Teaching project management to undergraduate engineering students

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A sensible and correct understanding of project management methodologies can be regarded as an important ingredient of the complementary skills set of an engineering graduate. The reason is simple. Projects are temporary endeavours undertaken to create unique products, services, or results [PMBOK® Guide] and many engineers, by nature of their role in society, find themselves in some project environment for a notable portion of their career. Since much of the knowledge and several tools and techniques for managing projects are unique to project management, related skills are seldom taught elsewhere in the undergraduate curriculum. As a result, engineers are often expected to simply acquire related knowledge as they progress in their career, with no guarantee that such principles would be understood or applied correctly. While a successful project manager undoubtedly requires several years of industrial experience and prior project exposure as a team member, the focussed learning of project management fundamentals at undergraduate level can provide the young engineer with a sound basis for effective participation in projects.

The successful execution of a project relies, amongst other, on effective team work, inter-personal skills and knowledge of management principles. Therefore, teaching project management also offers an ideal opportunity to expose students to the non-technical and ethical aspects of team work and group behaviour, while functioning in a multi-disciplinary team.

Against this background, and since 2006, the Engineering Faculty at Stellenbosch University incorporated project management into the undergraduate curriculum as a compulsory complementary module for all final year engineering students. Out of a total of *ca* 500 students, approximately 90 multi-disciplinary groups are formed, each group typically consisting of six students from various engineering disciplines. All students attend standard lectures and case-study discussions on the principles of project management, PMI code of ethics, professional conduct, etc. Each project group is also expected to execute and manage a virtual project for a period of eleven weeks. During this period, each team has to submit three assignment reports (project scope and plan, risk assessment and progress report, project closure) while they manage their virtual project via the SimProject™ simulator. Approximately eight project teams compete against each other in a similar project simulation.

SimProject™ is a web-based simulator that was developed at Pennsylvania State University and it allows an instructor to create and manipulate virtual projects that are unique. Team members work together to take unanimous decisions that impact on the progress of their specific project, *viz.* resource hiring and firing, resource allocation to tasks, assigning resources to training and a range of other managerial actions. These decisions (ring-fenced into 12 decision-making periods) impact positively or negatively on the classic project attributes, *i.e.* time, cost, functionality and stakeholder satisfaction. The consequences of such decisions are reflected in a team score, updated after each decision-making period and expressed as a percentile score compared to the other teams.

The final project mark achieved by each team is the weighted average mark for the three assignments, plus a bonus or penalty mark related to the team's SimProject™ simulation score. An individual student's performance in a team is monitored by means of confidential colleague performance appraisals, performed electronically after submission of each of the project assignments. The final project mark achieved by an individual student is then a function of the group mark and the student's buddy rating score. In addition to a sub-minimum requirement of 50% for the individual project mark, a student needs to write and pass two assessments on the theory and principles of project management in order to finally pass the module.

Project management by its nature requires structure, systems and adherence to deadlines. Therefore, this module offers an ideal opportunity to the group of lecturers to demonstrate and enforce well-structured project management principles, also in their expectations related to meeting of deadlines and professional behaviour. While large numbers of students can often impact negatively on both the student and lecturers' experience, the inter-team competition as enabled by the virtual project simulations on SimProject™, successfully supports and justifies the faculty-wide generic offering of the module. In addition, by following a multi-disciplinary team approach, the artificial polarisation that typically develops between students of different engineering disciplines (one of the adverse effects of several years of discipline-directed teaching) can be reduced notably.

Unfortunately, project execution on the virtual SimProject™ platform has some limitations. For example, the project plan is given and the students simply execute the plan. Provision therefore needs to be made for the compilation of a separate project plan. The simulations are, as with any model, extractions of reality and one may argue that some assumptions are not fully realistic, while the basic project plans could also be more complex to fully suit engineering students. Furthermore, a maximum of ten project groups can compete in a single simulation, so that several simulations need to be run simultaneously to cater for large numbers of students.

Nevertheless, the advantages are significant. Most notably, a uniform project environment is created for all students, so that student assessments and standards are uniform for all project groups. While a full project can be 'executed' within an academic semester, students can also be exposed to unexpected project events (triggered by the simulation manager) to test their risk management skills. Students also learn that project execution is a continuous action, with deliverables that must be submitted on a weekly basis. Finally, the simulation teaches them that time, cost and quality are interdependent project criteria, *i.e.* the winning team is the one that can best manage the *interaction* between these criteria.

Google maps - A visual introduction to the Cumulative Effects of Development for Civil Engineering students

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As more attention is now being given towards assessing the influence development has on mankind and the natural environment, civil engineers have a role to play (Edwards, 2000).

As professionals, civil engineers are morally obliged to acknowledge any negative impacts their actions have on communities and the surrounding environment (Franquesa et al., 2010).The problem however arises in that although civil engineers have a moral obligation and are mandated by policy to consider CEA they are seldom during their training exposed to the concept. One possible solution, which forms the cornerstone of this study, is to expose civil engineers to the concept of CEA during their training. Educating future civil engineers has a vital role to play in the sustainable development imperative. Exposing future engineers to the concept of what CEA represents could have a positive impact on how they approach sustainable development and in turn green design (Bilecet al., 2007). This study looked at giving students an understanding of CEA by visually representing it on Google maps. Two cohorts of students were tested after one cohort had been exposed to the visual representation of CEA. It was found after interviewing the students, that those that had been exposed the visual representation of CEA had a far better understanding of cumulative effects and how they influence both development and the environment.

The effect of the Numberwise program on first year students' academic performances at an University of Technology

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The purpose of this study was to determine the effect of the Numberwise program on first year students' mathematical skills at the Department of Civil Engineering, Durban University of Technology, Pietermaritzburg Campus. The benefits of the programme were queried by the faculty's management, which led to this research.

When it comes to the importance of arithmetic skills, most educators have their individual opinion as to what extent such skills are important in the learning and understanding of mathematics. Some believe that calculators should be totally banned from the classroom, while others promote the use of calculators even in kindergarten. However, some educators ask to carefully consider each teaching situation to determine the best way to learn.

The psychological theory of mathematics education has evolved greatly in the past 50 years. In accounting for the most straightforward-seeming psychological data, there is a need to be able to use not just one construct in isolation (be it rule learning, algorithms, strategies, construction of meaning, affect - where Numberwise helps a lot, or any other), but constructs in combination with each other. Professor Goldin of the State University of New Jersey believes that only then can we build a realistic, structurally adequate, sufficiently detailed theoretical model for the learning and teaching of mathematics (Goldin, 1998:142).

We should always aim to provide our students with the level of mathematics required by today's thinking citizen. Data of the Trends in International Mathematics and Science Study benchmark tests, indicates the extent to which countries had prepared their students to deal with the kind of mathematics they would meet in the street or the press (Howson, 2001). The final result was that South Africa came last out of 43 countries. With statistics like these, we need to be actively engaged in finding new ways to assist the students in fulfilling their roles as citizens of South Africa in the future.

The Department of Civil Engineering on the Indumiso Campus made an innovative decision to adopt the Numberwise program in 2007. This program is designed to assist students in actively developing their arithmetic skills without the use of calculators. The main aim was to limit the focus on procedural and arithmetic skills at the expense of conceptual understanding. This specific study investigated the impact of Numberwise on first year students' mathematic performances. This computer-based module is an additional component of Computer Skills l. Numberwise is a free computer program which is accessed online and designed towards the effective development of arithmetic skills.

The program revolves around the following components: an initial assessment, individual drills, and a final assessment test that acts as a benchmark for measuring basic numerical competency. One of the main reasons why Numberwise claims to be successful is that it promotes student confidence which can lead to even more success.

In this research project that included 928 students between the ages of 18 and 23, all the items pertaining to Numberwise proficiency and their relationship to mathematics achievement were explored. Information on students' first year performances was made available from the

University's database (ITS). The research study being reported attempt to answer the following question: Does the Numberwise program, designed towards the effective development of arithmetic skills, affect the academic performances of first year students (18 to 23 years) studying at this University?

In order to study the effectiveness of the Numberwise program, secondary data on past students' (only first year engineering students from the Department of Civil Engineering, Durban University of Technology, Pietermaritzburg) academic performances was supplied by the University's database program (ITS). The research design is an ex post-facto non-experimental design, as relationships are examined without any direct manipulation of conditions. The possible causes are studied after they have occurred.

The data of the Access and Diploma groups were investigated separately. The Access group consists of students who did not meet the necessary criteria to be allowed access to studying engineering. Durban University of Technology offers a model of 'extended education' at the Department of Civil Engineering, Pietermaritzburg campus, which means an additional 6 months of university preparation. The Diploma group are the students who met the basic requirements and study in the mainstream programme.

The mathematics marks were analysed and compared between students who enrolled in Numberwise with those who did not take Numberwise. Pass Rates of students are displayed in Table 1 below.

Table 1: Mathematics pass rates of students

	NOT Enrolled in Numberwise	**Enrolled in Numberwise**
ACCESS Group	23%	53%
DIPLOMA Group	22%	65%

The statistical model clearly indicates that in both Access and Diploma student groups, the average score of the students taking Numberwise were considerably higher than the scores of those students who did not enrol to Numberwise. Also, by making use of inferential statistics, the p-values of both the Access and Diploma groups (respectively 0.04 and 0.01) indicate statistically significant differences before and after the intervention of Numberwise. We can thus reject the notion that differences exist as a result of chance.

This research which was designed to investigate the effects of the development of effective arithmetic skills on first year students' academic performances, revealed that the investigated students' proficiency of basic arithmetic operations (the main aim of the Numberwise course) was a strong predictor of their success in mathematics. It also revealed that well developed procedural skills form a solid and necessary platform for further conceptual development. Students struggling with basic arithmetic and procedures tend not to focus on the phenomena under investigation and can easily be left behind.

An intervention such as Numberwise should therefore be kept as a compulsory module of Mathematics education at the department of Civil Engineering. Moreover, future possibilities regarding the synthesis of many perspectives in mathematics education should be further investigated as it can improve the teaching and learning of this incredibly interesting field of study. Due to the number of factors influencing a particular education system, educators should aim to use the different models complementarily and not contradictorily as so many educational philosophers have suggested in the past as this leads to an incomprehensive view on mathematics education.

Keywords: Numberwise program, civil engineering education, mathematics skills, student success, arithmetic skills.

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Flipping the classroom: Students' and lecturer's perceptions on the use of the inverted classroom method of curriculum delivery in a hydrology course.

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The current mode of delivery of Engineering education at Cape Peninsula University of Technology (CPUT) is the lecture method, which has been shown by research to be not particularly effective for promoting deep learning. As result, we argue that an alternative method of delivering curriculum in this field may be needed in order to improve student learning, through self-directed, active and collaborative learning. One such alternative method, which has gained increased interest in the recent times is the Inverted Classroom Method (ICM) of curriculum delivery, also known as 'the flipped classroom method'. This method moves the activities traditionally carried out during lectures to outside the classroom via technology. This is done by providing learning resources to students online, in audio, text or video format. Outside the classroom, students engage with the online materials in preparation for lecture time. During class or the lecture, the focus is on practice and application of concepts via guided learning activities, often done in student groups under the guidance of the lecturer and peers. Although research in this field is growing internationally, there seems to be lack of studies on the use of the inverted classroom method of curriculum delivery in Africa, particularly in resource poor contexts, such as South Africa.

Underpinned by self-directed, active and collaborative learning theory, this paper presents students' and their lecturer's perceptions on the benefits and challenges of the inverted classroom method (ICM) of delivering instruction compared to the lecture method, in a third year hydrology course, in the Civil Engineering field, at Cape Peninsula University of Technology, South Africa. Quantitative and qualitative approaches were used for understanding the phenomena under investigation and a mixed method approach of collecting data was used. An in-depth interview with the lecturer was carried out, and a survey questionnaire was distributed to the 50 students enrolled in this course to elicit the lecturer's and students' perceptions on the benefits and challenges of using the inverted classroom method of curriculum delivery. The survey questionnaire consisted of both open and closed-ended questions utilized to draw out students' perceptions on the inverted classroom method of curriculum delivery and the traditional lecturer method. The closed questions consisted of eight questions comparing students' perceptions on the flipped classroom method and the traditional lecture method, in terms of classroom attendance, level of enjoyment, engagement and understanding of the course materials, attentiveness in class, support during the learning process and the mode of delivery students preferred for future learning. A further four open-ended questions elicited students' perceptions on the ICM capability to facilitate active learning, group work and the time students' took to get used to the ICM of curriculum delivery. Open-ended questions required a ranked response, requiring students' to respond to a statement by selecting the following options: 1) strongly agree, 2) mostly agree, 3) not sure, 4) mostly disagree, 5)strongly disagree; with two open-ended questions asking students what they liked and disliked about the ICM and the TLM, requiring open-ended responses. Quantitative data analysis was executed by calculating means and standard deviations. A one tailed sample T-Test was executed to test for significant differences in perceptions of these two methods. Qualitative data analysis was done inductively, via constant comparative analysis, although concepts identified through the literature review and the theoretical framework influenced this analysis.

Some of the findings of this study showed that the inverted classroom method of curriculum delivery promoted: self-directed learning, students' preparation for class, active learning in and outside the classroom, students' attention in class, peer learning and allowed students' to study at their own pace. Students felt in general better prepared for their exams than when taught using the traditional lecture method. Challenges of using the inverted classroom method reported by the students' focused primarily on the lack of enough communication and support outside class and the lack of assessment of the understanding of the course content engaged with outside the classroom. The lecturer reported poor teaching facilities as a major challenge in the use of the ICM of curriculum delivery in the institution.

More research is needed to explore whether the benefits identified are transferable into other disciplines and to students in their first years of study. Furthermore more testing on understanding of the content engaged with outside the classroom may be needed to facilitate the understanding.

Keywords: Inverted classroom method, flipped classroom method, self-directed learning, active learning, collaborative learning, Civil Engineering, Higher Education

An investigation into causes of poor performance in a final level course in Mechanical Engineering

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As engineering educators many of us still teach in the manner in which we were taught. We need to question whether these pedagogies are relevant for current students (Felder, 2012) and understand their weaknesses before adapting teaching practices. This paper will explore methods that were used, by the first author, in the course Hydraulic Machines III, to better understand the competencies and learning practices of the students in the class. The study was non experimental and both quantitative and qualitative in nature. The framework under which the research was carried out was grounded action research.

A grounded theory is one that "is inductively derived from the study of the phenomenon it represents" (Corbin & Strauss, 2007) whilst action research is evaluative and reflective with the aims of improving practice (Burns, 1999). Grounded action research is a process of continual discovery, learning, rediscovery, and relearning (Simmons & Gregory, 2003). Its purpose is to develop an operation theory from the grounded theory and hence to create and apply practical solutions to social problems. This framework allows the freedom to refine an investigation as it progresses as well as to implement potential solutions and determine their efficacy.

Over the preceding four semesters, conceptual and theory questions were added to assessments in order to test students' understanding of the material, its applicability and context, rather than their ability to 'plug and chug'. Anecdotal evidence suggested that students could answer calculation problems adequately, but struggled with conceptual and theory problems. This paper shows that students, by and large, appear to struggle most with both conceptual questions and questions relating to the hydraulic machines section.

In order to determine if performance was generally poor, limited to certain sections of the syllabus, or related to certain question types such as calculations or conceptual problems, the performance of students in individual questions in the June 2012 exam was recorded.

Analysis showed performance in calculation problems to be much better than in conceptual ones. The average score for all calculation problems, bar one, was significantly higher than those for conceptual problems. The calculation question with the worst performance was the section covered last in class and not assessed in tests. Students under pressure as the exam approached may have opted to ignore this section and concentrate on sections they were more familiar with.

After this initial study it was decided to rearrange the syllabus, covering this section earlier, to see if this would improve results. Extra resources such as videos, tutorials, examples and quizzes were added to the subject's online platform to support this section and to provide support with regard conceptual questions.

The following semester's tests and exam results were analysed to see if these interventions were successful. Analysis of test results showed no real change. To determine why these interventions were not successful students were surveyed, and data from the online platform analysed to determine the extent that online resources were utilised. Usage was found to be limited.

Analysis of the test results also showed that moving the section, previously covered last, did not have a positive impact on the students' results. Analysis of the subsequent exam once again confirmed this.

Based on the analysis of test results, and usage of the online platform, it was decided to interview students to see if any further light could be shed on the problems identified. Weaker students would be interviewed as future interventions would be aimed at students like these.
15 students who had not met the exam subminimum for the course were invited to be interviewed and 10 accepted. This was an informal interview held with the students on an individual basis. This group cannot be seen as representative of the class but it does well to represent the weaker students and help direct both future interventions and investigations.
The predominant study method utilised by these students was to work through past test papers. Test papers were chosen over exam papers due to the availability of full model answers. Prescribed tutorials were generally not attempted; the reasons given by most students were "*these have no answers*".

When asked why they did not use the online examples the response can be summed up in the words of one student "*it's how we learn, we do past papers, we don't go online*". When asked why other online resources such as videos and quizzes were not used, the consensus was that they did not see any value in doing this '*extra work*'.

All of the students indicated that they would attempt calculation problems before attempting theory/conceptual questions. A minority even admitted that even if the theory questions were very easy they would not know as they would not read the question until they had answered all calculations questions first. When questioned as to why he didn't engage with the conceptual questions one student replied "*our minds are not programmed to think like that*".

Perhaps a self-reinforcing loop may be present within the department. If in lower level subjects a student is expected to answer only calculation questions, the weaker student will practice calculations at the expense of understanding the context and applicability. By the time he reaches final level subjects he has developed, up until this point, a 'successful' method of study.

Although the information gathered from the interviews cannot be applied to the class as a whole, it does indicate that further research should be undertaken to determine the prevalence of these attitudes and study methods within the class as a whole. Further research and a change in teaching methods and assessment practices, within the subject and the department, are needed to address these concerns.

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Using the Dynamics Concept Inventory to assess teaching effectiveness

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Dynamics at the University of Pretoria is taught in a large second year class, with between 500 and 750 students. It is a core course for mechanical engineering students, and a service course for students from a range of other engineering disciplines (mining, industrial, electrical, metallurgical). The class is taught in two lecture sections which meet three times per week, and students attend one of two two-hour tutorial sessions each week. Four lecturers are involved in different aspects of the course.

Lecturers have observed that many students disengage from the course. By the end of the semester in 2012, less than half of the enrolled students were attending class and tutorials. In consultation, it has been observed that students focus their energies on learning to solve typical problems through pattern recognition rather than on understanding core concepts. In order to quantify the conceptual understanding of students, the Dynamics Concept Inventory (DCI) has been administered since 2011.

The DCI was developed by Gray, Evans, Cornwell, Costanzo and Self (2003) as an instrument to measure the extent to which students understand fundamental concepts in dynamics. It was modelled on the Force Concept Inventory (FCI) of Hestenes, Wells and Swackhamer (1992), which has now been in widespread use for a quarter of a century and has provided valuable insight into the effectiveness of teaching techniques in the teaching of undergraduate physics courses. The DCI is administered at the beginning of the semester and again at the end of the semester, and should allow instructors to differentiate between students' prior knowledge and the concept formation which has taken place in the course.

Results of DCI tests from 2011 to 2013 are shown in the form of boxplots in Figure 1. The DCI scores of students entering the class are consistent over the three years of measurement. The measurements after a semester of teaching on Dynamics indicate that only small conceptual gains have been achieved. The median score improved from 7 correct answers out of a possible 29 to 9 correct answers by the end of the semester in 2011 and 2012. In 2013, the median score improved from 7 to 10 correct answers. It is concerning that many students have not developed a strong conceptual foundation through the course.

A comparison between scores on the final exam and on the post-semester DCI (2011 results) is shown in Figure 2. We can see that students who do well on the final exam (black bars) have an above average grasp of the concepts, and that students who answer a majority of the DCI questions correctly (hatched grey bars) in general pass the exam. However, it is clear that there is not strong correlation between measured conceptual understanding and performance on the final exam. The DCI results challenge the assumption that students cannot attain a distinction without a strong conceptual grounding. Further investigation is needed to determine whether all of the concepts evaluated by the DCI are appropriate as measurement for this course. Comparison between problem-based testing and concept-based testing on a narrow subset of concepts should also yield valuable information.

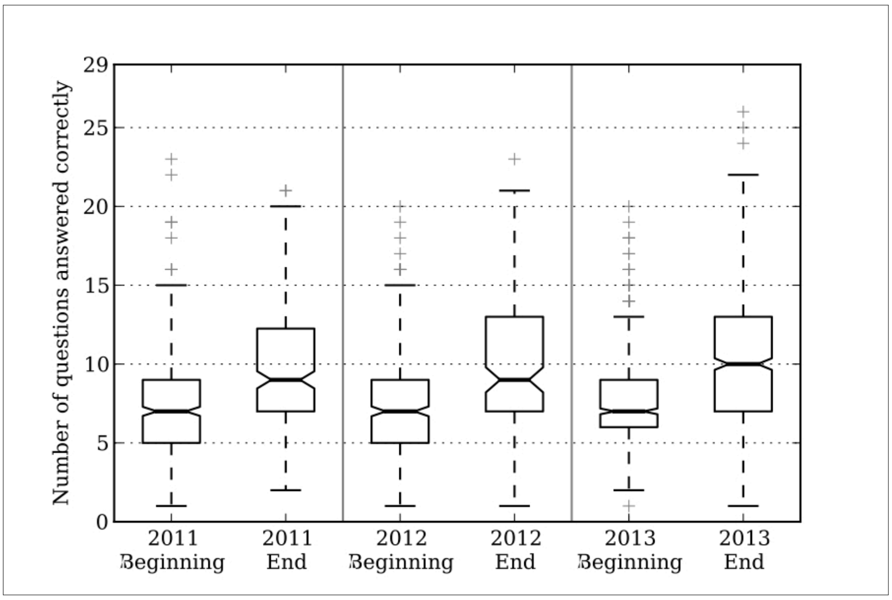
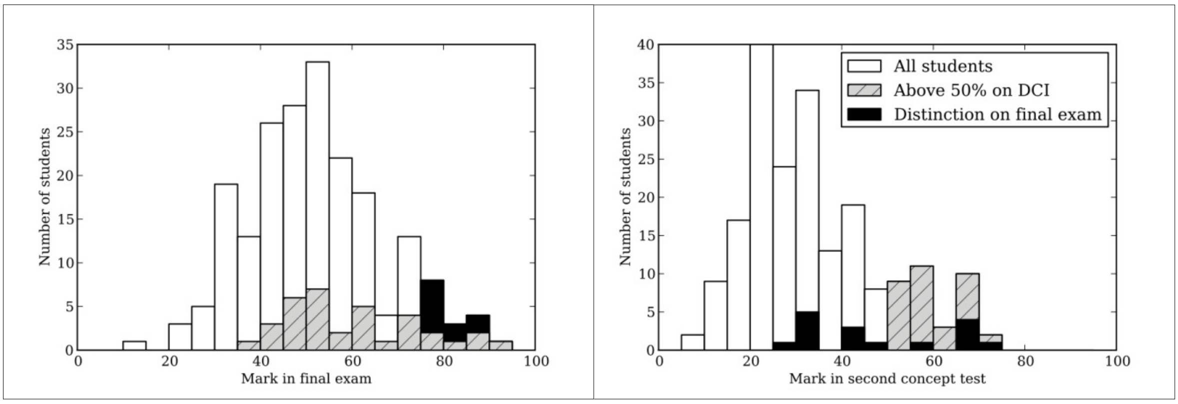


Figure 1: Notched boxplot figure showing distributions of scores on the DCI administered at the beginning and end of semesters. The median is indicated by a solid line, the first and third quartiles are denoted by the extent of the boxes, the whisker bars denote the extent of the majority of the data, with outliers indicated by grey crosses.



(a) *(b)*

Figure 2: Histograms of marks achieved on (a) the final exam and (b) the post-semester DCI in 2011. Students who obtained a distinction on the final exam are highlighted in black, while those who scored above 50% on the DCI are shown in grey with hatchmarks.

New teaching initiatives in 2013 have focused on improving concept formation. Techniques from the work of Mazur and colleagues, including Just in Time Teaching and Peer Instruction (Crouch & Mazur, 2001) have been implemented. Students complete reading assignments, watch video lectures and answer online quizzes before coming to class, allowing class time to be more interactive. Tutorial sessions are no longer voluntary. Tutorial tests, instead of being problem-based, are now concept-based.

The DCI can be used as a measurement instrument to estimate the impact of teaching techniques on student learning. Combined with other qualitative and quantitative observations (such as student and lecturer feedback), this encourages lecturers to ask questions about the effectiveness of teaching practices and continue to improve the course.

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Effectively spreading the Engenius Message: "Join the Engineering Team that makes our future happen!"

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Background

Sustainable engineering services are the basic cornerstones of economic development and wellbeing of communities. South Africa's National Skills Development Strategy III therefore intends to achieve significant increases in priority qualifications such as engineering to support initiatives such as the New Growth Path, the Industrial Policy Action Plan, the Human Resource Development Strategy and Sector Skills Plans *(DHET, 2010).*

Whereas engineering graduation numbers at South Africa's higher education institutions has increased, the training system is still not producing enough engineering professionals. To address the critical need SETAs are from 1 April 2013 required to allocate at least 80% of their discretionary grants to PIVOTAL[4] programmes which includes engineering education and training programmes *(DHET, 2012).*

Unfortunately, engineering programmes are not a choice for many young South Africans. Young people do not know what it means to be an engineering professional. They strongly connect engineering to mathematics and science skills but do not readily associate engineering with problem solving, creativity, or having a positive impact on the world and lives of people. Despite the impact of engineering on their daily lives, they are also largely unaware of the range of engineering professions or opportunities available through an engineering education.

The challenge

Figure 1 indicates that white students studying engineering were predominantly advised by their family and role models in their circles, as well as, career guidance materials at schools *(Lawless, 2004).*

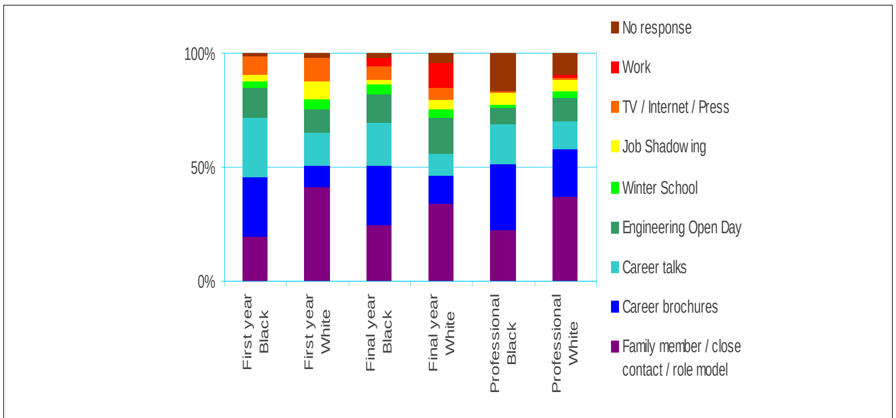

Figure1. Sources of career guidance information for civil engineering students and professionals.

[4] Pivotal Programmes is an acronym which means professional, vocational, technical and academic programmes resulting in qualifications or part qualifications on the National Qualification Framework

Previously disadvantaged learners, however, have neither of these privileges as few of their parents are engineering professionals and the opportunities to learn about these careers at their schools are limited. As such, their main sources of information are career talks and open days.

This is not a situation unique to South Africa. A study conducted in the USA by the National Academy of Engineering *(NAE, 2011)* identified the following key reasons for this international situation:

- A lack of understanding of the role of engineering professionals,
- A lack of conversations about engineering,
- Too few role models,
- No coordinated effort.

The Engenius Programme

In a response to provide learners with an understanding of the engineering profession, the Engineering Council of South (ECSA), considered the NAE study and initiated a nationally coordinated stakeholder programme called Engenius *(ECSA, 2011)*. This programme aims to promote the engineering profession to learners by:

- Promoting national collaboration, coordination and support amongst partner organisations involved in advancing the engineering profession.
- Developing messages, products & systems to support outreach activities of mainly partner organisations
- Supporting partners to communicate a consistent driving message.
- Training and empowering young engineering role models

National coordination and collaboration should contribute to the maximisation of effort and resources including facilities, role models, information, opportunities, whilst eliminating duplication.

Initiating the Engenius conversation nationally

In order to support partners nationally to communicate a consistent message to learners, Engenius in collaboration with stakeholders developed the driving message: “Join the engineering team[5] that makes the future happen”. This message steers all Engenius products which are made available to Engenius partners to enhance their activities.

What became evident during the first year of implementation was that young engineering role models were the most effective in inspiring learners. Through their testimonies and support during workshops, learners developed a clear understanding of engineering and were encouraged to make engineering their career of choice.

Engenius subsequently developed a two hour role model training workshop for engineering students, graduates and professionals. This workshop equips role models with the Engenius methodology, standardised learner presentations and Engenius kits. Engenius workshop kits contain animated DVDs, brochures, worksheet, materials and tool as well as promotional products for up to sixty learners per kit. As seen in Figure 2, these kits allow role models the opportunity to share their work, whilst providing learners with the opportunity to engage in

[5] The engineering team consists of researchers, engineers, technologists, technicians, inspectors, supervisors, draftsmen and artisans.

hands on engineering activities in different economic sectors. The outcome is that learners are positive about engineering activities as they associate it with problem solving, creativity and having a positive impact on the world and lives of people.

Figure 2. Girls designing and building a structure in an Engenius workshop.

Developing Engenius role models

During 2012 over 200 graduates, from over fifty organisations across six provinces were trained as role models. Whilst presenting these role model workshops it was found that the graduates also developed a better understanding of the problem solving competencies that were expected of them for professional registration *(ECSA, 2012).* This knowledge, together with the constructive contact with learners, committed them to support Engenius in a personal capacity as well.

Engenius is currently engaging universities and universities of technology to train engineering students as role models. If these thousands of students could be mobilised during their academic studies it could dramatically impact on the number of learners reached with the Engenius message.

Conclusion

All stakeholders in engineering, especially higher education institutions through their students, should take hands to spread the Engenius message. This will inspire the learners to make engineering a career of choice and will develop a broader public understanding of the importance of engineering.

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Sustainability, citizenship and ethics within the mainstream engineering curriculum?

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As mechanical engineering marches on into the 21st Century, there is increasing pressure on the syllabus to better prepare its graduates for an uncertain world. The core of a mechanical engineering (ME) curriculum is usually considered to be engineering science and technical design which are technically and scientifically demanding subjects. Concepts like sustainability, citizenship and ethics which are important for preparing students for their roles as active citizens are often considered to be “soft” subjects on the periphery of the curriculum. They are perceived by students as exotic, discomforting and not part of engineering. True engagement with sustainability, citizenship and ethics places cognitive (and emotional) demands on students as they challenge both our treasured value systems and behaviour, developing more holistic engineering identities (Allie, 2009). Students must undertake some emotional and cognitive work when re-evaluating their worldviews - this can be highly discomforting (Boler and Zemblyas, 2003) but also offers students opportunities for personal growth and the development of critical thinking skills. Within engineering, the normal practice is to teach sustainability, citizenship and ethics in dedicated courses outside of the mainstream programme. The danger is that students may compartmentalise their learning, and disengage from this type of critical thinking in the engineering context, which is a far from ideal outcome. This paper presents some empirical data supporting the need to address the issue of integration between sustainability, citizenship and ethics and “mainstream” engineering. It also reports on some preliminary work on bridging this gap.

Empirical evidence supporting the need for change was gathered from responses of students registered for the 2012 ME final year project course, a capstone design/research engineering course. For the past five years, students have been asked to write a short (250 word) essay on the potential impact of their project on society. Students who can perform complicated calculations, write complex computer code, build robots and perform accurate experiments find this 250 word essay to be highly challenging. Students do not engage deeply with this important idea and are not able to integrate the wider implications of project work with their technical considerations. Bridging the gap between sustainability, citizenship and ethics and the technical engineering context is something that students are not automatically able to do without support.

In 2012, a small pilot group of ten first semester project students were given blank sheets of paper and were asked to draw a picture describing that they thought or felt about their project. This was a first attempt to get students to think about their project in an unfamiliar, more reflexive, way. This type of exercise is from the family of participatory learning and action (PLA) techniques used by Bozalek (Bozalek, 2011) to address issues of community and identity in social science students. These techniques are aimed at minimising differences in language and academic expression (Bozalek & Biersteker, 2009), but are not the kind of exercises typically used with ME students. The ME students were hesitant about participating and the majority of the students drew process type diagrams, describing some technical aspect of what their project entailed. A few possible explanations for this exist – students may have been confused about the expected right answer, they may have been uncomfortable expressing their true feeling in this type of exercise or it could be indicative of the lack of reflexivity exhibited by the larger body of students in their impact essays. The lack of familiarity with the pictorial exercise could be overcome by using other PLA techniques with more familiar symbolism. Concept mapping was identified as the most familiar.

Concept mapping, a PLA technique for organising and representing knowledge in a visual form, was incorporated into a 3rd year mechanics course, as an introductory step towards future engagement with sustainability, citizenship and ethics and also as a useful tool within the technical context. Using PLA techniques like concept mapping in mainstream courses gives credibility to the technique and enables students to appreciate its benefits. The maps are workable representations of the cognitive structure of the mapper. This is, of course, highly simplistic but is useful if we can accept its limitations and recognise it as a way to bridge the gap. Since mapping is dynamic and based on constructivism, maps "allow off-loading of thinking and show the result of engaging in knowledge construction" (McAleese, 1994). Using concept mapping is aimed at getting students to think critically about how ideas and concepts in their world link together.

The third year Dynamics II students were required to draw concept maps to describe how certain topics in the course are inter-related and how they apply to the real world. Very few of the maps drawn in the Dynamics course have direct links to sustainability, citizenship and ethics, but they do provide students opportunities to organise abstract ideas, explore their inter-relatedness and to relate them to practical engineering problems. While it does not necessarily follow that concept mapping will promote engagement with sustainability, citizenship and ethics, it provides students with a framework for doing so. The 2012 student response to mapping has been mixed, as it was new and required additional effort from them when expressing their ideas and inter-relatedness.

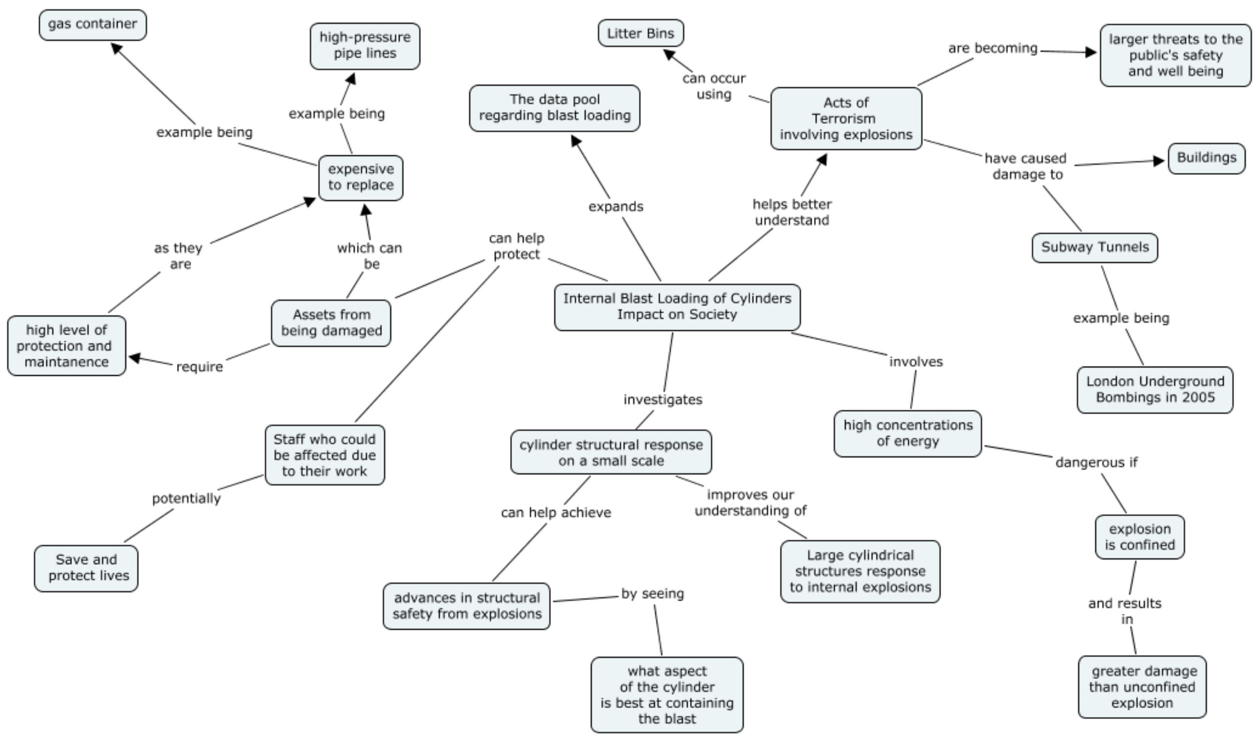

Figure 1: Concept map produced by a 4th year student as an aid to writing a societal impact essay as part of a final year project report (used with permission)

The 2012 third year students are now (in 2013) engaged in their final year projects. Due to curriculum changes, the impact on society mini-essay has been integrated into an interim progress report (rather than being isolated to a separate form) and students have been verbally encouraged to use concept mapping to assist them in articulating the relationship between their technical work and societal impact. As this was not a compulsory requirement, very few students included concept maps in their reports, indicating (perhaps) that they do not yet see the benefit in doing so. A concept map from a 4th year project student is shown in figure 1. The students that did include concept maps wrote more articulate impact essays, although it is conceded that those students are from the top academic group in the cohort.

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Writing laboratory reports in a Mechanical Engineering course at a comprehensive university: Knowledges, practices, beliefs and experiences of first-year National Diploma students

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The purpose of this 2013 research study on which this presentation is based is to identify analyse and discuss first-year students' knowledges, practices, beliefs and experiences enacted in the genres of two questionnaires (one administered at the beginning and one at the end of the first semester), as well as the genre of a written laboratory report. This is to inform the teaching and learning of literacies in Materials and Science 1 modules, as well as the National Diploma: Mechanical Engineering programme more broadly.

To identify and analyse the knowledges, practices, beliefs and experiences, we use the frameworks of Fairclough (2003), Ivanič (2004), Lillis (2006) and Janks' (1999, 2010). Fairclough's and Janks' frameworks refer to linguistic features, such as the choice and use of words, metaphors and grammar, which form part of particular disciplinary discourses and all four frameworks refer to literacies and discourses. In this repect, Fairclough (2003, 16) emphasises that describing documents and interpreting and analysing language and discourses "should not be seen as prior to or independent of social analysis and critique", but as open processes, which are "enhanced through dialogue".

The importance of this study stems from the emphasis that has been placed on all universities to improve throughput rates and equity of learning outcomes (National Plan for Higher Education 2001). Moreover, The Engineering Council of South Africa (ECSA) requires all programmes to integrate literacies in the curriculum, such as reading, writing and critical thinking practices. ECSA's (2012) generic exit level outcome 6 on 'Professional and Technical Communication' also "requires cohorts of engineering communities to be able to communicate effectively to discipline specific audiences or communities at large while engaging with different kinds of texts such as: technical reports, proposals and presentations".

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Industrial Partners' stance on Work Integrated Learning (WIL) informing transformation towards New Engineering Curricula at NMMU

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The Higher Education Qualifications Framework (HEQF) document was promulgated in 2007 by the then Minister of Higher Education, Ms N Pandor. In January 2013, the Minister of Higher Education, Dr B Nzimande, endorsed the Higher Education Qualifications Sub-Framework (HEQSF). According to the HEQF and the HEQSF, all South African Higher Education Institutions (HEI's) are obliged to align their current qualifications and/or curriculate new qualifications accordingly.

This alignment is perhaps more taxing on Universities of Technology (formerly known as Technikons) and some Comprehensive Universities (such as the Nelson Mandela Metropolitan University [NMMU]) currently offering engineering Diplomas that have Work Integrated Learning (WIL) otherwise referred to as Workplace-based Learning (WPL) components. In addition, the Baccalaureus Technologiae (BTech), Magister Technologiae (MTech) and Doctor of Technology (DTech) qualifications will cease to exist as they are not catered for in the HEQSF. Furthermore, the Engineering Council of South Africa (ECSA) has since 2007 developed Exit Learning Outcomes (ELO’s) for each type of qualification, i.e. certificates, diplomas and degrees, through the establishment of Standard Generating Groups (SGG's) by the Engineering Standards Generating Body (ESGB’s). HEI's wishing to offer any engineering qualifications will need to comply with the ELO’s as well.

NMMU, like most HEI's has developed a set of procedures if academic departments wish to curriculate new qualifications (programmes). One of the requirements is to liaise and consult with industry not only to inform them about the changes that will be taking place with respect to the various qualification types listed in the HEQSF but also to allow them an opportunity to express their views on the qualification type/s that will best meet their needs. In this instance the School of Engineering (SoE) in the Faculty of Engineering, the Built Environment and Information Technology (EBEIT) embarked on a survey, in the form of a questionnaire, to employers that currently offer WIL (WPL), after ethics clearance was obtained from the NMMU Ethics Committee. This survey comprised of a number of questions related to the new suite of qualifications as per the HEQSF and some with respect to the current Diploma. All supporting documentation, i.e. the HEQSF, a table of the different WIL typologies, a diagram related to the different suite of qualifications and a list of references, was electronically included.

The initial thinking of the academics in the SoE was that all departments currently offering Diplomas should curriculate for the Bachelor of Engineering Technology (BEngTech) degree, a 3 year programme, with a subsequent Honours degree (BEngTech[Hons]). The reason for this choice was to veer away from being compelled, by the HEQSF, to ensure learner placement if a WPL component is part of a qualification as is the case with the 360 Credit Diploma. However the responses received indicated that employers prefer the 360 credit diploma over the BEngTech degree for all engineering disciplines with the exception of Civil Engineering which was equally weighted (see Table 1). In this instance employers were asked to choose between the 360 credit diploma and the 3 year BEngTech degree or both. The specific responses per discipline are given in Table 1 below.

Table 1. Employer's responses with respect to preferred qualifications.

DISCIPLINE	360 Cr Dip (%)	BEng Tech (%)	Both (%)
Civil	40	40	20
Electrical	54	25	21
Industrial	58	25	17
Mechanical	53	29	18

WIL or WPL is considered as an important component of the current Diploma by 94% of respondents and 76.5% of respondents considered the need for both P1 and P2 as important. All employers believe that WIL or WPL prepares learners for the workplace (92.6%) and that it adds value to their employability opportunities (92.6%). Employers further indicate that a WIL or WPL component would also be beneficial in a 3 year degree programme (88%). This outcome, with respect to WIL or WPL was to be expected simply because employers have the opportunity to identify learners' scholarly and practical attributes. However mixed responses were received when asked which component would be more beneficial to learners in a 3 year degree programme given the typologies of WIL, i.e. Work-Directed Theoretical Learning (WDTL), Problem-based Learning (PBL), Project-based Learning (PJBL) and Workplace-based Learning (WPL). In this instance, 18% prefer PJBL, 25% WPL and 18% indicate a combination of PJBL and WPL. It should be noted that three of the four components of WIL can be incorporated into the curriculum of an engineering qualification offered by HEI's except for WPL. This follows the prescription of the HEQSF, which states that WPL is to be conducted at a company and the placement of learners at these companies will in the future be the responsibility of HEI's.

While the sample size may be considered by many as small (68 respondents), 65% of these were from large companies, i.e. having 250 or more employees. Although the purpose of the survey was met with respect to the WIL feedback, the qualification type indicated by employers was counter to expectation as it was hoped that they too would prefer the 3-year degree programme. It is clear from this survey that the SoE will need to rethink its Programme Qualifications Mix (PQM) in order to accommodate both Employers requirements and at the same time cater for learners wishing to embark on an Academic career by progressing to Doctorate level. However there are many unanswered questions that need clarification before embarking on a curriculation journey, some of which include:

1. Will Employers be prepared to enter into Memorandums of Agreement (MOA's) for providing learners WPL? This can be communicated through a further survey or workshop.
2. Will HEI's also be responsible for the costs incurred if learners have to relocate to complete the WPL component, given the fact that the onus of placing learners in the workplace is the responsibility of HEI's.
3. What will the WPL training entail, as this will need to be assessed with respect to the ECSA ELO's?
4. Will HEI's provide the resources/ funding and create new administrative and academic positions to organize the placement of students and the management process as prescribed by the HEQSF?

Mind maps as a teaching tool: Its relationship to learning approaches, materials science self-efficacy, and academic achievement.

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Materials science is part of the first year main stream engineering syllabus and is compulsory for all civil, electrical, electronic, industrial, mechanical, metallurgical, and mining engineering students. Materials science requires a solid basis in general chemistry, and students generally find it challenging. The present study reports on an additional materials science module in the fourth semester of an extended programme (ENGAGE) at the University of Pretoria. Students take the module simultaneously with a main stream module. Many students fail and repeat the main stream materials science module each year.

The present research draws on the Presage-Process-Product (3P) model by Biggs (2001). The 3P model describes learning as a dynamic system in which student factors, teaching context, on-task approaches to learning, and learning outcomes mutually interact. Student factors include prior knowledge, ability, and preferred approaches to learning. The teaching context comprises objectives, assessment, climate/ethos, teaching, and institutional procedures. The *Process* aspect deals with surface (i.e. memorisation) and deep (i.e. understanding) approaches to learning material (Beattie, Collins, & McInnes, 1997), although Biggs (2001) states that the teacher and student are jointly responsible for the outcomes of learning. Students can adapt their approach from a surface to a deep approach depending on the nature of the material, and vice versa. The *Product* aspect comprise learning outcomes, such as facts and skills. Teachers frequently use mind maps as a teaching tool to encourage a deep approach to learning (Buzan, 2010, Davies, 2011). Self-efficacy as first described by Bandura (1986) may be thought of as “people’s judgements of their capabilities to organize and execute courses of action required to attain designated types of performance” (p391). In terms of Bigg’s (2001) model, the presage level includes the mind maps (teaching context) and materials science self-efficacy (student factors). The process level comprises learning approaches, and the product or outcome aspect of the model comprises academic achievement.

In the present study I examine the relationship between the use of mind maps, learning approach, materials science self-efficacy, and academic achievement. The sample comprised 165engineering students (121 males and 44 females) enrolled in the Additional Materials Science course. Students were asked to submit a mind map summary of prescribed chapters to encourage preparation as part of a fortnightly assessment opportunity. Students were taught to make mind maps in a separate module (Professional Orientation) in the first semester of the first year. Students who gave informed consent completed the Revised Study-Process Questionnaire, and the Materials Science Self-efficacy questionnaire. Two mind maps were used in the analysis. The mind maps were analysed using the mind map assessment rubric (MMAR) (D’Antoni, Zipp, & Pinto, 2009). The MMAR assesses mind map depth based upon concept-links, hierarchies, examples, pictures, and colours. The MMAR was extended by adding formulas and graphs. Preliminary results indicate significant relationships between concepts and hierarchies with the final mark ($r = 0.204$, $p < 0.05$ and $r = 0.234$, $p = < 0.05$) and the mind map total with the final mark ($r = 0.284$, $p = < 0.01$). The mind map total correlated negatively to a surface approach ($r = -0.178$, $p = <0.05$) but positively with the deep learning approach ($r = 0.284$, $p = 0.05$). However it was not associated with materials science self-efficacy. The interrater reliability of the MMAR, these results and the impact of gender on the interplay of mind maps, academic achievement materials science self-efficacy, and learning approaches will be discussed.

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Using NSC results for placement in programs: correlation between NSC Maths, Physics and the 1st year courses Mechanics I and Mathematics I results in Mechanical Engineering at Durban University of Technology.

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This paper aims to explore the relationships between students' National Senior Certificate (NSC) results and success in first semester of studies in Mechanical Engineering at Durban University of Technology and how these can be used to place students into mainstream or extended curriculum programs.

Departmental entrance requirements, which are based on NSC results, should ensure that students admitted into the program have a reasonable chance of success. To do otherwise would be both unfair to the students and detrimental to the department in terms of throughput. The current entrance requirements for the diploma are a level 4 (50%) in NSC Maths, Physics and English. It follows that if students who meet, but do not substantially exceed the entrance requirements, have little chance of success, than these requirements should either be raised, or interventions be put into place to support these students. The department will offer a four year extended curriculum program in the near future and this research, originally undertaken to better understand success in the program as whole, will be utilised to determine which students should be placed onto the extended program where they can receive additional support.

A pilot study, using a small cohort, was undertaken to determine if correlation could be found between a student's NSC results and success within the program. As correlation coefficients are dependent upon context (Cohen, 1988) the following were utilised due to their applicability to research in the social sciences.

Table 1. Correlation Coefficients

Correlation	Negative	Positive
None	−0.09 to 0.0	0.0 to 0.09
Weak	−0.3 to −0.1	0.1 to 0.3
Medium	−0.5 to −0.3	0.3 to 0.5
Strong	−1.0 to −0.5	0.5 to 1.0

The study utilised Mechanics I, Mathematics I (Maths I) and Engineering Materials and Science I (Materials I) from the departmental programme, and NSC Mathematics, NSC Physical Science and NSC English. Mechanics I and Maths I were chosen as they historically have poor success rates. Materials I was chosen as it assessed predominantly via short essay type questions, as opposed to calculations which tend to dominate the other subjects.

The pilot study showed a much stronger correlation between NSC Mathematics and Material Science I than between English (2nd language) and Material Science I. This ran counter to expectation as it was assumed that proficiency in English would be a major factor in success in Material Science I, especially for second language English speakers.

The NSC results for both Mathematics and Physics showed correlation with performance in Maths I and Mechanics I, but NSC English, both 1st and 2nd language, showed no significant correlation with Maths I and Mechanics I.

Based on the above it was decided to further explore the relationship between results obtained for NSC Mathematics, NSC Physics, Maths I and Mechanics I. The final marks of all students registered for Mechanics I and Maths I for the 1st time in 2009, 2010 as well as the first semester of 2011 were used. Students repeating these courses were excluded from the study.

Correlations between individual subjects' final marks, as well as a combined NSC Maths and Physics mark, were determined for each semester and are presented in tables 2 and 3. Due to varying class size each semester, a weighted average was used in order to prevent the smaller samples skewing the data.

Table 2. Correlations between NSC results and Mathematics I final marks.

Maths I	**Sem1 '09**	**Sem2 '09**	**Sem1 '10**	**Sem2 '10**	**Sem1 '11**	**weighted ave**
NSC Math	0.43	0.18	0.55	0.43	0.60	0.54
NSC Physics	0.22	0.32	0.37	0.66	0.43	0.38
Maths + Physics	0.39	0.25	0.54	0.68	0.59	0.54
sample size	26	17	86	27	93	249

Table 3. Correlations between NSC results at Mechanics I final marks

Mech I	**Sem1 '09**	**Sem2 '09**	**Sem1 '10**	**Sem2 '10**	**Sem1 '11**	**weighted ave**
NSC Math	0.33	0.55	0.46	0.41	0.42	0.43
NSC Physics	0.33	0.43	0.38	0.40	0.44	0.40
Maths + Physics	0.37	0.54	0.48	0.48	0.50	0.48
sample size	26	17	92	29	91	255

The correlation study confirms that students who perform well in the NSC are most likely to perform well in their equivalent S1 subjects. The limitation is that it does not show how NSC results influence a student's chances of success.

To further explore the effect of NSC results on performance the same data was used in a different manner. The results of students in Mechanics I and a Maths I were grouped in bands according to NSC performance. The success rate of students in each of these bands was then calculated. After examining the individual results it was found that combination of the NSC Maths and Physics results provided the better measure of success than the individual results.

Table 4. Relationships between NSC results and Mathematics I and Mechanics I success (2009, 2010 and 1st semester 2011).

NSC marks Maths & Phys	Math 1 success	Mech 1 Success	% of cohort
<110	31%	25%	11%
110 - 119	36%	27%	19%
120 -129	66%	52%	23%
130-139	57%	51%	19%
140-149	77%	62%	14%
150-159	89%	89%	11%
160+	100%	90%	4%
			n = 249

From table 4 it can be seen that students with a combined NSC result of less than 120 have extremely poor success rates. These students will need significant support in order to pass. Students with these results currently make up 30% of the intake and could easily be accommodated within an extended program in the future.

Using a combined NSC result would be more flexible for placement into the extended programs than using individual NSC achievement levels. If students with achievement level 4 (50%) in NSC Maths and Physics are placed in the extended program and those with level 5 (60%) in the mainstream program, potentially successful students may get misplaced. For example, a student achieving 59% (level 4) for Physics and 75% (level 6) or Mathematics would have a combined score of 134. This student scores substantially more than the 120 limit, but would have been placed on the extended program if only achievement levels were used.

Based on the above, the department intends placing students with a combined score of less than 120 into the extended program when introduced.

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