Cause-effect Analysis: Improvement of a First year Engineering Students' Calculus Teaching Model

Quay van der Hoff
Ansie Harding

Department of Mathematics and Applied Mathematics, University of Pretoria, Pretoria, South Africa

Department of Mathematics and Applied Mathematics
University of Pretoria
0002 Pretoria South Africa
T: +27124202738
F: +27124203893
quay.vanderhoff@up.ac.za

Abstract
This study focuses on the mathematics department at a South African university and in particular on teaching of calculus to first year engineering students. The paper reports on a cause-effect analysis, often used for business improvement. The cause-effect analysis indicates that there are many factors that impact on secondary school teaching of mathematics, factors that the tertiary sector has no control over. The analysis also indicates the undesirable issues that are at the root of impeding success in the calculus module. Most important is that students are not encouraged to become independent thinkers from an early age. This triggers problems in follow up courses where students are expected to have learned to deal with the work load and understanding of certain concepts. A new model was designed to lessen the impact of these undesirable issues.

Keywords:
Teaching model; engineering calculus; cause-effect analysis; independent learning; technology in teaching.

1. Introduction

This study is set at a research intensive university (referred to as the University) in South Africa, one of the top five residential universities in the country, delivering around 14 000 graduates per year. Universities in South Africa have experienced a growth spurt in student numbers since the change in political dispensation after 1994, giving access to a wider spectrum of students. Student numbers in the school of engineering, for example, has increased from 1845 to 8062 over the period 2000 to 2015 (BIRAP 2015).

South Africa's National Development Plan 2030's (NDP) ambitiously intends to expand the production of highly skilled professionals and enhance innovation capacity. This brings pressure, particularly on politicians responsible for education policies, to produce adequate numbers of engineers. Politicians in turn are compelled to escalate these pressures on to institutions of learning, further adding to pressure on universities. Simultaneously, research pressure on universities has increased, a worldwide phenomenon. The dual expectance of maintaining excellence in teaching, despite large student numbers, as well as increased research output is experienced at all levels within universities (Altbach, Reisberg, and

Rumbley 2009). The University is set on maintaining its position in the top 500 ranking in the world, a quest that has intensified research pressure. The vision of the University is thus to increase research output while retaining its focus on teaching. The dramatic rise in student numbers, coupled with the strategic research initiative launched by the university for realising its vision has resulted in rethinking of teaching models on departmental level.

Under preparedness of students entering university has become a problematic issue over recent years, a phenomenon that has also been experienced internationally (Wood 2001), but especially in South Africa where the gap between secondary school and university is seen to be increasing (Engelbrecht, Harding, and Phiri 2011). Systemic problems at school level will be discussed subsequently. Yet, increased pressure for optimal pass rates is experienced at university level. For this purpose teaching staff is encouraged to be innovative in initiating practices to address the under preparedness of students that will result in improved pass rates. A number of such initiatives have been put in place in order to bridge the gap between secondary school and university (Harding 2012; Case, Marshall, and Grayson 2013).

This study focuses on the mathematics department at the University and in particular on the teaching of first year engineering students. The department has enrolment figures of around 3000 engineering students in mathematics modules per semester, combining first and second year levels. Student numbers in the first year calculus module (Calculus I) for engineering students have steadily risen over recent years to around 1650.

The paper describes the teaching model used for first year engineering students as well as factors that impact on the model. An innovative business process improvement method of cause-effect analysis is applied to the teaching model, informing changes for an amended model.

2. The Teaching Model

The teaching model followed up until 2014 was that of large group teaching (around 200 per group), dividing the Calculus I group into nine lecturing groups of varying sizes, depending on the various engineering disciplines. The nine lecturing groups were taught, for four hours per week, by different lecturers of varying ability with one or two of the lecturers taking two groups each. Maintaining uniformity in teaching approach and standards across so many groups is challenging. In addition to lectures, compulsory three hour tutorial sessions were hosted with the intention of offering a working session where individual assistance was offered, maintaining a lecturer/student ratio of about 80:1, making individual assistance an ideal rather than a reality. Six biweekly tutorial sessions were written, each at the end of the three hour tutorial session, with the purpose of serving as formative assessment. These tests added considerably to the grading load experienced in running this course. Attendance dropped considerably when a tutorial test was not due. Students did not view the tutorial session as a learning opportunity, but rather as an activity enforced through test writing.

An online homework system was used, based on the textbook, but this system was not used optimally. Administrative challenges caused a late start in using the system, assignments were not given on a regular basis and staff members were still building expertise.

Two term tests were written, one five weeks into the semester, the second after another five weeks. An examination written at the end of the semester tested the accumulated study content, requiring a pass mark of 50%. Students who fell in the performance bracket 40 – 49% were allowed into a supplementary examination, still within the exam period. Of these students, those who still failed were allowed into the so-called Winter school – receiving tuition on the full module content over eight days and followed by an examination. Normal module fees apply for Winter school attendance. Because of repeated opportunities a fairly impressive cumulative pass rate exceeding 80% was obtained.

3. Problem Statement

The success of the model described above has been questioned. If pass rates alone indicate success, the model is beyond criticism. Yet students passed because of enforced activities and because of being provided with repeated examination attempts and were not seen to be academically mature. Cultivating conceptual thinking, required for tertiary mathematics, remained problematic because a procedural approach to mathematics was ingrained at school level. The success that students achieved in secondary school mistakenly resulted in over confidence and led to students not taking responsibility for their own learning. The transition to independent learning did not materialise. The under preparedness for first year mathematics seems to have been transferred to follow up years where the same concerns were brought to light. In short, despite acceptable pass rates, students were not equipped for dealing with follow-up courses. Rethinking the model became a priority for successful transitioning of school leavers into tertiary students, skilled in mathematical thinking and independent learning.

Literature was consulted for addressing teaching of large groups, the role of additional Support Session, online homework systems as well as cause-effect analysis, the technique used for designing an amended model for the Calculus I module for engineering students.

4. Literature review

4.1. Large Group Teaching

At university level classes of 30-55 have been considered to be of medium size whereas classes of 100 - 130 are classified as large (Gleason 2012). In the Calculus I module almost all classes exceeded the numbers quoted for large classes in Gleason’s classification.

Numerous studies have investigated the influence of class size on student attitudes, behaviours, and outcomes. The overwhelming majority of these studies have focused on elementary school and even pre-school effects of class size on student achievement. The conventional opinion amongst parents, teachers, school administrators, and policy makers is that smaller class sizes translate to improvement in student learning and outcomes (Monks, and Schmidt 2010). This view has, however, not been universally supported by empirical evidence. Clearly, the educational environment at a tertiary institution is dramatically different from the learning environment of the elementary or secondary school setting. Even so, the conventional view of the benefits of small class size persists in postsecondary education. While a number of studies have found support for the importance of class size on student achievement, others strongly refute this claim concluding that class size has little to no impact on objective student outcomes (Monks, and Schmidt 2010).

Class size does impact on the university ranking of a university. A university’s ranking is dependent on the percentage of course sections that it offers with fewer than twenty students and the percentage of course sections that it offers with fifty or more students. The former enters the rankings formula positively, and the latter negatively (Raftery 2014).

Large college classes can offer benefits such as being especially advantageous for shy or withdrawn students who would prefer that class participation not be taken into consideration for grades, as is often the case in smaller classes. Large classes are most likely to be held in a lecture format with students taking notes and occasionally asking questions (Monks, and Schmidt 2010).

4.2. Additional Support

Although comprehension in mathematics education is of the utmost importance, care should be taken not to underplay the importance of repetition and practice that underlie fluency. The problem with focusing relentlessly on understanding is that mathematics and science students can often grasp essentials of an important idea, but this understanding can quickly slip away without consolidation through practice and repetition (Oakley 2014). For this purpose and for improved understanding tutorial sessions, or the equivalent, forms part of the teaching model in mathematics at most tertiary institutions.

Provision of additional mathematics support for undergraduate students is common practice in higher education institutions, and mathematics support centres are frequently the means of delivering such support (Croft et al. 2011). The intention is to employ postgraduate students to offer one-to-one assistance to students who "drop in" in order to enhance students' learning of mathematics. Such learning is considered to be additional, optional and non-compulsory and is designed to assist students in developing mathematical confidence and skills (Croft et al. 2011). It therefore seems obvious that the students that attend these sessions have a willingness to improve.

These support centres have become common at various universities world-wide. For example, as reported on their website, Maynooth University developed a Mathematics Support Centre (MSC) to offer additional support to all undergraduate mathematics students and found that regular and appropriate attendance at the MSC helped improve students' experience of mathematics at the University. Sydney University of Technology in Australia operates a Mathematics Study Support Centre. According to their website this constitutes a drop in room where academic staff members are available on a scheduled timetable for one-to-one assistance.

4.3. Online Homework Systems

In the last twenty years, it has become an option for colleges and universities to implement online homework software for students to submit assignments online rather than via the traditional paper and pencil method. These software programs are rapidly gaining popularity, partly due to the fact that many textbook publishers are involved in such programs. Primary reasons for this expansion are to decrease time and costs associated with grading and to provide immediate feedback to students on their work (Malevich 2011).

Several studies have been conducted to investigate the effect of online homework systems, for example by Bonham, Beichner, and Deardorff (2003), Axtell and Curran (2011), Hirsch and Weibel (2000), Hauk, Powers, Safer, and Segalla (2004) and Demirci (2006). From these and other sources there is as much evidence supporting as there is opposing this form of activity. There is still much to be considered when it comes to online homework systems because it is still relatively new and is constantly expanding and adapting. Malevich (2011) provides a comprehensive list of pros and cons to online testing of which a few are noted. Online homework systems save time on grading, provide immediate feedback, are flexible with respect to access and provide links to helpful information when a student has trouble solving a problem. On the other hand, online homework systems focus on the final answer rather than the solution process, do not provide partial credit, cannot fully recognize conceptual understanding, could encourage a 'trial-and-error strategy' when multiple submissions are allowed, are prone to technical errors and can incur cost to the student. It could be argued that online homework systems is a reality that forms part of the technology revolution and that it would be short sighted to ignore it.

5. Teaching Goal

The vision of the mathematics department at the University with respect to teaching is to "deliver graduates with considerable mathematical skills and the desire to be involved in problem solving". In order to deliver such graduates, a process needs to be followed, starting at the onset of the first year of study and delivering students to follow up semesters with mathematical skills and problem solving capabilities that will enable smooth progression

through the undergraduate programme and towards the ideal of delivering mathematically skilled graduates.
The goal of the first semester of mathematics education at the university is not only to deliver students that are skilled in mathematical thinking and problem solving appropriate for transition to the next level but also to cultivate mathematical maturity in terms of independent learning and enabling students for taking responsibility for their own learning.

6. Applying Cause-effect Analysis in a Tertiary Setting

In this study we do a cause-effect analysis, following three basic steps commonly used in industry for improved performance (Manktelow 2015). The first step of an improvement process is to identify "bottlenecks," factors that hamper progress, referred to by some as undesirables. These can involve *inter alia* people, supplies, information, equipment, or even policies, and can be internal (e.g. within the University's span of control) or external (e.g. outside the University's span of control). The undesirables are identified by seeking the origin of a problem i.e. finding the undesirable issues, as well as some root causes responsible for them. The second step is to address the undesirable issues by devising a strategy for improved performance by removing the underlying core issues responsible for the majority of controllable issues. The third step in the process is to continually evaluate the devised strategy.

When doing a cause-effect analysis in a tertiary mathematics education setting, the first step would be to identify undesirable issues such as the under preparedness of students when entering the tertiary environment and the lack of independent learning. The origins of these undesirables are traced and linked. Secondly a new teaching model is to be devised for addressing and minimising the effect that these undesirables have on achieving the goal set out above. Thirdly the new model needs to be evaluated after implementation in order for it to be revised for a next iteration. We focus on the first two steps in this paper and address the third step using currently available data.
We subsequently describe the actions taken in the first two steps of the cause-effect analysis conducted in improving the first year experience in a calculus model. The constraints are grouped into external undesirables and internal undesirables.
The constraints analysis was conducted by two experienced lecturers in the course under the guidance of a cause-effect analysis consultant. The analysis was then presented to the department as a whole for further comments and approval.

6.1. Identifying and analysing the undesirable issues

The cause-effect analysis is represented graphically in a cause and effect diagram of the *External undesirable issues* and *Internal undesirable issues*, shown in Figures 1 and 2, respectively. For clarity of exposition the cause-effect analysis is embedded in the Bigg's Presage-Process-Product (3P) model (Biggs, 1996; Wikispaces). Although the Biggs model was intended to describe interaction between lecturers and students in the three phases named Presage, Process and Product we found the model ideally suited for a three tier classification in the educational cause-effect analysis under discussion. Under the Presage heading we group issues that foreshadow the educative process. Under the Process heading we group issues related to the education process itself and under the Product heading we group issues resulting from the education process. Figure 1, showing the External undesirable issues refer to issues related to secondary school level. The issues listed under Product in Figure 1 are then transferred to be listed under Presage in Figure 2. Figure 2 represents Internal undesirable issues that is issues related to tertiary level. Relationships between issues are indicated by directed arrows and will be referred to in the discussion below.

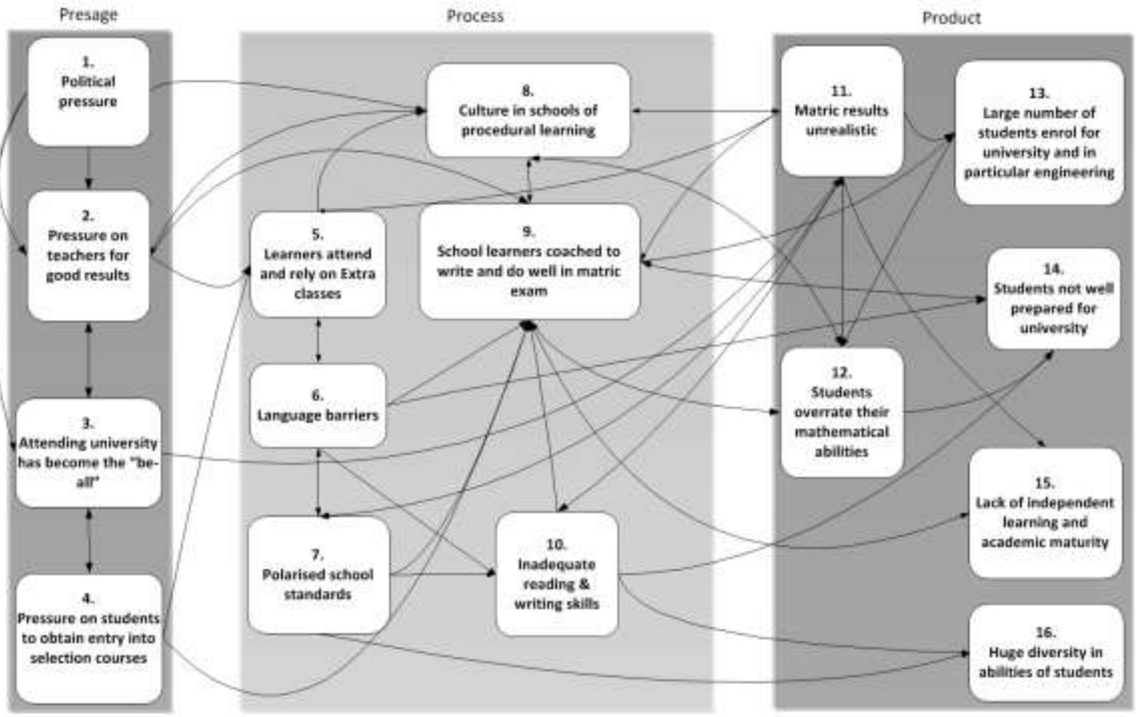

Figure 1: External undesirable issues

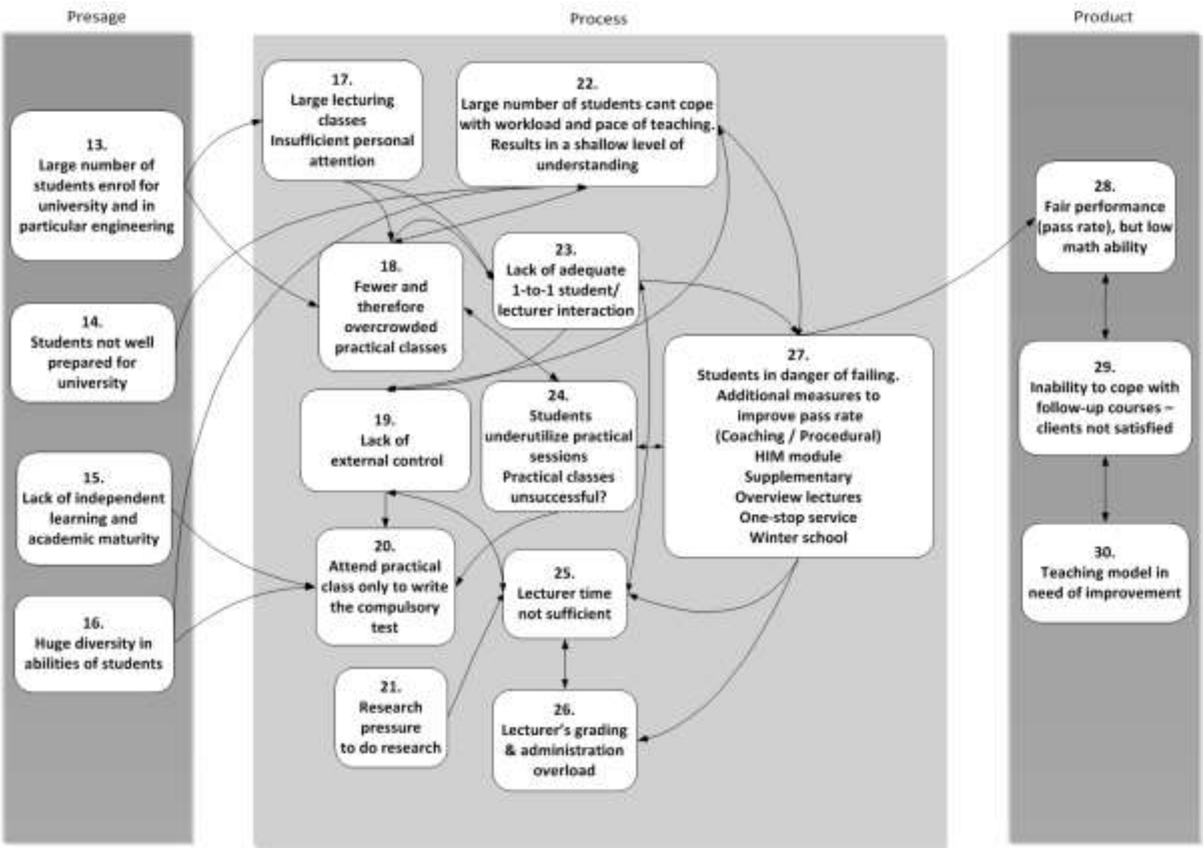

Figure 2: Internal undesirable issues

*6.1.1. External undesirable issues (*outside the University's span of control)
South Africa's National Development Plan 2030's (NDP) puts pressure on politicians responsible for education policies, who, in turn are compelled to escalate their pressures down to institutions of learning**.**

Presage: The foregoing, as well as poor performance in final year results in general, but in mathematics specifically, has resulted in pressure on the system for obtaining optimal results to improve the less than satisfactory final year school performance (1). Such pressure is escalated down to teachers who are evaluated on obtaining a good pass rate (2). Downward escalated political pressure has also resulted in increased emphasis on the importance of a university education (3), which in turn causes a huge demand by students applying for selection courses, putting pressure on students for obtaining results that will lead to selection (4).

Process: Due to the high premium on school leaving results the practice of learners attending and relying on "extra classes" (after hour external tuition) (5) has become common in the more affluent areas. Polarised school standards (7) appear to be a phenomenon of the education system in South Africa, as in many other countries, where the range of schools stretches from expensive private schools with an image of excellent tuition to poor rural schools with a lack of resources, culminating in substandard education, leading to language barriers (6) and inadequate reading and writing skills (10). The culture of procedural learning in schools (8) is another result of the premium put on optimal results. The overall effect of the constraints listed under Presage is that learners are coached for performing well in the final year examinations (9).

Product: The result of coaching practices as well as extra class practices at well-resourced schools, combined with downward escalated political pressure is that final year results are questionably high for these students (11), and students overrate their mathematical abilities (12). The undesirable issues discussed under Process lead to four main factors (impediments) impacting on entrance level university education in mathematics: large numbers of students apply for and enrol for, in particular, an engineering degree (13); under preparedness of school leavers for the university education and mathematics in particular (14); a lack of independent learning and academic maturity (15); substantial diversity in abilities of students (16).

6.1.2. Internal undesirable issues (within the University's span of control/responsibility):

Presage: The four factors identified as undesirable issues, stemming from secondary school level, namely the large number of students enrolling for university and in particular engineering (13), the under preparedness of students (14), the lack of independent learning and maturity (15) and the huge diversity in abilities of students (16), impact on the first year mathematics offering to students on tertiary level.

Process: The first undesirable issue under Presage, namely large numbers of students enrolling for university and in particular engineering (13) leads to large lecturing classes with insufficient personal attention as staff numbers are not proportionally expanded (17). This undesirable issue also impacts on practical classes where the intention is to have more personal contact with students but numbers lead to overcrowding (18) which in turn leads to a lack of adequate one-to-one student/lecturer interaction (23). Students entering university suffer from the lack of external control (19) referring to the freedom offered by the university environment and personal challenges faced by students which lead them to attend practical classes only when they know a compulsory tutorial test is written at the end of the session (20). It becomes clear that the opportunity offered by the time allocated for practical sessions is underutilised and the practical class model is unsuccessful (24). Research pressure on staff (21) leads to lecturers suffering from the pressure of limited time and divided tasks (25). The second undesirable issue under Presage, inherited from school level, namely under preparedness of school leavers for university education, and mathematics in particular (14) results in large numbers of students not coping with the heavy workload and pace of teaching that students are typically exposed to at university level, which in turn leads to a shallow level of mathematical understanding (22). The third undesirable issue under Presage, namely lack of independent learning and lack of mathematical maturity (15) as well as the fourth undesirable issue, the huge diversity in abilities of students (16) are contributory factors to the lack of effectiveness of the practical sessions (24), of student practices of only attending when forced through compulsory tutorial tests (20) and of a shallow level of mathematical understanding (22).

All the undesirable issues under Process culminate in additional measures that have been taken because of the danger of students failing, subject to the external pressure for improving pass rates (27). Such measures include having overview lectures at the end of the week, a one-stop service for enquiries, a supplementary exam followed by a Winter school for those still not making it. The university has also identified so called High Impact Modules (HIM) of which mathematics is one and for which extra funding is available for innovative methods of improving pass rates. These measures lead to additional grading and administration (26), thus impacting on lecturers having restricted time (25).

Product: The issues and practices under Process lead to fair performance of students but still accompanied by low mathematical understanding and ability (28). This leads to students not being able to cope with follow up courses - not only are the lecturers teaching these follow up courses dissatisfied (the clients) (29) but, more importantly, the goal as stated is jeopardised. The final conclusion is that the teaching model is in need of improvement (30).

By listing and analysing the undesirables issues impacting on the teaching model along with its causes and effects it appears that too much emphasis has been placed on student pass rate instead of on their ability to work independently. The first year student is afforded multiple chances to pass the module, allowing weak students, unable to work independently, to pass the course. In fact, it appears that when students are expected to apply the supposedly acquired knowledge in follow-up courses they seem to be unable to do so. It is apparent that a bottleneck develops when students face the danger of failing the course. Instead of guiding students throughout the semester to learn independently and to take responsibility for their learning, the department "saves" students at risk of failing, only to pass this problem on to the next level, while simultaneously adding extra work and pressure to the staff involved.

The cause-effect analysis has firstly indicated that there are many factors that impact on secondary school teaching of mathematics, factors that the tertiary sector has no direct control over. The analysis also indicated the undesirable issues that are at the root of impeding success in Calculus I for engineering students, namely:

1. A large number of students enrol for university and in particular engineering (10)
2. A lack of independent learning and academic maturity typifies these students (16)
3. Students entering university in general suffering from under preparedness (15)
4. Huge diversity in abilities of students (17)

6.2. Addressing the undesirable issues

A proposed new model was designed to lessen the impact of these constraints by creating learning opportunities intended for this purpose.

6.2.1. Proposed New Model

1. *Large numbers:* Large lecturing groups are almost unavoidable with the dramatic rise in student numbers and, from literature, there is little proof supporting claims that large classes are detrimental at tertiary level. Decreasing group sizes was not considered to be a feasible option and the decision taken was rather to embrace the concept of large groups and specifically cater for that. The premise was that the use of large, well-equipped lecture halls with suitable technology facilitates large groups and if care is taken to ensure that students can hear and see well in class, there is no real need for concern. The decision was thus taken to decrease rather than increase the number of teaching groups and in so doing increase the size of the groups even further. Well-equipped venues and appropriate technology are used and experienced staff teaches these groups, thus also limiting the diversity in teaching style and approach. Staff involved is alerted to guard against a procedural approach and cultivate conceptual thinking instead.

2. *Independent learning:* From the constraints analysis it appears that lack of independent learning is an important constraint and it is clear that academic maturity needs to be fostered amongst students. The responsibility must be moved away from the lecturer to the student in order to make the transition to independently learning. The decision was taken to use an online homework system, in the paradigm of blended learning, to aid in cultivating independent learning. Students are given a weekly online homework assignment (Webassign), which needs to be completed at the beginning of the week, based on the previous week's work, and allowing multiple attempts. Should the student have any problems in completing the assignment, he/she is expected to sort out this problem by attending a support session (discussed subsequently). For the student to assess his progress formative assessment is used. After the Support Session a students is expected to complete a test on ClickUP (the Learning Management System). This test contributes more to the term mark than the online homework assignment and has a time limit for completion. Both the online homework assignment and the online test rely on "multiple choice" and "fill in the blank" questions. Not wanting to underplay the importance of written testing, two theme specific written class tests along with the two term tests discussed previously are be given. The phenomenon of enforced attendance of tutorial sessions through test writing, and poor attendance otherwise, is seen as another symptom of a lack of academic maturity. For this purpose the compulsory three hour practical session per week is replaced by voluntary Support Session. Every student has a three hour session allocated on the timetable in which he can attend such a session. Four such sessions per week are scheduled in large venues. Staff and teaching assistants are available for the duration of each session. Students are encouraged to attend these sessions, emphasising the benefit of it rather than enforcing the sessions. Students are permitted to attend more than one session per week.

3. *Under preparedness:* It was fortuitous that on institutional level an initiative was launched for adding a week onto the first semester of entering students, thus starting a week early. The four classes gained were then used for addressing the under preparedness. The focus was both on under preparedness for university studies as well as for subject content and skills. The four periods were spread through the semester and used, for example, before a term test for addressing issues of under preparedness.

4. *Diversity in abilities of students:* The flexibility that the proposed model offers caters for the diversity in abilities. Students are allowed repeated attempts for doing online homework assignments, making provision for students to complete it first time round as well as for students to need more time and opportunities. The support session structure also allows for students to fully utilise the time and assistance available or, ability permitting, to spend very little time there at all.

6.3 Evaluation of the devised strategy

The issue of large numbers of students enrolling at university and in engineering courses in particular (1. above) was counter-intuitively addressed by making the teaching groups even larger. The excellently equipped venues and experienced teachers made this a viable option. Figure 3 represents students' experience of the large group teaching showing that more than half of the students (55%) do not find it to be a problem. Only 7% of students do not like it at all whereas 38% would have preferred smaller classes but tolerate it. Data therefore show that the model is accepted by the majority of students and there does not appear to be valid justification for changing the model towards smaller classes.

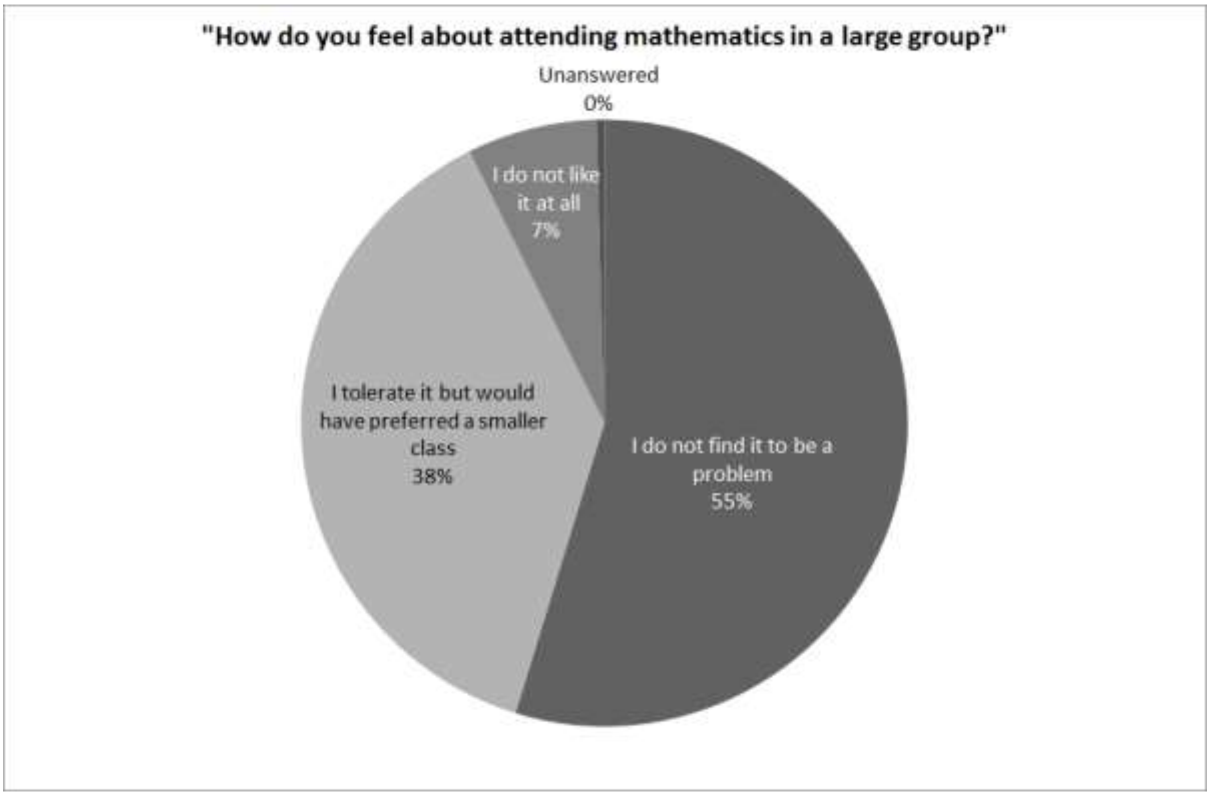

Figure 3: Large group experiences

A significant undesirable issue appeared to be a lack of independent learning and academic maturity amongst students (2. above). The problem was addressed in three ways – making substantive use of an online homework system, having students write weekly online assessments on ClickUP as formative assessment and converting the enforced practical session into voluntary Support Session. Figure 4 shows that students overwhelmingly feel that they benefited from the online homework system (Webassign) - 92% agreed or strongly

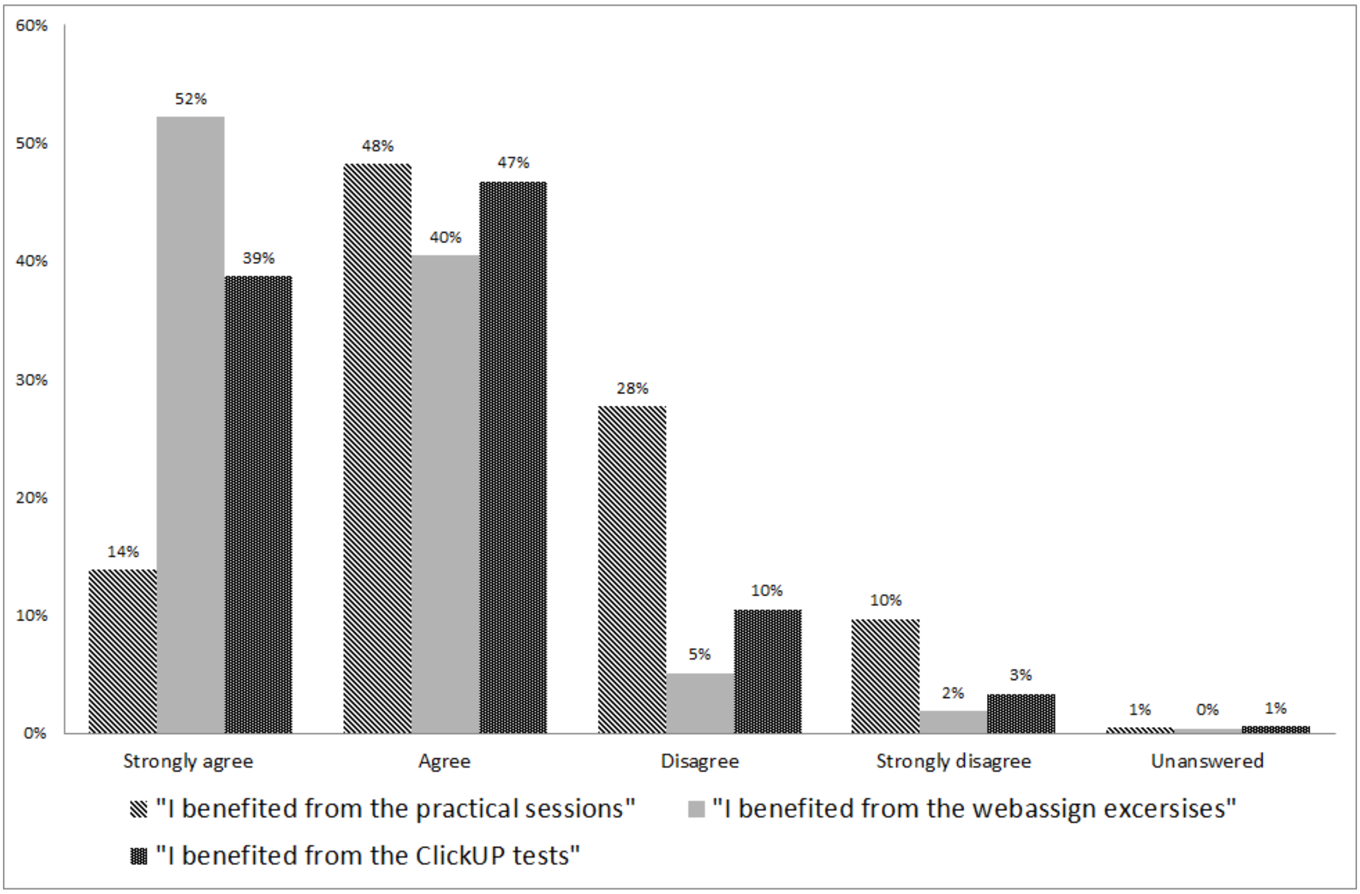

Figure 4: Benefit from activities

agreed that they benefitted. Students could work in their own time, at their own pace and were given the option of repeated attempts, features that clearly resonated with students and that promoted independent work. Figure 4 also shows that students strongly felt that they benefitted from the weekly ClickUP tests (86% agreed or strongly agreed). Although the response is slightly less positive than towards doing the online homework assignments, it is still clear that this initiative is seen to be beneficial to the extent that it warrants future usage. Although doing both a Webassign task and a ClickUP test every week added considerably to the time demand on students it is pleasing to note that the majority of students (88% (71% + 18%)) experienced the activities as “Tough but doable” and even “Enjoyable” (Figure 5).

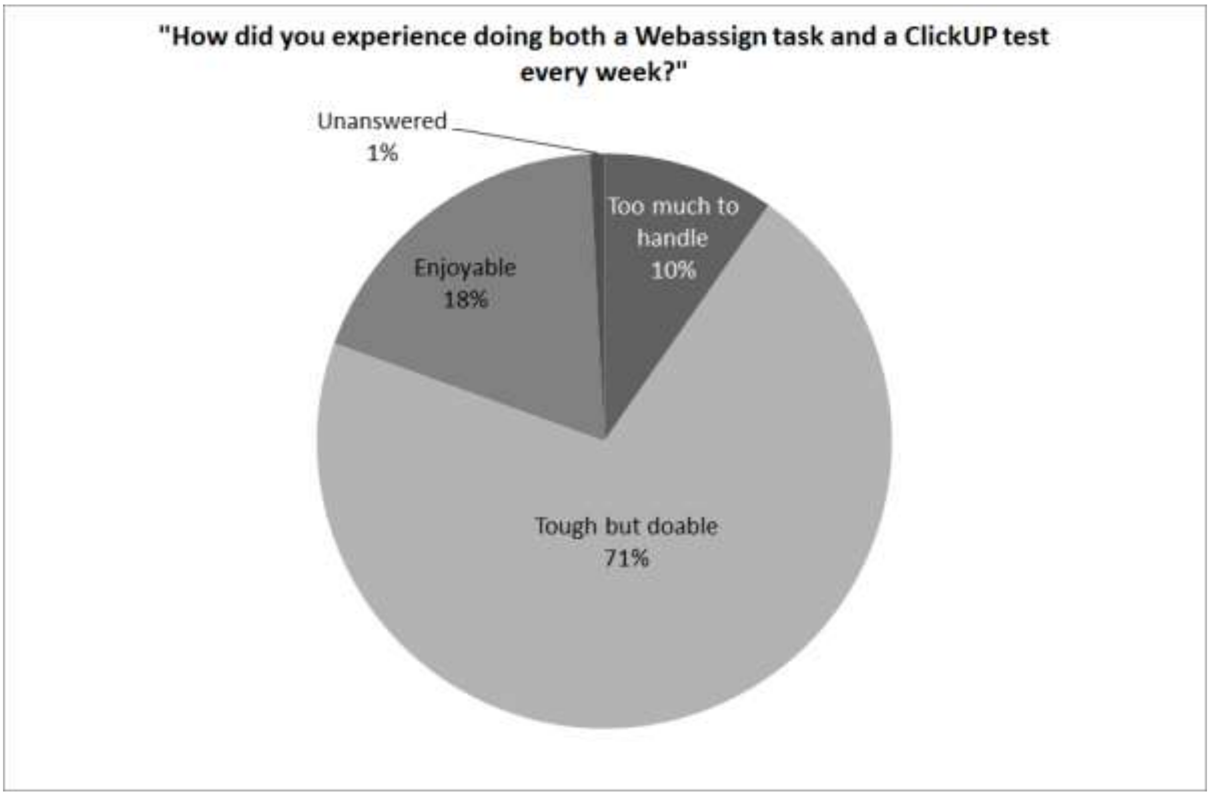

Figure 5: Impact of activities

Of the three initiatives for cultivating independent learning the Support Sessions are perceived by students to be least beneficial although 62% still agreed or strongly agreed that they benefitted from these sessions. To quantify the success of these sessions is difficult. Academically stronger students may not have need of these sessions and would therefore not have benefitted from these. Attendance fluctuated considerably and peaked just before term tests. We believe that a change in culture of voluntary attendance is emerging and that this culture will grow as students become academically more mature. We also believe that the activities for creating independent learning aided in catering for the diversity in abilities of students (4. above).

In response to the question "To what extent did the learning activities develop you into someone who can work independently?" a total of 22% of students felt that they were independent learners at the onset (Figure 6). Discounting this percentage, of the remaining students considerably more students felt that the learning activities assisted them to a greater extent rather than a lesser extent in becoming independent learners (48% compared to 30%).
As for evaluating the success of the university wide initiative for addressing the under preparedness of students (3. above), we conclude that measuring this is not an easy task and leave it for further investigation.

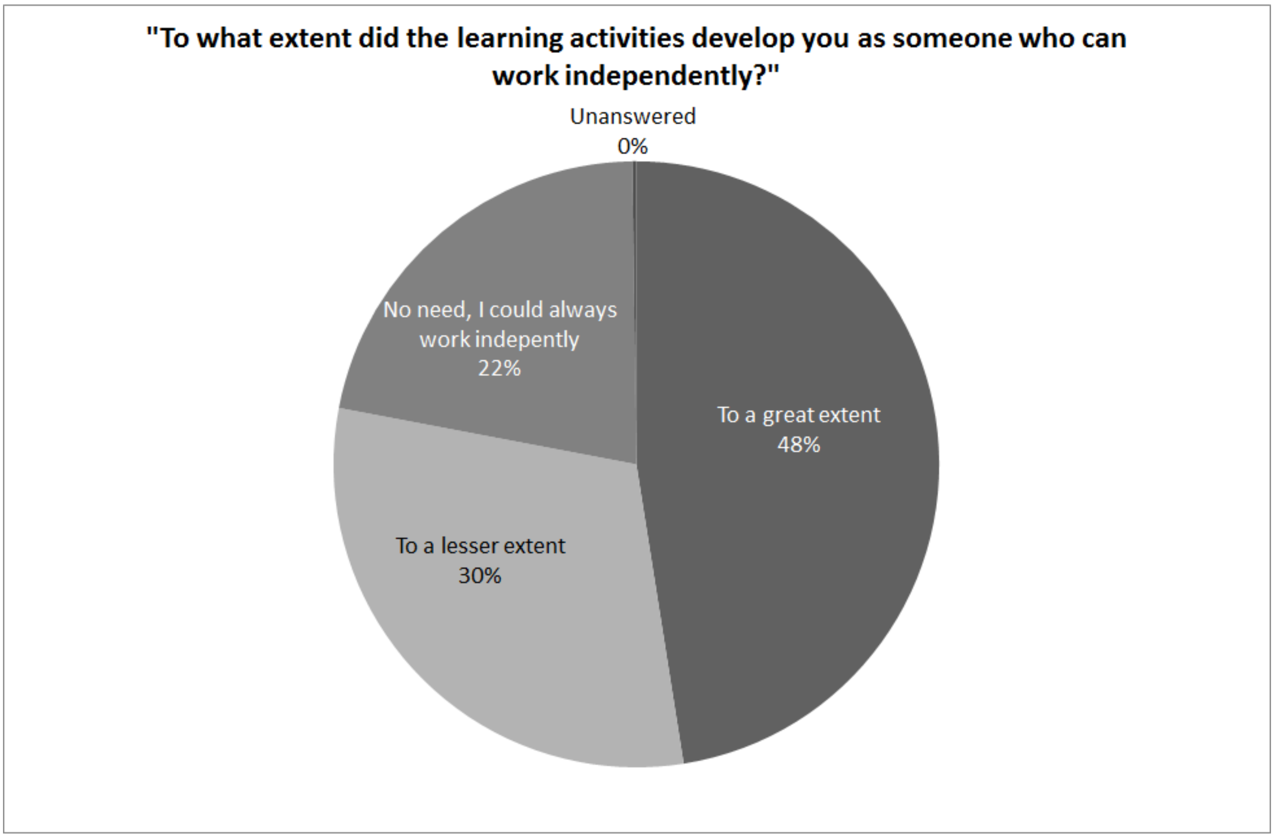

Figure 6: Independent learning

7. Conclusion

By using cause-effect analysis we identified four underlying issues that impact on student progress in Calculus I for engineering students of which a significant issue is that students are not encouraged to become independent thinkers from an early age. This issue triggers problems in follow up courses where students are expected to have learned to deal with the work load and understanding of certain concepts.

A new model has been designed to guide students through the first semester and encouraging them to do these activities on their own while also providing opportunities for assistance when required.

Initial evaluation of the model appears to be positive. Increasing class sizes was a leap of faith and was also logistically cumbersome but the majority of students seem to have taken to it and the intention is for it to be maintained, a finding that is of value to other institutions in a similar position.

To address the undesirable issue of a lack of independent learning three initiatives were put in place – an online homework system, formative online assessment and changing the format of the tutorial session to Support Session. The overwhelmingly positive response towards the online homework system and to the online formative assessment is pleasing and indications are that it answers in the quest of making learners more independent. The Support Session are still under scrutiny as the success of it has not fully been established. The first two activities are still enforced to a certain extent whereas Support Session are completely voluntary and are not perceived as positively by students. The conclusion is that the format of these sessions could still be improved on.

Independent learning is a culture that needs to be entrenched and the hope is to improve it over time, building on the encouraging experiences emanating from the activities in the new model.

References

Altbach, P.G., L. Reisberg, and L.E. Rumbley. 2009. Trends in Global Higher Education: Tracking an Academic Revolution. United Nations Educational, Scientific and Cultural Organization. UNESCO.

Axtell, M., and Curran, E. 2011. The effects of online homework in a university finite mathematics course. Proceedings of the 14th Annual Conference on Research in Undergraduate Mathematics Education (1): 16-24.

Biggs, J. 1996. Western misconceptions of the Confucian-heritage learning culture, in The Chinese learner: cultural, psychological and contextual influences, eds D Watkins & J Biggs. Comparitive Education Research Centre and The Australian Council for Educational Research Ltd, Camberwell, 45 – 67.

BIRAP. 2015. UP Statistics at a Glance. Bureau: Institutional Research & Planning. Department of Institutional Planning, University of Pretoria.

Bonham, S.W., R.J. Beichner, and D.L. Deardorff . 2003. Comparison of Student Performance Using Web and Paper-Based Homework in College-Level Physics. Journal of Research in Sience Teaching (40) 10: 1050-1071.

Case, J., D. Grayson, and D. Marshall. 2013. Mind the gap: Science and engineering education at the secondary-tertiary interface. South African Journal of Science (109): 7-8 Pretoria

Croft, A.C., J.W. Gillard, M.J. Grove, J. Kyle, A. Owen, P.C. Samuels, and R.H. Wilson. 2011. Tutoring in a Mathematics support centre: A guide for postgraduate students. Published by The National HE STEM, Programme, University of Birmingham.

Demirci, N. 2006. Developing web-oriented homework system to assess students' introductory physics course performance and compare to paper-based peer homework. Accessed 26 August 2015. http://www.eric.ed.gov:80/PDFS/ED494339.pd

Engelbrecht, J., A. Harding, and P. Phiri. 2010. Are OBE trained students ready for university mathematics? Pythagoras 72: 3-13.

Gleason, J. 2012. Effect of Class Size on Student Outcomes in Mathematics Courses with Technology Assisted Instruction and Assessment. Proceedings of the 13th Annual Conference on Research in Undergraduate Mathematics Education. Accessed 25 August 2015. http://sigmaa.maa.org/rume/crume2010/Archive/Gleason.pdf

Harding, A. 2012. On the horns of a dilemma: The transition problem from school to university in South African Universities. 12th International Congress on Mathematical Education, COEX, Seoul, Korea, July 8–15

Hauk, S., R. A. Powers, A. Safer, and A. Segalla. 2004. Impact of the web-based homework program WeBWorK on student performance in moderate enrollment college algebra courses. Accessed 25 August 2015. http://hopper.unco.edu/faculty/personal/hauk/segalla/WBWquan.pdf.

Hirsch, L., and C. Weibel. 2000. Effectiveness of Rutgers Calculus Formats. Accessed 26 August 2015. http://www.math.rutgers.edu/~weibel/effectivenessII.html

Malevich, K., 2011. The Accuracy and Validity of Online Homework Systems, MS Thesis: Program in Applied and Computational Mathematics, Department of Mathematics and Statistics, University of Minnesota Duluth

Manktelow, J. The Theory of Constraints (TOC) Strengthening Your "Weakest Link". Accessed 2 June 2015. http://www.mindtools.com/pages/article/toc.htm

Monks, J., and R. Schmidt. 2010. The Impact of Class Size and Number of Students on Outcomes in Higher Education. Robins School of Business, University of Richmond, Richmond, VA 23173. Accessed 2 May 2015.

http://digitalcommons.ilr.cornell.edu/cgi/viewcontent.cgi?article=1145&context=workingpapers

National Development Plan 2030 Our Future-make it work. National Planning Commission. Accessed 3 September. http://www.poa.gov.za/news/Documents/NPC%20National%20Development%20Plan%20Vision%202030%20-lo-res.pdf

Oakley, B. 2014. Sorry, education reformers, it's still memorization and repetition we need. Accessed 3 May 2015. http://nautil.us/issue/17/big-bangs/how-i-rewired-my-brain-to-become-fluent-in-math-rd

Raftery, J. 2014. News & Analysis. Why we should be cautious about university rankings? Accessed 2 May 2015. http://www.politicsweb.co.za/news-and-analysis/why-we-should-be-cautious-about-university-ranking

Wikispaces, 2016. Bigg's work 1. Retrieved on 4 May 2016 from https://inclusive-teaching.wikispaces.com/Biggs's+work+1

Wood, L, The secondary-tertiary interface. In: D Holton (Editor), The Teaching and Learning of Mathematics at University Level: An ICMI Study. Kluwer, 2001. p.87-97