complacency may have many sources e.g.:

- Too much happy talk from management.
- The absence of major and visible crises.
- Too many visible resources.
- Low overall performance standards.
- Organisational structure focusing employees on wrong goals.
- Measurement/performance systems rewarding incompetence.
- A lack of sufficient feedback from the real customer.
- Human nature with its capacity for denial, especially if people are already stressed.
- A kill-the-messenger culture.

Error 2 – Failing to create a sufficiently powerful guiding coalition. Weak committees are not effective and will not win, *especially if they do not even have a clearly defined purpose*. One person does not do it, a big enough coalition is needed to overcome the massive sources of inertia.

Error 3 – Underestimating the power of vision. Plans and programmes are not vision; a clear compelling statement is needed that can generate both interest and understanding.

Error 4 – Undercommunicating the vision by a factor of 10 (or 100 or even 1000). Communication in both words and deeds is necessary to really make the message 'stick'.

Error 5 – Permitting obstacles to block the new vision. Often obstacles are in people's heads, but often they

are also real, and management must confront and solve those for a change initiative to succeed.

Error 6 – Failing to create short-term wins. A period of 6 to 18 months is generally what people are willing to tolerate; it is not good enough to just to hope for short-term wins, it must happen for people to believe in.

Error 7 – Declaring victory too soon. Remember that changes must seep deep into the culture and can take 3 to 10 years; if victory is celebrated too soon, the powerful forces associated with tradition will take over.

Error 8 – Neglecting to anchor changes firmly in the corporate culture. Performance/promotion criteria and measurements must change, or else the old rules will continue in force...and nothing will really have changed (*such as student assessment*).

To address the abovementioned problems Kotter (1996) has suggested a number of strategies. These have been adapted and summarised to be used as a checklist during the planning phase of the project. (See paragraph 6.4. for details.)

Public institutions usually do not have the classical dependence on a typical paying customer, and therefore the average faculty member currently does not experience the urgency for change necessary for survival and growth. It will therefore be necessary to investigate how this risk can be addressed and its effects minimised. Kotter (1996) says explicitly that "failure is usually associated with underestimating the difficulties in producing change" and the need for "strong line leadership that is required to overcome what is called massive sources of inertia." It is believed that the placement of a guiding coalition or project team should be thought through **strategically** and the risk of not being in the right place prevented.

5.1.3 Different roles and communication

It is important to differentiate between roles that will be needed during the different phases of change a project undergoes. Grundy (1993) offers a graphical presentation in Figure 4:

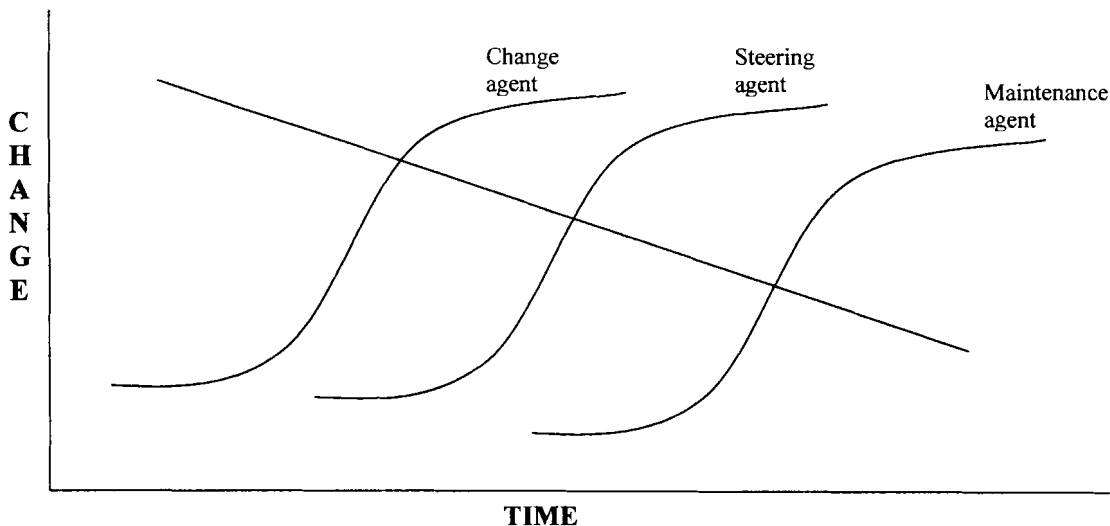


FIGURE 4 - AGENTS REQUIRED AT DIFFERENT STAGES IN TRANSFORMATION PROJECT

The *change agent* is an external or internal role player whose task is to start up the change process. A change agent *must have legitimacy among personnel*, and must have certain skills such as negotiation and communication skills (Van der Waldt, 1998). The change agent is introduced by the 'catalyst' (usually the top manager) initiating the change.

The *steering agent* is the agent whose task it is to ensure that once a change initiative is up and running it does not get diverted or lose momentum, especially in the earlier stages. It can be in the form of a project manager.

The *maintenance agent* is necessary for effective role-out of the change and requires great tenacity and patience since change interventions reshaping management culture and "those active at the core of the organisational paradigm" may for example take 4-6 years (Grundy, 1993).

The most critical success factor in managing change is communication in the management of expectations to the stakeholders involved. "Expectations management is defined as the shaping of beliefs about the change – why it happens, what will happen and how. Communication is defined as the channelling of information about the change top-down, bottom-up or horizontally within an organization and also externally" (Grundy, 1993). It is critical to have a communication plan to achieve the right stimulus at the right time. It is important for the value added by a change initiative to be reviewed continually and to be checked against the organisational vision/mission and objectives.

In order to plan a communications strategy it is useful to do a stakeholder analysis to determine what effort to put in with whom and where. A tool is offered by Grundy (1993) as shown in Figure 5:

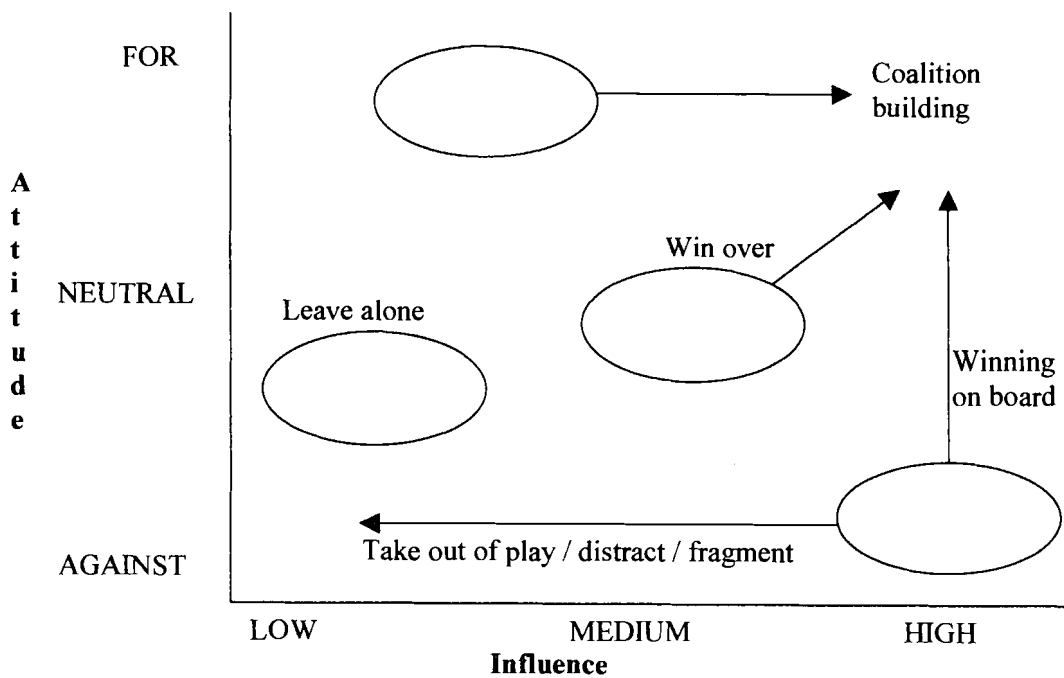


FIGURE 5 - STAKEHOLDER ANALYSIS TOOL BY GRUNDY (1993)

Although implementing strategic change is very different for a public than a private institution, since the institutions differ in their aims, mission, objectives and measurements, it is possible to achieve strategic change by following a project management approach (Van der Waldt, 1998). This is described in the next paragraph.

5.2 Project management

Should this change initiative be implemented, it will be structured and managed as a project. Some background on project management is therefore given in this section.

The simplest fundamental definition of a project is that it is a specific effort aimed at achieving a **specific objective** with a *definite beginning and end*. Projects differ from repetitive efforts or normal operations and therefore require a different management approach – the project management approach. Apart from this research study being a project in itself, it is suggested that a transformational change initiative be defined as a project and therefore managed as a project. "Project management has made a significant contribution to the practice of management. It provides the organization with powerful tools to improve the organization's ability to plan, organize, implement and control its activities" (Meredith, 1985). Projects involve doing something that has not been done before and that is therefore unique. A project may also exist of multiple projects. "Project management is the application of knowledge, skills, tools and techniques to project activities to meet or exceed stakeholder expectations from a project" (PMI, 1996). "Project management as a management approach proves to be **very effective** where **change and uncertainty prevail**" (Steyn et al., 2003). "Project management is defined as a systems oriented approach to management because it considers the project as a system of interrelated tasks and work units operating in an influential environment" (Nicholas, 1990).

5.2.1 Project life cycle (simplified)

In its simplest form any project will go through at least four phases, as shown in the diagram below. This research project is the startup or initiation phase of a total improvement project (not yet defined) at the North-West University Faculty of Engineering. The output of this research will be to supply enough information to enable continuation to the project planning phase.

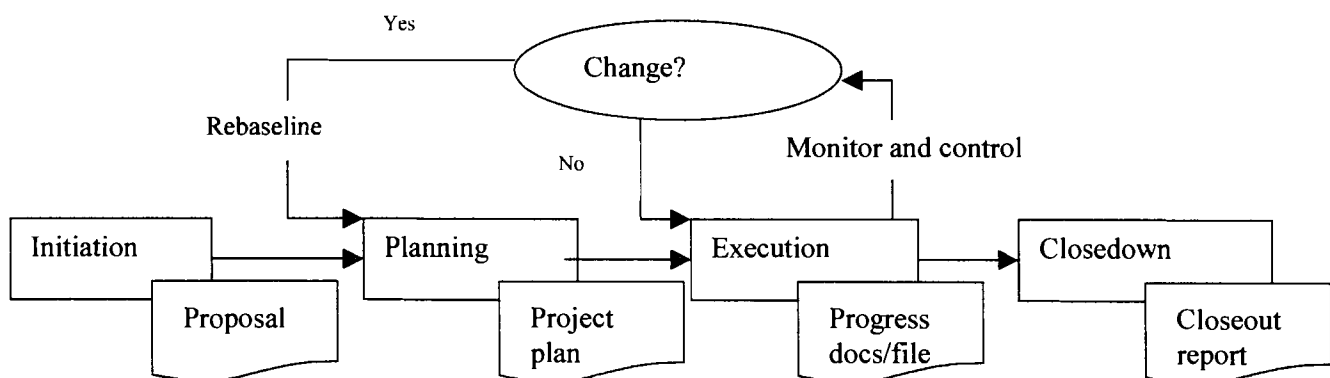


FIGURE 6 – PROJECT MANAGEMENT LOGIC SIMPLIFIED

The process phases depicted above can and will overlap and occur concurrently. It is important to define the project type in order to define the project scope better, and for improved planning purposes. The project type suggested is a Business Engineering project, or as it is more commonly known, a Business Process Reengineering (BPR) project type, described in paragraph 5.3.

5.2.2 Lessons learnt on project planning

The Open University in the Netherlands has done a comprehensive study on the sustainability of innovation projects within higher education institutions. Different universities have been included in the study. The report includes eight lessons learnt that have to be taken into account when planning such an innovation project (Open Universiteit Nederland, 2005):

1. Project success is not innovation success.
2. An organisational manager is not a project manager.
3. Sustainability should be a planned strategy for maintaining change and not some kind of afterthought.
4. Avoid the six sure-fire failure causers, namely:
 - Lack of balance between investments and output e.g. high investment with low output.
 - Information politics where power is abused and information is not transmitted.
 - Lack of responsibility, especially when uncertainty regarding their responsibility is felt by people inside and outside the project.
 - Culture gap, especially the gap between information technology experts and the rest of the organisation and between those planning education (managers) and those administering education (teachers).
 - Over-commitment, including not knowing when to cut one's losses and to stop a project.
 - All-in-one solutions as defined in trying to do everything at once instead of using multiple projects, steps and phases.
5. Embrace the four critical 'win drivers' namely:
 - Define and anchor the project objectives early to involve the stakeholders and anchor a common understanding and commitment.
 - Determine the roles and responsibilities of all actors (clients, participants, stakeholders, owners).
 - Strategically plan change management.
 - Systematically and thoroughly monitor and measure control and performance.
6. Small changes are often larger than we think.
7. Innovation is like a nuclear reaction: Small is beautiful.
8. Opinion leaders – Know your enemies and make them allies.

5.3 Business Process Reengineering

For the purpose of this study Business Process Reengineering was not redefined, but researched as background to the development of a strategy for change.

The following definitions are relevant to the study:

- "Business Process Reengineering (BPR) has been identified as a key change initiative for achieving business improvement for organisations" (Braganza, 1997).
- BPR is defined by Hammer and Champy (1993) as "the fundamental **rethinking** and radical **redesign** of business **processes** to achieve radical improvements of critical, contemporary measures of performance such as cost, quality, service and speed." Reengineering's primary focus is on redesigning the processes, but in most cases this results in other elements of business being affected.
- Bennis and Mische (1995) define reengineering as "reinventing the enterprise by challenging its existing doctrines, practices, and activities and then innovatively change these to optimize the organisation's competitive position, value to shareholders and contribution to society. This is extremely difficult since it means permanently *transforming* the organisation, challenging and discarding traditional values, historical beliefs, conventional wisdom, tried and tested processes, retraining workers and redirecting the enterprise."
- "It reconsiders the way in which an organisation's culture, structure, systems and people are viewed" (Braganza, 1997).

The nature of a BPR project is such that it usually involves the whole organisation especially if the core

business process is being redesigned. It is then called a Business Reengineering project. If one looks at a model of the reengineering spectrum by Coulson-Thomas (1996) in Figure 7, one can see that the scope of work is determined by the ambition a business has.

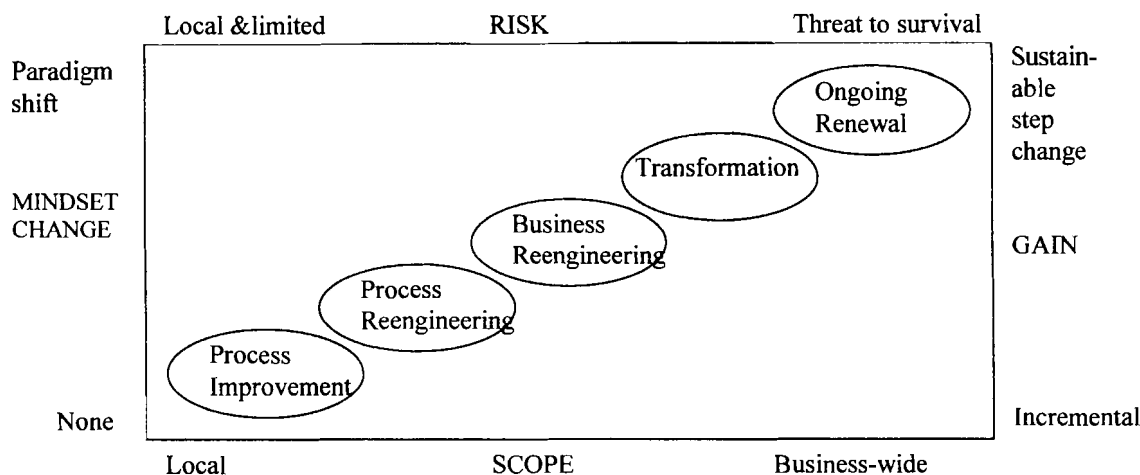


FIGURE 7 – REENGINEERING SPECTRUM BY COULSON-THOMAS (1996)

What is envisioned at the North-West University Faculty of Engineering is a new process of educating engineers, the core process of an engineering faculty. The implementation will require major paradigm shifts by both faculty members and students alike and the scope of implementation is faculty-wide, not just a few modules/subjects to be changed to a new model. It can therefore be concluded that the ambition of the NWU Engineering Faculty lies between Business Reengineering and Transformation on the model. According to Kallio, Saarinen and Tinnila (2002) it is important to classify the type of project correctly as the failure or success of a change project depends to a large extent on the objectives of the initiative. This project may be classified as a **strategic Business Reengineering project**.⁴

Although literature may also differ on business reengineering's definition, planning methodology, implementation, etc., it has been studied with the objective of gaining a better understanding in general as conveyed in the paragraphs below. However, there is still a gap in the literature describing how engineering education improvement initiatives may or have benefited from applying reengineering methodology specifically.

5.3.1 What is reengineering?

According to Bennis and Mische (1995), a reengineering effort contains 5 essential elements:

1. **A bold new vision** of the organisation's future and the passion necessary to turn that vision into reality.
2. **A systemic approach** – a change effort that has far-reaching organisation-wide implications, a total reinvention and transformation, and not just a situational solution to a specific problem.
3. **A clear intent and mandate** – often organisations implement some change effort and afterwards call it reengineering because it has some marketing value. Instead, to effect systemic change it is necessary to start with a specific intention, call it what it is, and realise that the end point will be an entirely different organisation.

⁴ Only three references to reengineering projects in the public sector could be found in the literature, two of which are irrelevant to the research conducted as part of this study. The first one entitled "Business Process Reengineering in the public sector: The case of the housing development board in Singapore" deals with studying the differences between the public and private sector and the implications for BPR. (Thong, Yap & Seah, 2000) The second one entitled "Business Process Reengineering and University Organisation: a normative approach from the Spanish case" deals with how a university at large can benefit from applying reengineering principles (Adenso-Diaz and Canteli, 2001). The third one "Business engineering and process redesign in higher education: Art of Science?" (Grotevant, 1998) is the most relevant and is worthwhile to study on its own as it gives background and describes different change management strategies or methodologies.

4. **A specific methodology** – without an understood method, the path will be unclear and might result in different expectations and communications resulting in chaos.
5. **Effective and visible leadership** – without this the effort will fail; leaders must have creativity, vision, influence, credibility, people skills, excellent judgment, coaching skills and character.

The core goals of BPR is to simplify and radically redesign processes and to ensure fundamental frame-breaking change. Thus the outputs of a reengineering project are the new, more effective process supporting the business goal. It may also require an appropriately structure redesigned to reward value-added activities rather than bureaucracy and a lack of trust. The contribution to the organisation's goals and objectives and core process should be the measurements for recognition of a reengineering project.

5.3.2 What reengineering is not

Listed below are seven myths about reengineering, set out in order to better define what it is not (Bennis and Mische, 1995):

1. If you're contemplating reengineering you must have been doing all the wrong things all along. (No it is not true. Reengineering is a process allowing recognition of success while striving to identify and capitalise on opportunities for improvement.)
2. Reengineering is about information technology. (Although information technology might be an enabling change agent and definitely needs to be investigated as such, the process of reengineering is trying to produce quantum improvement results with or without IT.)
3. Reengineering means doing more with less. (Reengineering is about doing things differently and more effectively, it does not start from the premise of eliminating jobs. Reengineering got a bad name by organisations mistakenly calling downsizing reengineering.)
4. Reengineering can be used to fix any problem (It's a process that changes the organisational culture and creates new processes, new structures, new systems and new ways to measure performance and success.)
5. Reengineering can be managed by anyone. (The transformation leader must have strong leadership skills, mature business judgment, experience in managing organisational transformation and having knowledge of the reengineering process.)
6. Reengineering creates anxiety and chaos, which are detrimental to the organisation. (Reengineering is change, and change can be excruciatingly difficult, but if managed properly it doesn't need to be chaos.)
7. Reengineering is a scientific process. (It is not necessarily absolutely scientific.)

5.3.3 Why reengineering

Reengineering requires one to be bold. It is important to decide whether one is ready for reengineering or not. "Where reengineering is at its most powerful and effective is when it is used as a critical element in the fundamental rethinking and redesign of the business itself, not just its processes. It offers the opportunity to take an integrated view of the business and create a platform from which to grow and shape the future of the business success" (Coulson-Thomas, 1996).

5.3.4 The negative side of reengineering

Coulson-Thomas (1996) suggests that "no-one seeking radical change should feel compelled to undertake BPR. Many organisations have introduced new patterns of work and have achieved fundamental changes without implementing BPR as such. Creative thinking, benchmarking, culture change, innovation, etc. can all be undertaken quite independently of BPR. Other frameworks and approaches exist, of which BPR may provide one approach or methodology. Approaches, methodologies, techniques and tools are a means to an end and should never be allowed to become an end in themselves. Confusion about BPR is widespread, and therefore it may also be classified as an emotive topic. There is a huge gulf between the rhetoric of BPR

and the reality of its application. *Where inspired by a vision of the future and properly used, BPR can represent a useful element in a corporate transformation programme or business excellence model. A sense of balance needs to be maintained.*" It is hoped that the perspective of this study will be keeping this balance.

5.3.5 The reengineering methodology or process

From the literature two models have been chosen to represent and recommend as strategies. Both models indicate a project-logic, and they complement each other well. The first one is taken from Coulson-Thomas (1996) and represents three phases with high-level activities that must take place per phase:

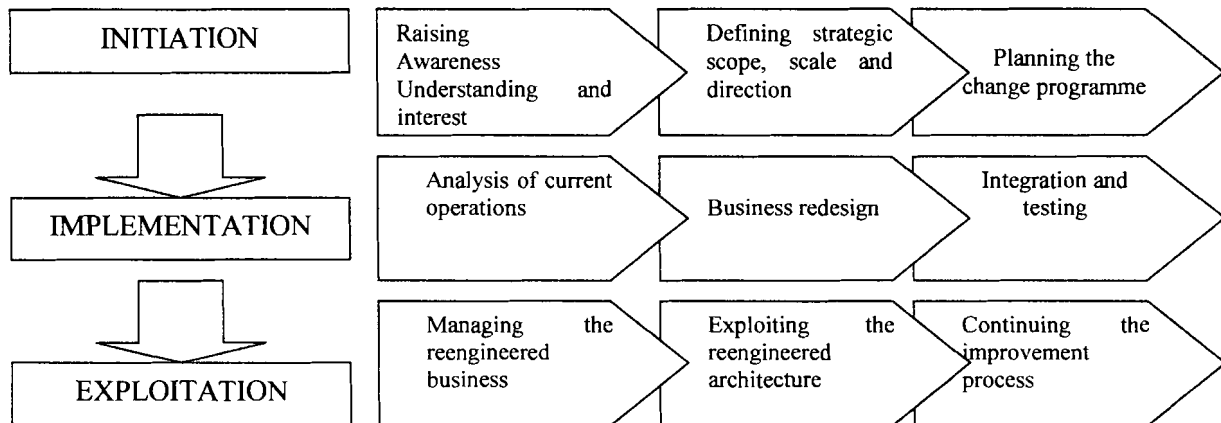


FIGURE 8 – BUSINESS REENGINEERING MODEL THREE PHASES

The second model was adapted from Bennis and Mische (1995), where the activities are defined in more details and only five phases are mentioned. The project phases have been included as well.

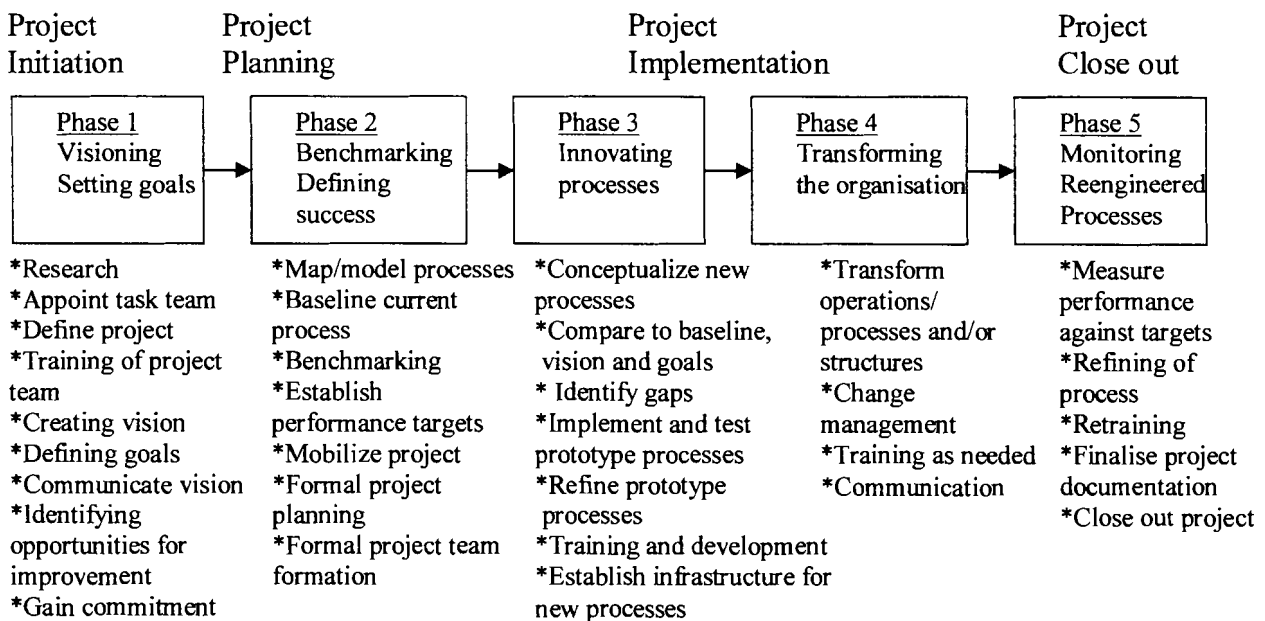


FIGURE 9 – BUSINESS PROCESS REENGINEERING MODEL FIVE PHASES

In this model the following is recommended: (adapted from Bennis and Mische, 1995):

- The fulltime project team should be *formally removed* from daily responsibilities, *educated and rigorously trained* in process innovation, reengineering and organisational change and the *proper*

environment created for the team.

- **Baselining** involves acquiring quantitative and qualitative information about a process and the functions that support the process. It may involve mapping the process as current. It is essential to use consistent measuring processes, techniques and definitions, determine the value of the process, cycle time, costs, employees involved, service levels, customer satisfaction, etc. From these one can then determine performance objectives. A baselining of current staff motivations with reasons why they are there is also a good way of getting to know the level of commitment available.
- **Benchmarking** difficulties may be experienced since usually quantitative measures rather than qualitative are used. Gathering and analysing information should be performed in the same way. Part of benchmarking constitutes identifying, copying and improving on best practices.

From the above one can conclude that reengineering is difficult, radical and significant (Bennis and Mische, 1995). In general the change management aspect is mentioned as being the most important factor contributing to the success of a reengineering effort (Hiatt, 1998). The kind of resistance one can expect from a reengineering project is both active and passive. Active resistance is obvious where people actively seek to oppose and withstand an initiative. Passive resistance is not so obvious, as the people appear to support a change but have in actual fact not accepted it. Active resistance does not in general present a significant threat to the programme, it is passive resistance that will require more specific change management strategies (Coulson-Thomas, 1996).

With the background on improvement implementation strategies the next section will propose a recommendation to move from the status quo to the future or envisioned state.

6 Recommendation

I agree most with the following thoughtful comment from Glasgow (1997) "teachers can trust their own senses more for what is important to know and to do, by looking at what successful people are required to do in the real world. Real world learning has a backbone of problem-solving, production of work-authentic products, investigation and research, in which all knowledge, processes and techniques connect and are used. Learning in the real world is a routine, continual activity." One must not underestimate the complexity of the teaching and learning process, but one must also not underestimate its simplicity.

This section describes a recommended strategy developed for moving from the status quo to the vision described in the previous sections. It will then describe a recommended methodology as well as the risks and limitations involved in following the strategy. The section closes by including a few checklists to be used when implementing the recommended strategy.

The recommended strategy is not aimed at achieving incremental improvement but rather aims to achieve radical improvement because it will affect most of the model elements during implementation. This is aligned to the vision of the faculty's top management of introducing project-based learning in the education process, as described previously. Obviously, the more radical the change envisioned, the higher the risks and the more difficult it would be to sell. The detailed planning of a strategy will be a project in itself, and is not part of the scope of this thesis. The strategy suggested will require many years to implement and is not to be seen as a short-term project. Change management will play a critical role in the process.

6.1 Improvement strategy

If this study is seen as the initiation phase of a project, the logical next step from here is to proceed to the planning phase of implementation of a new form of project based learning. Implementation of a new pedagogical model as encompassing as the suggested one should be done with reference to the proposed engineering education process model to serve as a guiding structure. A clear vision and agreement with the model is a prerequisite. Implementation of this new model implies radical changes to the current engineering education process in terms of the teaching culture, faculty' roles, the organisational structure, changes to facilities, assessment strategies and management responsibilities. Since it implies radical changes to the core process, this implementation should be defined as a Business Process Reengineering (BPR) project, and therefore apply both project management and such BPR methodology, tools and techniques as necessary. Since it will require major paradigm shifts to be made, formal change management activities should be planned not only for faculty members, but also for students and other stakeholders. Implementation of a new engineering education model should not be seen as an experiment, but as the model for educating engineers of the future.

A very important part of the strategy is to *allow enough time for rethinking*. Bruyns (2001) suggested that "higher education institutions should strive to use reengineering to increase their desirability of their products and services in the market place but remember that it will take an explicit effort of *rethinking* to enable the paradigm shift to take place that will be needed for a successful transformation from as-is to want-to-be." It is also not only management that will have to do the rethinking, but everybody included in the engineering education process.

6.2 Recommended methodology

If the project is defined as a business process reengineering (BPR) project, the methodology chosen is BPR methodology. By using BPR methodology as a basis and expanding it to include project management phases and deliverables in order to visualise progress, a diagram (Figure 10) was developed, which can help in conceptualising the proposed methodology. Each of the following proposed project activities are major undertakings and could be viewed as discrete sub projects in themselves, as part of an improvement project/programme:

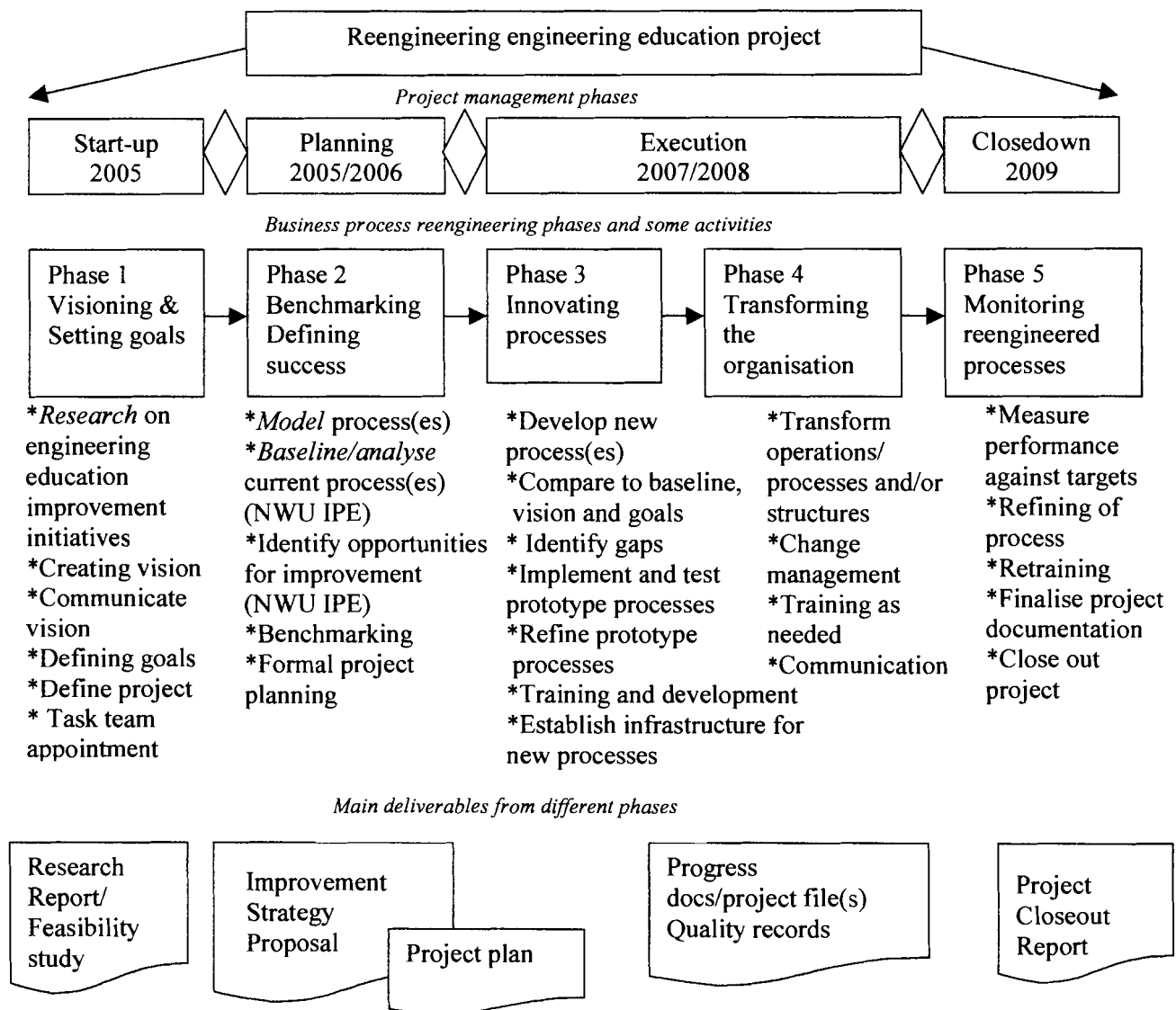


FIGURE 10 – RECOMMENDED METHODOLOGY FOR IMPROVING ENGINEERING EDUCATION

The vision and goals for the faculty need to be developed. This thesis provides input for this activity, as it has defined a possible vision for the faculty. The importance of a vision is well enough documented. The vision defines the level of change necessary. The vision stretches the faculty in order to be the 'trigger' for radical change. The vision and goals need to be of a practical, visible nature and it must be possible to use it to inspire change agents to want to become involved in the transformation process. A vision statement can often be something that has nice words but no inspirational value. Included in the vision must be a refocus of university teachers' commitment to teaching as one of their primary activities (Brimoh, 2003). The vision recommended should be about educating engineers who are excited about engineering – about "facing an open-ended challenge and creating something that has never been" (De Camargo Ribeiro, 2005). The

vision should also give more specific clarity of what the faculty perceives engineering to be. If, for example, engineering is seen as always being associated with design problems, then the vision must reflect that design will be core to the curriculum designed. The vision then needs to be communicated, frequently, in different forms and continuously so that faculty may comprehend and realise the commitment behind the vision.

The project scope and objectives need to be defined and planned. This activity may require some more research. The most critical part of the project will be the planning of a change management strategy and approach. Checklists for supporting this activity have been developed, and are described in paragraph 6.4. People management will be critical to really achieving the paradigm shifts required. With a major transformation strategy, formal change management suggests that management needs to know exactly how each individual member feels about the strategy, how and where members view themselves as part of the vision and how they see their roles in the future. It is suggested that a change management strategy will have to be developed by management in enough detail so that every individual's concerns, reactions and suggestions can be managed.

It is recommended that interviews with staff be held to determine their personal vision for growth in the faculty. Interviews should be done by people with whom they can be honest. This may give some indication on how much commitment faculty members have towards the envisioned change initiative. It will be important to identify the 'opinion leaders' early on in the project. Table 4 summarises the different responses one might get from people involved (Bennis and Mische, 1995). *A strategy for handling each of these attitudes should be anticipated and developed.*

LEVEL OF SUPPORT ↑	<p><u>Passive proponents</u></p> <ul style="list-style-type: none"> • Knows something must be done • Unsure as to how to do something • Mindful of change and can be cautious • Will support proponents • Can be led to active support with demonstrated results 	<p><u>Reengineering proponents</u></p> <ul style="list-style-type: none"> • Advocates and champions • Chartered with project • Perform reengineering • Seek approval • Can be overly aggressive • Can elevate expectations • Can intimidate
	<p><u>Neutral</u></p> <ul style="list-style-type: none"> • Can be aloof and passive • May be interested, but non-committal • May be slow to embrace reengineering • Could be easily swayed or persuaded • May become apathetic • May require senior leadership and intervention to get going 	<p><u>Inhibitors</u></p> <ul style="list-style-type: none"> • Sceptical and protective • Resist change and challenge whole effort • Can be political adversaries • Will not co-operate • Will attempt to discredit effort • Usually require direct senior leadership involvement
	LEVEL OF PARTICIPATION →	

Table 4 – Responses from people involved in reengineering

Lastly it is recommended that a dedicated project team needs to be appointed. It is recommended that this team should be separate from the faculty management team. The task team should be formally appointed and their function communicated to the rest of the faculty. The reengineering team structure should include the following roles (adapted compilation from Bennis and Mische, 1995 and Hammer and Champy, 1993):

- Executive sponsors or leaders – who endorse, provide direction, set the tone, instil motivation.
- Reinvention steering committee – which establishes policies and strategies, ensures resource availability, resolves issues regarding effort.
- Transformation leader – who educates the teams, guides/directs, has an oversight function, who may be the external consultant understanding and developing reengineering tools/techniques and

associated forms necessary for effort. May also be the project manager initially, although ownership of processes does not reside with him/her.

- Process champion or process owner – who is the business manager responsible for a specific process (if allowed in the structure) and might be considered as the project manager of the reengineering team responsible for his/her process as the project is executed.
- Team members (including three to seven people (never more than ten)) – with the following characteristics: they must have specific knowledge of processes, the organisation's vision and direction, be creative, adaptable, courageous, open-minded, able to assimilate new ideas, roles and responsibilities quickly, able to assess the rationale and value of work, have high energy, enjoy a challenge, be able to contribute under significant pressure, willing and able to challenge existing paradigms, able to comprehend complex business issues and their implications, and be committed to transformation. Team members should have secure personalities, tolerance for indifferences and uncertainties and should assume personal and collective accountability (Coulson-Thomas, 1996). The team should never be wholly internal or wholly external – a *combination is ideal*.
 - **Internal staff** will be exposed to the following risks – they may fall victim to inertia, seek only tried and true methods, lack perspective to question current status, *underestimate* the magnitude of the effort, be linked to hidden agendas, be inhibited by organisational politics and titles and be distracted by problems in certain areas.
 - **An external consultant** – has a sense of perspective, knowledge of appropriate tools and techniques, understands what needs to be done and the effort that is required, has objectivity as a result of being outside of the organisation's politics, culture and history, and is able to make difficult recommendations.

6.3 Risks, limitations and problems

In this section some of the risks and possible problems will be discussed with relation to the proposed strategy and methodology.

"The biggest risk will be the stereotypical, longheld ideas and traditions that have created an educational inertia in the learning communities that inhibit changes and adjustments that may need to take place." (Glasgow, 1997) In this regard a big risk of not overcoming this inertia completely is when one misleads oneself by thinking one is already providing problem-based learning or project-based learning, when one is teaching by using problems, or letting students work in groups. This will not really be the paradigm shift that is required for radical change to happen.

Savin-Baden (2003) warns that "problem based learning is more than small group teaching or doing problem solving in a classroom with students sitting around tables and not in rows." De Camargo Ribeiro (2005) also criticises the way problems are proposed in the engineering classroom: "seldom are these problems related to real situations faced by practicing engineers and they often make use of inadequate problem solving procedures in which relevant factors are neglected, leading to the correct solution of the wrong problems." This does not mean that no attempt should be made to improve, since some active learning may still be better than none, but educational inertia should not be allowed to justify the status quo.

A decision to reengineer should not be made lightly. If it is realised that the effort required for mindsets to change may not be worth the value added, the logical choice may even be not to reengineer. McNulty and Ferlie (2004) state that "a reliance on strong leadership by itself is a weak basis for transformational organizational change in large, complex and professional organizations." Management should avoid classic pitfalls when contemplating reengineering. The following list will aid in this activity (as compiled from Bennis & Mische (1995)):

- The **inappropriate use of the term reengineering** when it is not what is being done – e.g. when thought of as a cure for chronic leadership and management problems, when reengineering is attempted without making organisational changes, and when those involved are being overconfident and are attempting too many projects at once.
- **Lack of vision** – one will know the warning signs if one cannot produce a clear vision statement or

definitive objectives, when it is only defined for a specific department and not overall. Vision should be sweeping and bold, create a sense of urgency, energy and commitment, and should serve as a guide for organisational activity.

- An **ineffective reengineering team** – assigning inappropriate resources to the team, failing to create a fulltime team, failing to assign dedicated workspace to the team, failing to designate sponsorship and 'protection' for the team, failing to adjust measurements of compensation and success to reflect participation in the team.
- **Inappropriate empowerment** – when workers are empowered too much, leadership and management are diluted, when too little, traditional doctrines are not challenged, the result being phantom empowerment without really wanting to change anything.
- **Rationalisation of the process** – often reengineering is embraced by managers until it affects their areas, then processes are rationalised and in actual fact nothing changes. Warning signs of this happening is when processes are forced to match the current design or status quo and *when the structure, systems and performance measures as well as everything else stays the same*.
- Relying exclusively on information technology to change processes – IT supports business processes and is not the reengineering effort in itself.
- The use of geographical or traditional organisational boundaries to demarcate differences.
- The **failure to understand reengineering** and its implications – being unable to discuss what it is and is not, viewing the effort dispassionately or avoiding it, or when used to avoid or reinforce politics.

The researcher does not believe that the necessary sense of urgency for major radical change is evident in the current status of the programmes. Enthusiastic support to new ideas does not necessarily reflect commitment to change. Quick-fix solutions to the curriculum are already expected, whereas the deeper problems to the curriculum are not perceived. "A false sense of educational wellness creates educational inertia that is hard to rechannel into new programmes or strategies" (Glasgow, 1997).

A real risk for the project is the current lack of capacity in both faculty and academic support services, both in terms of workload, available time and required knowledge with respect to educational concepts and experience with respect to change management implementation. A painful 'unlearning and relearning' of what project-based learning, really means will have to take place throughout the organisation.

Improvement in any one element in a model may lead to incremental improvement of the whole process. If radical improvement is required one should rather look at the whole process and redefine interacting elements, and the associated and supporting elements of the process. The conventional way of improving is to only look at elements individually without keeping the whole process in mind, for example, only to redesign the curriculum without redefining the teaching process and associated assessment. Often the process responsibility is split up between different functions responsible for the individual or for the groups of elements, also resulting in individual elements being improved without a co-ordinated effort of the whole. Where short-term improvements are implemented with a limited view of the whole process, only incremental benefits may be realised. The danger is also that too many changes may cause unnecessary pain, where a strategic holistic strategy may ensure more co-ordinated change management.

The dynamics of academic autonomy may impede the decision-making process and may necessitate much more emphasis on appropriate change management strategies. The pressure within South Africa to have appropriately distributed staff ratios may also pose a risk to having motivated staff as part of a major change initiative.

There is a risk of not generating the "critical mass of champions" needed for achieving real radical change to processes. The risk of losing the vision is real, as illustrated by this quote: The "ambition of reengineering was diluted by managers" when they actually tried to create the changes to suit them, the "reformative spirit was weakened and the initial strategic intent dissolved, and the vision lost" (McNulty and Ferlie, 2004). Change initiatives are often shaped and transformed by the very conditions they are supposed to transform. It has been clear from literature that reengineering can thus be abused to serve personal agendas and thus not achieve its original intention.

With the transformation to a new structure, a new process and new facilities, one must remember to update

the supporting processes that rewards the desired behaviour. Performance management processes will have to be redesigned in a new process and structure, depending on what the new performance requirements should be. These processes are not totally within the faculty's domain and there may be a constraint upon this realistically happening.

6.4 Improvement strategy planning checklists

The following checklists have been developed with the purpose of supporting the planning phase activities as discussed in the improvement strategy and recommended methodology sections. It does not claim to be the only tools to be used in the planning activities. The checklists have been developed from the literature surveyed.

6.4.1 Eight error prevention strategies

The following strategies can be employed to prevent the eight errors Kotter (1996) has described, as discussed previously:

<i>Tick box</i>	<i>Strategy</i>	<i>Related activities or explanation</i>
	Establish a sense of urgency. (A visible crisis can be enormously helpful in drawing people's attention and increasing urgency levels.)	Ways to raise the urgency level may include: * Creating a crisis (by allowing a financial loss, exposing managers to major weaknesses or allowing errors to blow up). * Eliminating obvious examples of excess. * Setting new financial goals so high that it cannot be achieved by doing business as usual. * Stopping happy talk and start being and communicating honestly, the real facts. * Stopping measuring subunit performance with wrong measures. * Sending more data about customer feedback. * Insisting that people talk to customers more, especially the unhappy ones. *Using external consultants to force more open and honest meetings. *Bombarding people with information on future opportunities.
	Identify and discuss a crisis, potential crisis and major opportunities and do not underestimate the task.	
	Create a strong guiding coalition with enough power to lead the change.	
	Structure and appoint the team.	The team must have the following characteristics: *Position power – are enough key players on board, especially the line managers? *Expertise – are the various points of view relevant to the task at hand, so that informed, intelligent decisions can be made? *Credibility – does the group have enough people with good reputations in the firm so that its pronouncements will be taken seriously by others? *Leadership – does the group include enough proven leaders to be able to drive the change process?
	Create trust and develop a common goal that is sensible to the head and appealing to the heart.	Suggestions to create trust include enough off-site events, lots of talks and joint activities.
	Develop a vision and strategy.	An effective vision's characteristics are:

Tick box	Strategy	Related activities or explanation
	(Leaders create vision and strategies, managers create plans and budgets.)	Imaginable – conveys a picture of what the future will look like. Desirable – appeals to the long-term interest of employees and customers. Feasible. Focused – clear enough to provide guidance. Flexible. Communicable – successfully explained in 5 minutes.
	Communicate the change vision.	Use every possible vehicle constantly to communicate and role-model the expected behaviour, for example large-group meetings, memos, newspapers, posters and informal one-on-one talks. Do not be afraid of repetition, and walk the talk.
	Empower broad-based action.	
	Get rid of obstacles.	Remove barriers, which might include a lack of needed skills, formal structures or systems (performance appraisal, compensation and promotions), making it difficult to act. Remember that a 5-day training course does not easily replace habits and paradigms built up over many years.
	Change systems and structures that undermine the vision.	
	Encourage risk-taking and non-traditional ideas, values and actions.	
	Generate short-term wins.	A short-term win has three characteristics: * It is visible, and large numbers of people can see for themselves whether the result is real or just hype. * It is unambiguous; there can be little argument over the call. * It is clearly linked to the change effort.
	Recognise and reward the people who made the wins possible.	The role of short-term wins are that it: * Provides evidence that sacrifices are worth it. * Rewards change agents with a pat on the back. * Helps fine-tune vision and strategies. * Undermines cynics and self-serving resisters. * Keeps bosses on board. * Builds momentum.
	Consolidate change and produce more change.	
	Reassess and communicate progress to prevent complacency going up again and letting tradition come back with powerful force.	The facts are: * Cultural change comes last, not first. * It depends on results, only if it is very clear that the new way works and is superior to old methods. * It requires a lot of talk. * It may involve turnover – sometimes the only way to change is to change key people. * It makes succession-related decisions crucial. * Complexities, messiness and scary issues are to be expected.
	Anchor new approaches into the culture.	
	Develop the means to ensure leadership development and succession.	

6.4.2 BPR critical success factors

The following list has been compiled and adapted from Coulson-Thomas (1996) and the Institute of Industrial Engineers (1994). This list may be used as part of the planning phase activities.

<i>Tick box</i>	<i>Critical success factor</i>
	The BPR vision stretches the minds of people and the vision is shared
	The BPR vision has a case for action supported by evidence – it is not just a 'good idea' to 'try out'.
	Is top management really effective? Is there a need for retraining?
	The project governance structure is established and the team has been selected.
	The BPR team has interpreted the business strategy and reasons for improving.
	The relation of current improvement initiatives to the reengineering effort has been determined.
	Project objectives are clear and are communicated continuously.
	Internal communication is clear, well-timed, effective and persistent.
	Senior management involvement is sustained.
	People are equipped to fulfil new roles and/responsibilities.
	The effort focuses on the essence of what needs to be done to generate value and build relevant capacity.
	The effort is kept simple.
	There is evidence of clear thinking, foresight and an ability to identify what is important.
	Information technology's potential value and/or support to the process as a radical improvement enabler has been investigated.
	Mutual trust has been established.
	The BPR strategy has a holistic approach to the problem.
	The BPR team has the necessary authority.
	Team members have secure personalities.
	The BPR exercise is defined as a project.

6.4.3 BPR reasons for failure

Reasons for failure of business process reengineering can also be used as a checklist for preventing these failures. This list can be used during the project progress. The list has been compiled and adapted from Coulson-Thomas (1996) and Hammer and Champy (1993)

<i>Tick box</i>	<i>Failure prevention statement</i>
	BPR goals or objectives are not too modest or inappropriate.
	Commitment is not superficial.
	The BPR effort is part of an overall transformation vision.
	There is not a lack of vision.
	The external real customer is not ignored.
	An internal focus only is not allowed.
	Not too much time is spent on analysing the current way of doing things.
	Alternative models are thoroughly investigated.
	Internal projects do not rival and compete.
	There is a central co-ordination of initiatives.
	BPR is not trying to 'fix' a process.
	Everything except process redesign is not ignored.
	People's beliefs and values are not neglected.
	We are willing to settle for minor results.
	Prior constraints are not placed on the definition of the problem and the scope of the reengineering effort.

Tick box	Failure prevention statement
	Existing corporate cultures and management attitudes are not allowed to prevent reengineering from getting started.
	We are not trying to make reengineering happen from the bottom up.
	Someone who is experienced in the reengineering effort is assigned to lead.
	There is no skimping on resources devoted to reengineering.
	The reengineering effort is not buried in the middle of the corporate agenda.
	Energy is not dissipated across a great many reengineering projects.
	The top manager is not two years from retirement.
	We do not fail to distinguish reengineering from other business improvement programmes.
	We are not trying to make reengineering happen without making anybody unhappy.
	We do not pull back when people resist making reengineering changes.
	We do not drag out the effort.
	We have done adequate risk management including identification, analysis and control.
	We do not quit too early.

7 Conclusions

The research problem was a problem of assuming that engineers can be educated more effectively. It was a problem of not understanding our engineering education process well enough, and also of not knowing enough about potential improvement opportunities available that will improve the process. This study addressed these by having defined a model for engineering education that served as a guiding structure in identifying improvement opportunities to result in the definition of a vision for more effective engineering education.

The main objective was to envision a more effective model for engineering education at the North-West University, and to recommend a strategy for improvement. A detailed description of a vision for more effective engineering education is described in chapter 4.5 and the recommended strategy is described in chapter 6.

The research objectives were:

1. *To research various engineering education improvement initiatives.* This was achieved by the literature study in chapter 3 as well as by studying the implementation of improvement initiatives by visiting selected universities.
2. *To develop a model for the engineering education process.* This was achieved as evidenced in chapter 4 of this study where the model is presented. The current status at the North-West University Faculty of Engineering has been described in chapter 4.3. A comparison to selected European university's way of educating engineers was made in chapter 4.4.
3. *To research relevant improvement strategies or methodologies.* This was achieved, as evidenced by the literature study in chapter 5.

It was expected that the study would show that:

1. The engineering education process needs better definition to be understood and analysed better.
2. There is room for improvement at the NWU Faculty of Engineering with respect to their engineering education process.
3. For radical improvement, the most effective models for improving the process will be those that radically change the pedagogic approach and not just incremental improvement activities.

The study results concluded that:

1. Having a model against which to measure the process is valuable in gaining a better understanding and establishing a common language amongst faculty members. The model provides a holistic perspective on all the elements of the engineering education process. The model is effectively used as a measuring tool to measure the current status of the faculty's education process as well as to aid in the comparison of the NWU's engineering education process to other universities' process of educating engineers.
2. Yes, there is room for improvement in the engineering education process at our faculty.
3. By studying the literature it was clear that only the models changing the pedagogical approach could achieve radical improvements. However, it was also clear that this is the most difficult route to follow with the most risks. It can be so difficult that it might not be worth the effort. It is also clear that the timing must be right for radical change to be considered in a professional bureaucracy, as professionals must be convinced to embrace the change. High profile change management will also be necessary since changing a pedagogical approach will affect people much more deeply than merely changing activities. It was also clear from the literature and the visits that the level of deep insight required to really appreciate activity changes might never be achieved. This could make the implementation of sustainable change difficult or even impossible. At the University of Twente a large number of staff proposed to start with small projects and scale them up over the years – that was the secure approach. However, it was not effective in accomplishing a change in vision or paradigm (Ruijter, 2002). One should therefore be careful to think we can implement a new model in any other way than in the radical way, or else one might also only achieve little improvement at best.

Reading this thesis should provide a *better understanding* of how one can improve the engineering education process. If the improvement strategy is realised and implemented, it is envisioned that a better engineering education process shapes a better education for future engineers, making them more prepared, more effective and more valuable to society at large. It is hoped that this thesis has shown that "being future wise is about more than mere predictions, it is about shaping the future" (Park, 2003) As engineers one should not be afraid to experiment, as that may be the way in which one as an engineer learns best.

The researcher trusts that this thesis inspires a *new vision of engineering education* for the Faculty of Engineering at North-West University and that the vision will in turn inspire the energy necessary for change to happen, and not remain a suggestion only. "Fundamental change cannot be attained without a corresponding readiness to conceptualize our world in ways that have seemed a dream – that is the burden of vision" (Kgaphola, 1999).

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