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Improvement of first year mathematics modules with a success rate of less than 50%

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Abstract

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The success rate of Technical Mathematics (TMA105C) for Higher Certificate and Engineering Mathematics I (EMA105B) for Bachelor of Engineering in Technology programmes was declining in the last three years. In 2020 the sharp decline was observed due to the impact of COVID-19 pandemic. The modules were then classified as high-risks due to a success rate of less than 50%. The study reports on the development progress of first-time entering students who attend additional Mathematics Saturday online classes for Technical Mathematics and Engineering Mathematics I. The aim of the Mathematics Saturday online classes is to improve basic mathematical skills for students and to assist students to adjust to university level. TMA105C and EMA105B are year modules hence the additional Saturday online classes are continuing till end of 2021 academic year.

The outcomes of the study showed that students who attended majority of Saturday online classes performed better than those who occasionally or do not attend completely. The results showed that the first summative assessment was poorly performed but an improvement was evident with second summative assessment. The data generated also showed that students struggling with socio-economic challenges made use of the services provided by the Academic Excellence Office to cope with their studies. It is evident that most first entering students have little knowledge of mathematical skills needed in most engineering disciplines. The study showed that students' class and tutorial sessions' attendance are a challenge and such additional support should be well structured and made compulsory for all first year students.

Keywords

High-risk modules, first-time entering students, success rate, engineering mathematics

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Abbreviations

AEO	Academic Excellence Office
APS	Admission Points Score
BEngTech	Bachelor of Engineering in Technology
DHET	Department of Higher Education and Training
DQP	Directorate: Quality Promotion
FEBE	Faculty of Engineering and the Built Environment
FCSR	Faculty Committee for Success Rate
FCTL	Faculty Committee for Teaching and Learning
FoS	Faculty of Science
HC	Higher Certificate
HEDS	Higher Education Development Support
HEQSF	Higher Education Qualification Sub-Framework
LMS	Learning Management System
NATED	National Accredited Technical Education Diploma
NSC	National Senior Certificate
NSFAS	National Student Financial Aid Scheme
SDS	Student Development Support
SFC	Student Faculty Council
STEM	Science, Technology, Engineering and Mathematics
TIMSS	Trends in International Mathematics and Science Study
TUT	Tshwane University of Technology
TVET	Technical Vocational Education and Training
UCDG	University Capacity Development Grant
WR	Written Summative Test

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1. Introduction

The Faculty of Engineering and the Built Environment has been experiencing a decline in the faculty's success rate for the past three years as compared to other faculties. The success rate of 75% should be achieved per faculty as prescribed by the Department of Higher Education and Training (DHET) to receive funding. FEBE's success rate was 68.4%, 68.0% and 66.7% in 2018, 2019 and 2020, respectively. A slight decline of 1% observed in 2020 could be attributed to the unprecedented effects of COVID-19 pandemic. The success rate for FEBE has raised a lot of concern since it has been below 75% as per DHET norm for the past three years. Hence, it was important to identify modules that majority of students are failing and resulting in students to drop out or not to articulate to the next level of their academic studies. Generally, mathematics in the faculty of Engineering and the Built Environment was identified as a main obstacle for engineering students in the beginning of their studies. It is evident that most first-time entering students have little knowledge of mathematical or physics skills needed in most engineering disciplines.

The main challenge is most mathematics modules are offered by the Department of Mathematics and Statistics in the Faculty of Science (FoS). Technical Mathematics (TMA105C) for Higher Certificate and Engineering Mathematics I (EMA105B) for Bachelor of Engineering in Technology (BEngTech) programmes were identified as high-risks modules with success rate of less than 50% in 2020 as stated previously . FoS provides TMA105C and EMA105B service to FEBE. FEBE do not have full control in terms of the offering methods and the appointments of lecturers. FoS appoints mostly part-time lecturers since they do not have capacity to offer the modules to most faculties or departments. Some of the part-time lecturers are either permanently appointed somewhere or busy with their postgraduate studies and tend to show less commitment to the job offered. These has always created lot of challenges since FEBE is not involved in the appointment processes. The study will focus on TMA105C and EMA105B because the modules have been identified as prerequisite to most of the engineering modules. To reach the aim of this study is to establish factors that are affecting the low success rate in mathematics and identify possible approaches to improve the success rate. The aim of this study is to integrate the findings of the quantitative study and link the results of this study with existing students' academic performance challenges. If the above-mentioned challenges causing students to fail are addressed, the students will be able to complete on time and their mathematical skills might improve as well. The research findings are discussed and future recommendations are made. The study will be conducted as a desktop project i.e. from the annual success rate report of the Faculty of Engineering and the Built Environment and other faculty committee minutes or reports.

2. Objectives of the study

The main aim of the study is to implement interventions that would improve the pass rate of TMA105C and EMA105B mathematics modules that most first-time entering students failed to improve the success rate of the faculty. Furthermore, the students support will be developed to assist students with academic and social challenges that are affective to improve their academic performances. Hence, this section provides the envisaged development of the outcomes, research questions and the scope of the study.

2.1 Expected outcomes

The envisaged development outcomes of this study are:

- Implementation of interventions to increase students' participation in mathematical activities.
- Implementation of student-centred approach by strengthening educational support and care.
- Development of efficient pre- and post- assessment processes to assess mathematical competencies of first time entering (FTE) students in 2022.

2.2 Research questions

The research questions to be answered for the outcomes are as follow:

RQ1: How do we propose a plan to assists first-time entering students who are not coping well up to now?

RQ2: What are the key challenges that contribute to students' low pass rate in Mathematics?

RQ3: How do we assess mathematical competency for first-time entering (FTE) students in 2022?

2.3 Scope

The study development plan is designed for the Technical Mathematics (TMA105C) and Engineering Mathematics I (EMA105B) that are being identified as the high-risk modules as mentioned previously. The information gathered will be generated from mathematics' reports the lecturers submit for the faculty success rate committee meetings. The scope of the study will focus on:

- Developing a plan for students' engagement with lecturers and tutors to master mathematical skills.
- Implementation of academic support and care systems to assist students who are struggling with Mathematics.
- Developing the pre- and post- assessment processes to assess mathematical competencies of first-time entering students in 2022.

3. Theoretical framework

This section presents the theoretical framework and literature review of the study. This includes correlation between the first year students' mathematical skills, lecturer teaching methodology and learning theories, class and tutorial attendance, socio-economic challenges and first-time entering students' admission criteria.

3.1 Description of the context

Currently, there are four departments offering the Higher Certificate qualifications (HC) and Technical Mathematics (TMA105C) is one of the HC modules that the Faculty of Science (FoS), Department of Mathematics and Statistics is offering service to the Faculty of Engineering and the Built Environment (FEBE). Technical Mathematics and Engineering Mathematics I is one of the high-risks modules that are always causing bottlenecks and causing most students to be excluded from the programme. Table 1 shows the departments that are offering the HC programmes. Students who completed HC qualification will be considered for admission to BEngTech programmes with an average of at least 60% for the qualification and 60% in Technical Mathematics.

Table 1: Departments offering Higher Certificate qualification.

Department	Higher Certificate programme
Civil Engineering	Higher Certificate in Construction Engineering, NQF Level 5 ***Option 1***: Construction Material Testing (HCCM18) ***Option 2***: Water and Wastewater Engineering Infrastructural Operations and Maintenance (HCCW18)
Electrical Engineering	Higher Certificate in Electrical Engineering NQF Level 5
Industrial Engineering	Higher Certificate in Industrial Engineering NQF Level 5
Mechanical and Mechatronics Engineering	Higher Certificate in Mechanical Engineering NQF Level 5

Table 2 shows the departments that are offering the Bachelor of Engineering in Technology (BEngTech) programmes. The Faculty of Science (Department of Mathematics and Statistics) also offers EMA105B module to the following engineering departments:

Table 2: Departments offering Bachelor of Engineering in Technology qualification.

Department	Higher Certificate programme
Chemical, Metallurgical and Materials Engineering	Bachelor of Engineering Technology in Chemical Engineering, NQF Level 7 Bachelor of Engineering Technology in Materials Engineering in Polymer Technology, NQF Level 7 Bachelor of Engineering Technology in Metallurgical Engineering, NQF level 7
Civil Engineering	Bachelor of Engineering Technology in Civil Engineering, NQF Level 7
Electrical Engineering	Bachelor of Engineering Technology in Electrical Engineering, NQF Level 7
Geomatics	Bachelor of Geomatics, NQF Level 7
Industrial Engineering	Bachelor of Engineering Technology in Industrial Engineering, NQF Level 7
Mechanical and Mechatronics Engineering	Bachelor of Engineering Technology in Mechanical Engineering, NQF Level 7 Bachelor of Engineering Technology in Mechatronic Engineering, NQF Level 7

For BEngTech, students who fail EMA105B will not be able to register some of the 2nd semester or 2nd year level modules as shown in Table 3. Repeating EMA105B module and registering other modules that do not have prerequisites causes timetable clashes and this results in causing bottleneck, poor class attendance and cancellations of number of modules.

Table 3: Mathematics as a prerequisite for engineering modules.

Programme	Module	Mathematics as Prerequisite to listed modules
Bachelor of Engineering Technology: Chemical Engineering	Engineering Mathematics I	Engineering Mathematics II Probability and Statistics
Bachelor of Engineering Technology: Civil Engineering	Engineering Mathematics I	Engineering Mathematics II
Bachelor of Engineering Technology: Electrical Engineering	Engineering Mathematics I	Probability and Statistics Conversion Systems Electromagnetic Fields and Waves
Bachelor of Engineering Technology: Geomatics	Engineering Mathematics I	Engineering Mathematics II
Bachelor of Engineering Technology: Industrial Engineering	Engineering Mathematics I	Engineering Mathematics II Production and Automation Probability and Statistics Production Engineering Operational Research Simulation Design
Bachelor of Engineering Technology: Mechanical Engineering	Engineering Mathematics I	Design Machines Engineering Mathematics II Fluid Mechanics Probability and Statistics Thermodynamics
Bachelor of Engineering Technology: Materials Engineering	Engineering Mathematics I	Engineering Mathematics III Probability and Statistic Plastics Part and Tool Design
Bachelor of Engineering Technology: Metallurgical Engineering	Engineering Mathematics I	Engineering Mathematics II Probability and Statistics

3.2 Literature review

This section aims at finding methods implemented by other researchers by improving mathematical preparedness of prospective first year students. Generally, mathematics in the Faculty of Engineering and the Built Environment was identified as a main obstacle for engineering students in the beginning of their studies. It was observed that difficulties with mathematics led to high failure rate in mathematics. The literature findings will be used for guidance in developing the research framework to address the research questions to improve mathematical skills for first-time entering students.

3.2.1 Lecturer teaching methodology and learning theories

We are living in an era where technology plays a central role in nearly all aspects of our lives. The COVID-19 pandemic has forced higher education sectors to be more innovative and adapt swiftly to multimodal remote online teaching and learning. Currently, lot of things are changing in higher education space in terms of technology to keep abreast with global trends and still be relevant. It is important to explore the teaching and learning methodology of the lecturers because it might have a direct impact for students' poor class attendance. Lecturer's teaching style has a direct impact on students' performance. Hence, learning design therefore needs to incorporate a variety of educational technologies in a learning approach to create flexibility and anticipate the realities of future digital worlds. In a range of face-to-face and online learning interactions, a digital approach is an underpinning philosophy resulting in all modules having a digital presence. Students are introduced to the constancy of change and benefit particularly from the comprehensive use of digitalisations. Lecturer's evaluation is key since students' feedback is important for the academics to refine their course materials and improve their teaching methods to provide the students with better learning experiences.

According to Ouahada (2019, 9) proposed the procedure to improve the low success rate as shown in figure 1. It is reported that evaluation and monitoring of the lecturer's teaching style, study guides, tutorial sessions, practicals, presentation of lecture notes, prescribed and recommended books can assist in identifying the lecturer's strengths as well as areas that need improvement. He further reported that a pass rate of 75, 95 and 100% was observed in some modules due to constant feedback from students that led to improve teaching styles. Students and colleagues' feedback is crucial for lecturer to evaluate the course and address any deficiencies identified. Improvement of teaching style resulted in a high-quality and friendly educational environment for students and the most important factors in improving class participation and pass rate.

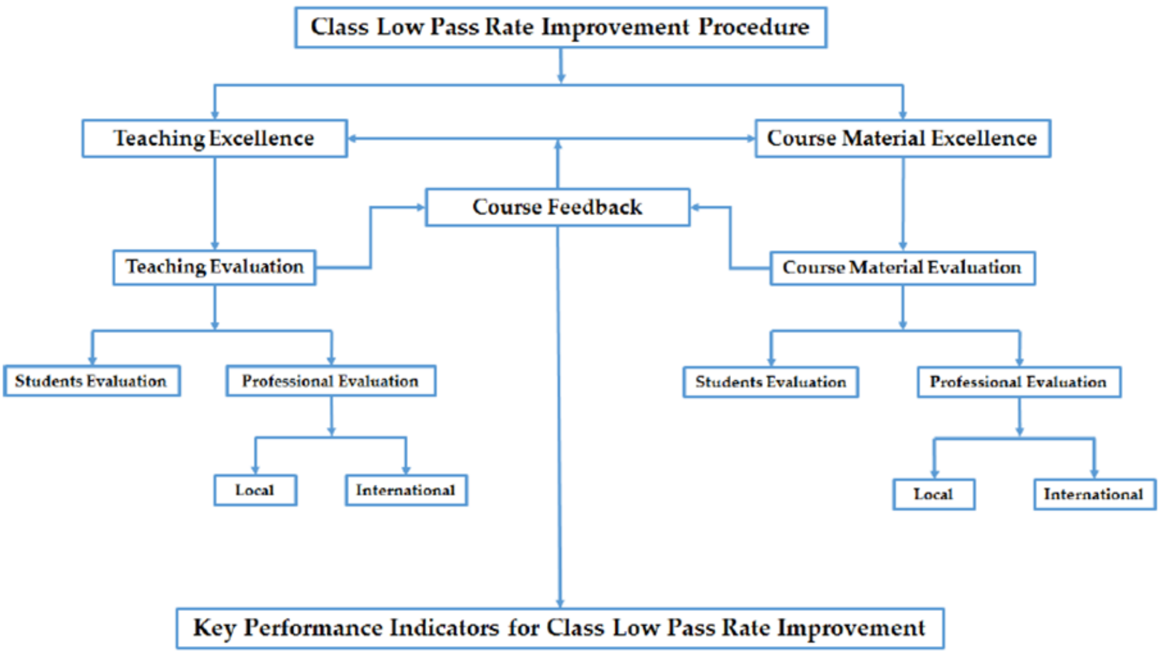


Figure 1: Key performance indicators for class low pass rate improvement procedure (Ouahada, 2019, 9)

Hence learning theories are necessary to understand adaptive patterns, representative of current state and existing in networks. The favourable learning theory to be adopted by TUT is connectivism and constructivism. If those learning theories are properly applied, have the potential to significantly improve education through the revision of educational perspectives and generate a greater shift toward learner-centered education.

Connectivism (complex learning, rapid changing core, diverse knowledge sources) was introduced as a theory of learning based on the premise that knowledge exists in the world rather than in the head of an individual. Learning is distributed across information network that can be stored in a variety of digital platforms. Learning takes place through the recognition and interpretation of patterns. Learning can take place by:

- Collaborative use of technology in pairs or small groups that is usually more effective than individual use. Struggling students/educators may need guidance on how to collaborate effectively and responsibly.
- Remedial and tutorial use of technology can be particularly practical for lower success rate subjects. Students struggling with certain module concepts/practical work, especially those from disadvantaged backgrounds the use of technology (e.g. interactive videos to demonstrate difficult concepts) will provide intensive support to enable them to catch up with their peers.

Constructivism (social, vague): It is a theory of communication and suggests that each listener or reader will potentially use the content and process of the communication in different ways. Learning takes place when individuals engage socially to talk about and act on shared problems or interests (Bada, 2015, 5). The Communities of Practice are groups of people (experts or practitioners in a particular field) who share a concern for something they do and learn how to do it better as they interact regularly, therefore having the opportunity to develop themselves personally and professionally. Cognitive and behavioural approaches continue to be a part of educational psychology today. The main application of this theory in teaching of mathematics can be seen in the skill of problem solving. Problem solving is a significant element of mathematics education. In fact, problem solving in mathematics helps students to develop a wide range of complex mathematics structures and gains the capability of solving a variety of real-life problems (Tarmizi & Bayat, 2012, 32).

3.2.2. Class and tutorial attendance

Tutorials and class attendance are meant to assist students to understand the mathematical concepts and be able to apply them in different engineering disciplines. One of the challenges identified is the students' tendency not to attend class and tutorial sessions because of other demanding modules. Sibanda *et al* (2015, 2) indicated that students sometimes lack interest in the module, self-discipline, self-motivation, dedication and commitment. This study is to determine if class and tutorial attendance are critical or have a negative impact on assessment grades of first year mathematics module for mechanical engineering students. Matsoso & Iwu (2017, 8) study confirms that class attendance when supplemented by tutorial attendance had a higher impact on the performance of the students. The study further explain that students should motivated and be eager to learn as well as participate in tutorial sessions to enhance knowledge gained in the classroom. Lecturers should make tutorials exciting by incorporating mathematical games since students need solutions to the problems rather than engaging in the discussion to solve problems.

According to Picciano (2017, 21) various online methods such as Learning Management System (LMS) is used for discussions. Figure 2 shows an example of a teacher-led fully online course. The discussion interaction among lecturers and students, students and students, students and tutors are facilitated through content board, blog, and wiki. The lecturer allows students to watch recorded lecture available in the LMS. The students are required to respond to a series of questions on the discussion board. Students' responses are used as the ground for an interactive discussion board activity among students guided by the lecturer. The model also provides for reflection and collaborative activities. This model allows collaboration and the development of personal relationships among peers and opportunity to advance in technology.

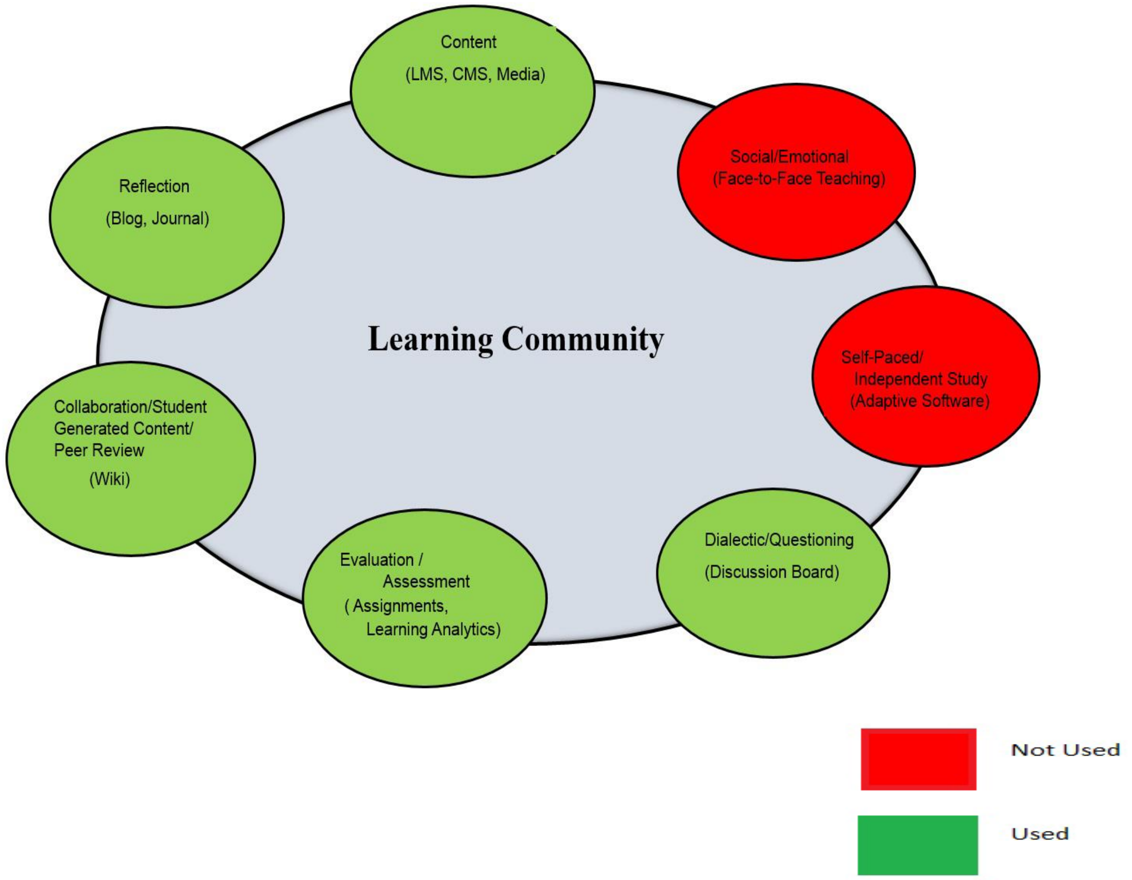


Figure 2: Example of a teacher-led fully online course (Picciano, 2017, 21)

According to Higgins & Read (2012, 35), tutorial attendance and students engagement was very low for first year mathematics students. The tutorials was not structured and standard and not monitored properly. It was observed that the tutorial attendance during the first third semester declined with about 30% and the overall average about 50% of students attending the mathematics tutorials for the remaining of the two thirds of the semester. Poor attendance and lack of participation resulted in poor results in assessments. There was a pressure for lecturers to increase and maintain the pass rate. Higgins & Read (2012, 35) reported that different strategies for teaching were introduced into tutorials to address students' low attendance and lack of participation problems. The mathematics tutorials for first year engineering subject were restructured by introducing the following systems: An electronic barcode attendance monitor was implemented and a mathematical task was used to encourage participation and engagement. The barcode stickers that students were issued with were scanned to collect attendance data. Students were also given task sheets to complete and the completed sheets handed over to lecturer with barcode stickers which were scanned into student database recording attendance. The results showed that the overall average tutorial attendance increased to 78% from the 30% previously. The final grades results showed that students who attended most tutorial sessions performed well with high passing marks.

3.2.3 Poor socio-economic background of students

Globally, universities were forced to move swiftly to online teaching and learning due to COVID-19 pandemic. The pandemic has poses various socio-economic challenges to previously disadvantages students. Most students did not have the devices to connect online or the environment at home was not conducive for studying to lockdowns. Academic support structures are key to assist students because the pandemic had a huge impact on people's health and how to live and learn.

The majority of our students are coming from underprivileged communities, with many societal ills. Students experience stress, lack of adequate learning spaces at home, financial and emotional issues. Bayat *et al* (2014, 45) reported that there is significant difference between first-generation students and who are not in terms of academic success. First-generation students are those from households where neither of their parents studied at tertiary level. Stephen *et al* (2004, 2) findings indicated that students also struggled with English language to succeed in their academic studies. The findings showed that there was a significant difference between two ethnic groups. The Indian group exhibited superior English language proficiency levels when compared to black counterparts. Most students experienced great difficulty in communicating or writing in academic English required by university since some of their schooling had been conducted in their first language (Tanga & Maphosa, 2018, 35). There is no one to guide first-generation students in terms of analytical and problem solving skills and how to meet study requirements and deal with external commitments. It is believed that students who have someone in the family who completed some post-matric qualification before them, tend to have better knowledge of what is expected from them.

3.2.3.1 Lack of learning devices and access to learning materials.

The advent of COVID-19 forced the university to develop a Covid-19 Multimodal Teaching, Learning and Assessment plan that was approved and implemented during 2020 and further revised on 12 January 2021. The university had to adopt online learning and faced many challenges, such as students' access to technology and academics' ability to design online content and deliver teaching and learning remotely. Most of South African students do not have proper devices for online learning and they rely on National Student Financial Aid Scheme (NSFAS) which is government scheme that support disadvantaged students who wish to further their studies at public universities or Technical Vocational Education and Training (TVET) colleges received laptops. The students who received laptops are applicants whose combined household income is not more than R350 000 per year. The government delayed in providing laptops for NSFAS students in 2020 and only supplied laptops in 2021. Most students were using their cell phones to access online learning materials and to connect online for class. The government of South Africa went into partnership with private network providers to zero-rated applications and educational websites (Mhlanga & Moloi, 2020, 10). A website is defined as zero-rated when a mobile operator does not charge the usage of the application or website against a user's monthly data allotment, which renders its use as effectively free. Academics were trained on how to develop the online content i.e. voice over PowerPoint slides, recorded videos, activities, assessment etc.to ensure that no student is left behind during the lockdown. Despite university's efforts to ensure equitable access to learning, poorer students were less able to afford a proper cell phone, laptop and were forced to return home where the environment was not conducive for learning. Table 4 below depicts some of the e-learning challenges students experienced even before COVID-19 epidemic.

Table 4: Challenges of e-learning adoption in South Africa (Bagarukayo & Kalema, 2015:11)

Author(s)	Challenges
Jaffer et al. (2007)	varying learner academic preparedness; large classes; multilingualism in 1st language context; inadequate curriculum design; diversity in (school) background; and academic ability
MacGregor (2008)	low bandwidth and unequal access
Brown et al. (2008)	range of organisational contexts; practices and cultures; infrastructural constraints — proportion of internet users to PCs, bandwidth, slow and internet costs; demographic divides, cell phone subscription LMS instability; lack of use of interactive web potential; access inequality; negative eLearning perceptions; no management support; lack of time and resources; and oversubscribed internet systems that limit applications use
Mlitwa & Van Belle (2011)	inadequate technical support; limited infrastructure capacity; network capacity; inadequate coordination and limited technological support; technology instability; resistance to change; tedious administrator processes; access issues; literacy limitations; institutions users with troubled network systems; and poor user support
Venter et al. (2012)	scarce resources; educational inequalities; technology access shortage; low throughput rates; technological cost; satisfaction & infrastructure; lecturer efforts; graduate competencies; business strategy shortages; learners' frustration with e-Learning; underutilised systems; bandwidth cost of high speed internet; and user penetration
Isabirye & Dlodlo (2014)	no institutional support; non-integration of eLearning business strategy; no eLearning culture; exclusion of academia from eLearning development programmes; instructor attitudes; technological challenges; lack of pedagogical strategies; cost and quality; lack of university policy, training, motivation, incentive; under preparedness; no facilitating conditions; logistical issues, lack of management; and ICT support
OERAfrica (2014)	weak ICT skills; lack of resources; low computer and internet access

3.2.4 Mathematical skills' support for first year students

A report released by South Africa's Department of Basic Education about the country's National Senior Certificate (matric) results for the class of 2019 showed that there is a reduction in the number of students writing mathematics from 270,516 in 2018 to 222,034 in 2019. The matric pass rate for 2019 was 54% of the pupils who wrote the exam when compared to pass rate of 58% in 2018. The minimum score for a pass is 30%, 7.9% of the pupils achieved more than 60% of which only 2% obtained distinctions. The 30% pass only granted the pupils diploma or university entrance while 60% and above pass allowed them access to admission to degree studies at university. The 30% pass pose as a disadvantage to students since the low pass mark will not prepare students to succeed at mathematics at university level.

According to Lewin (2014, 1), South Africa's low student success rates has been recognised as systemic and rooted in the schooling system. South African learners who transition from school to university, show a marked decline in both Mathematics and Physics (Wolmarans *et al* 2010, 18). This is a matter of concern because the systemic performance is poor relative to other similar developing countries and so much talent is being wasted. South Africa is currently experiencing a shortage of high-level engineering skills and an unprecedented economic growth. Thus, the associated demand for human resources has exacerbated the "skill shortage" particularly in the scarce categories like engineering professions. Joubert & van Der Merwe (2019) indicated that in South Africa majority of the engineering fields are listed on the scarce skills list. This is a serious challenge since five engineering disciplines are in the top 10 scarce skills in South Africa. Improvement of engineering education can positively increase the availability of engineers that can design and implement solutions for the future that will make a difference in industry and the economy of South Africa. According to Fisher (2011), the pipeline of qualified candidates from the school system into Science, Technology, Engineering and Mathematics (STEM) fields in higher education is constrained by the poor quality of schooling, and many entering students, although in the top decile of their cohort, are academically under-prepared and financially disadvantaged. Despite students aspiring to attend university, the general entry requirements for undergraduate programmes in South African universities have changed little in the past ten years. It is important to explore some of the issues that determine whether those entering undergraduate programmes are likely to experience success in their academic endeavours.

According to Fraser & Killen (2003, 23), in South Africa, there is an assumption that learners who have achieved an above-average performance in their school matriculation examination will be capable of success at university. However, there can be no guarantee that these students will eventually satisfy the requirements for graduation. There is evidence that students entering tertiary study lack knowledge in certain mathematics topics due to under-preparedness in mathematics. The under-preparedness of incoming students for the mathematical demands of engineering degree schemes has led to an increase in engineering dropouts. Newman-Ford *et al* (2015, 2) reported that engineering mathematics is a key facet of all engineering degree courses. It was indicated that Bridging Technology course was designed to provide students with mathematical understanding and confidence prior to commencing a degree in an engineering and technology capacity. It was reported that students who had completed the Bridging Technology with Mathematics course had performed as well, if not better, in the mathematical elements of their degrees compared with their peers. Almost 70% of students said that they would have struggled in level I Mathematics module had not completed the Bridging Technology course beforehand. The Bridging Technology course assisted to develop students' understanding of the relevance of mathematics to engineering disciplines.

Engelbrecht & Harding (2015, 46) reported that a one week refresher course preceding the first semester was presented to address the needs of first year students in mathematics. Basic concepts from the high school curriculum that are applicable to the first year curriculum were revised during the refresher course. The mathematics intervention implemented showed that the students' mathematics performance improved after attending the course as shown in Table 5.

Table 5: Pre-test and post-test results in the refresher course. (Engelbrecht & Harding, 2015, 46)

Year	Number of students	Average for the test written before the course	Average for the test written after the course
2006	34	39%	58%
2007	92	51%	68%
2008	63	47%	65%
2010	131	43%	61%
2011	96	28%	56%
2012	74	39%	71%
2013	100	30%	55%
2014	82	28%	57%

In addition, tutorials attendance is another method of intervention that is perceived to improve students' performance. Students tend to be more relaxed and engaged with their peers within a smaller group setting as compared to normal classroom environment. According to Matsoso & Iwu (2017, 8) tutorial sessions should be structured in a formal time table to increase students' participation and support. Furthermore, it was reported that tutorial attendance is crucial if supplemented by class attendance for students to perform well. Hence, there is a need for a more transformed and improved tutorial program to assist with positive students' outcomes. Engelbrecht *et al* (2010, 72) studied the correlation between school mathematics results and students' performance at first year level as depicted in Figure 3. Their findings showed that there was a strong shift to the left from the Grade 12 marks when compared to marks in Semester Test 1 and Semester Test 2 with a slight shift to the left. Based in their conclusion, there are positive indications that there the students have adapted and improved over a semester.

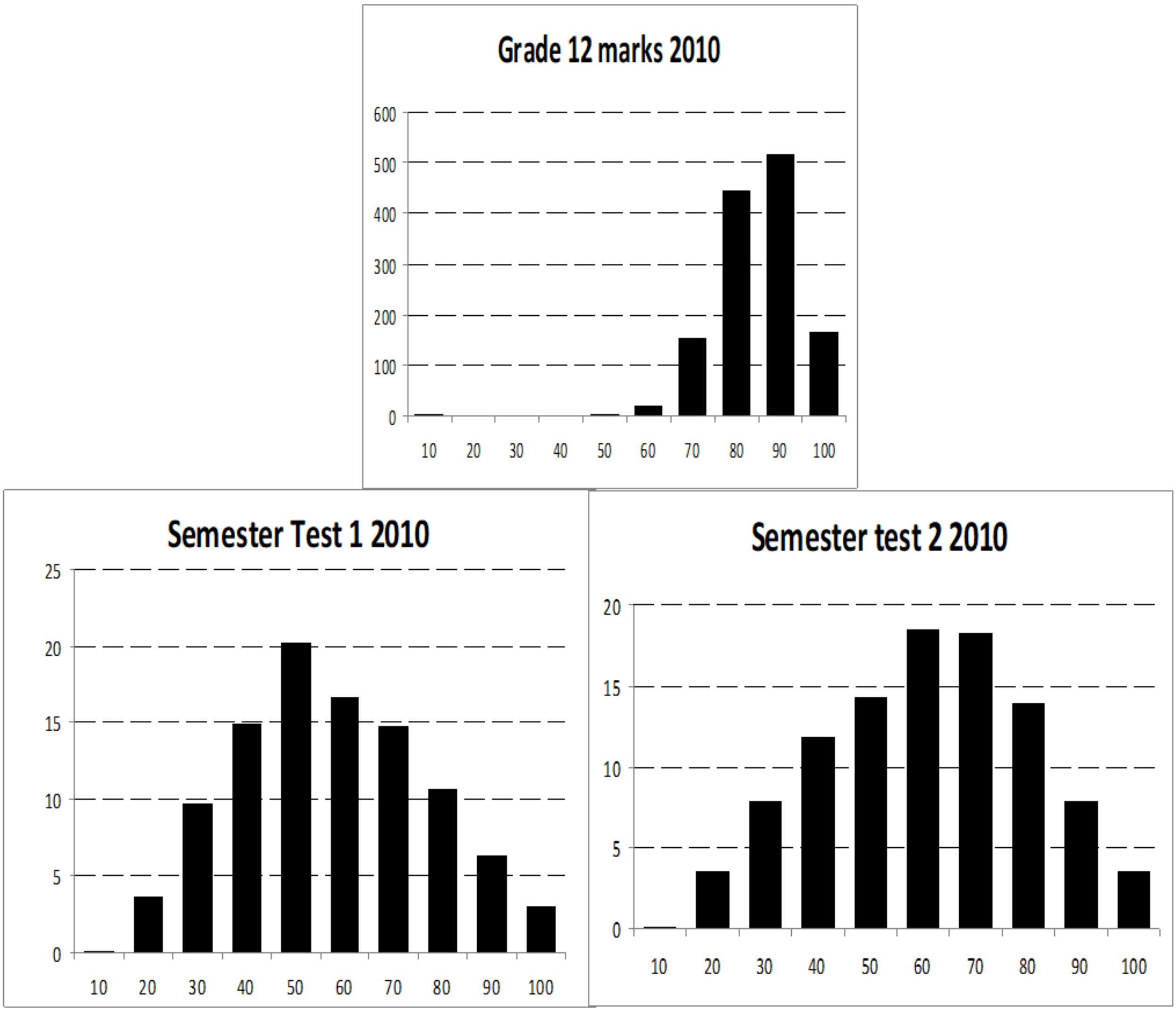


Figure 3: Student performance in Grade 12 and in Semester Tests 1 and 2 (Harding *et al*, 2010)

Khashi'ie *et al,* 2017, 87) studied students' performance in pre- and post- assessments of Mathematics competency test during their first year of study at the faculty of Engineering Technology. The pre- and post- Mathematics competency questions were designed as shown in Table 6 below.

Table 6: Description of content in Mathematics Competency Test (Questions 1-20). Khashi'ie *et al* (2017, 87)

Content	Question No.	No. of item	Weightage
Algebraic Expression	1,2,3,4,5,11	6	30
Trigonometry	13,14,15,16	4	20
Solving Equation	6,7,8,9,10,12	6	30
Function and Domain	17,18,19,20	4	20

There are 30% questions on Algebra and solving equation and 20% questions on Trigonometric and Function. According to Khashi'ie *et al,* 87) findings after the students have completed the assessments concluded that students showed lack of understanding and knowledge in the topics of algebraic expression, trigonometry, solving equation and function since the percentage of students who were able to answer the question correctly was low based on the results as shown in figure 4.

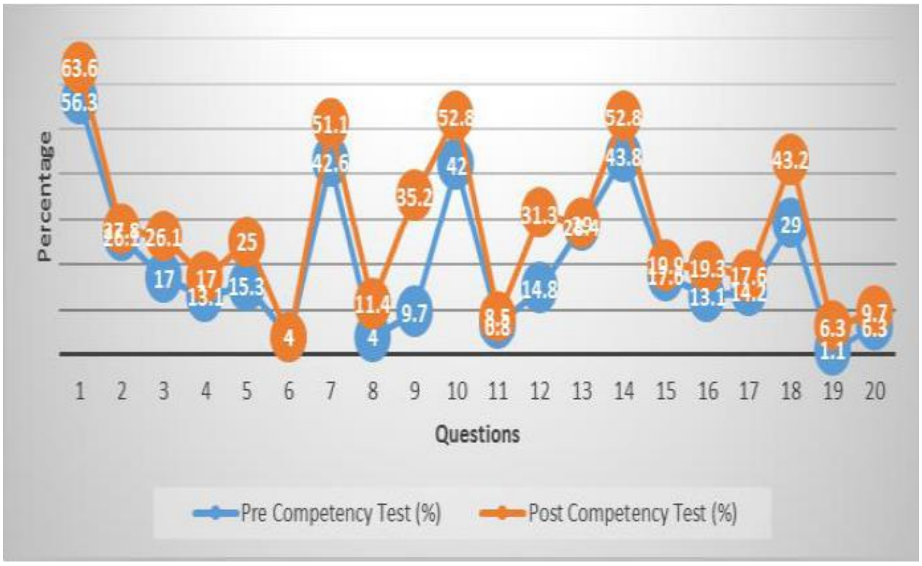


Figure 4: Percentage of JTKM students' performance for pre- and post-competency test by question and content (Khashi'ie *et al,* 2017, 87)

Furthermore the following findings were found based on the results:

- For algebraic expression component, students failed to express and simplify the given question in the simplest way and mostly repeated the same error in pre- and post-tests because they misunderstood algebraic concepts.
- For trigonometric questions, students completely failed to understand the questions and did not use the trigonometric function very often in daily life even though the percentage of the post- result was higher than pre-assessment.

- Lastly, for the function component the findings showed that more than half of the students answered the questions incorrectly for both in pre- and post-tests. The students' results showed that there is an inability to understand the relation between domain and range in a graph, as well as misunderstanding the basic concepts in Mathematics.

Based in their conclusion, the results showed that there were slightly significant difference between 'pre' and 'post' tests. This shows that the students were able to gain more conceptual understanding of mathematics by the end of the semester and are improving their skills and abilities in solving mathematics problems.

4. Methodology

4.1 Introduction

The existing literature and own experiences regarding challenges that students experienced are used to develop a framework that will serve as a basis for specific interventions to address the needs of first year students in mathematics. It is important to align the literature review conducted with research methods to address research questions and the interpretation of the results. Anderson (2011, 2) describes the online learning model that could be adopted to improve high-risks modules. The model illustrates the learner and teacher, their interactions with others and the module content. Matsoso & Iwu (2017, 8) study concluded that tutorial and class attendance had a higher impact on the performance of the students. Hence, one of the development plan is to implement additional Mathematics tutorial sessions to supplement scheduled class sessions.

4.2 Experimental design

The Faculty of Science (FoS) offer Mathematics subject to engineering students at the Faculty of Engineering and the Built Environment (FEBE). The Faculty of Engineering and the Built Environment (FEBE) had several engagement with the Faculty of Science (FoS) regarding the poor performance in mathematics modules. It has been identified that first year subjects such as Technical Mathematics (TMA105C) and Engineering Mathematics I (EMA105B) pose a huge risk to the success rate of the faculty. Hence, FEBE decided to put interventions in place by introducing online Saturday classes for TMA105C for Higher Certificate groups and EMA105B for Bachelor of Engineering in Technology groups to provide additional support to students who are struggling with Mathematics. TMA105C and EMA105B mathematics are year modules. The UCDG funds was used to appoint the part-time lecturers and tutors for 2021 academic year. Firstly, the appointment of TMA105C lecturer and tutors was conducted while the appointment of EMA105B lecturer and tutors was completed three months later. The survey was conducted to establish the time and the duration of the class that the students preferred. In addition, survey data for multimodal teaching and learning generated by Directorate: Quality Promotion Office (DQP) is used to establish if the students were familiar with remote multimodal teaching and learning process. The outcome of the survey data generated by DQP will guide if students will be able to connect online for Saturday Mathematics classes without any challenges. Mathematics Saturday online plan and mathematical activities to be covered are discussed below. Furthermore, the implementation of student-centered approach by strengthening educational support and care by Academic Excellence Office is also discussed.

4.2.1 Development plan for additional mathematics class for students.

One part-time lecturer and five tutors were appointed for TMA105C as well as for EMA105B for Saturday classes. The tutors form part of the class to monitor and assist the lecturer during class and consultation time. Figure 5 shows the number of appointed tutors and lecturers for each mathematics module.

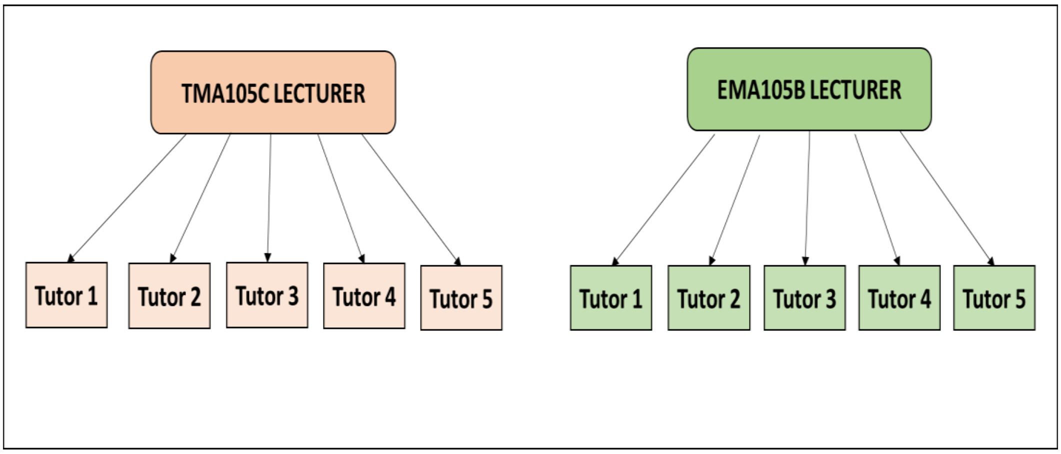


Figure 5: Part-time lecturers and tutors structure for TMA105C and EMA105B Saturday classes

Time slot survey conducted for TMA105C and EMA105B

The students' survey was conducted to establish their preferred day and time slot to hold additional mathematics class. The following information was sent to students to complete:

- Do I find online classes for Mathematics useful?
- Would I prefer 9:00am or 2:30pm slot?
- Would I prefer 2 or 21/2 hour sessions?

In addition to the survey conducted for TMA105C and EMA105B time slot, the students' survey that was conducted by DQP office is considered and the survey covered the following topics for students to respond to: orientation, support and communication. The data gathered was used to identify issues students experienced and the interventions to be put in place to help them participate in teaching and learning (including mathematical activities).

TMA105C and EMA105B schedule

Table 9 and 10 show the schedule designed by the TMA105C and EMA105B lecturers for allocation of tasks and slots amongst tutors appointed for Saturday classes and during the week. The students were to attend online Saturday class voluntarily from 9H00 until 11H00. The lecturers with the assistance of tutors present the class and at 13H00 tutors share the groupings as shown below. The tutors are allocated different groups to assist with tutorials and consultations during the week. Each tutor communicates with students within their allocated groups through WhatsApp and TUT Learning Management System (LMS), D2L BrightSpace platform. The schedule is given to students in advance to familiarize themselves and know when to connect online.

For TMA105C, tutors 1 and 2 are allocated Mechanical Engineering group, tutors 3 and 4 Electrical Engineering group and tutor 5 and the lecturer assist Civil Engineering and Industrial Engineering groups. Table 7 also shows different time slots for students to be aware of and mathematical activities taking place.

Table 7: Saturday class plan for TMA105C

Day	Tutors/Lecturer					
	Mechanical Engineering group		Electrical Engineering Group		Civil and Industrial Engineering Group	
	Tutor 1	Tutor 2	Tutor 3	Tutor 4	Tutor 5	Lecturer
Monday	Consultation with a tutor from 13H00 to 15H00					
Tuesday						
Wednesday						
Thursday						
Friday	Revision of topics covered from 13H00 to 15H00					
Saturday	Lecture on topics to be covered from 9H00 – 11H00 and Tutorials and examination past papers at 13H00 – 15H00					

Table 8 shows the days and time slots students can contact the tutors during the week to assist them with mathematical topics that they are still struggling with after attending Saturday class. The students have to make appointment with tutors in advance.

Table 8: Saturday class plan for EMA105B

Day	Tutors/Lecturer					
	Engineering groups (Chemical-, Civil-, Electrical-, Industrial-, Materials-, Mechanical- and Mechatronics Engineering)					
	Tutor 1	Tutor 2	Tutor 3	Tutor 4	Tutor 5	Lecturer
Monday	Consultation with a tutor: 13H00 – 14H00 and 14H30 – 15H30 or per appointment					
Tuesday	Consultation with a tutor: 12H30 – 13H30 or per appointment					
Wednesday						
Thursday						
Friday						
Saturday	Lecture on topics to be covered from 9H00 – 11H00 and Tutorials and examination past papers at 13H00 – 15H00					

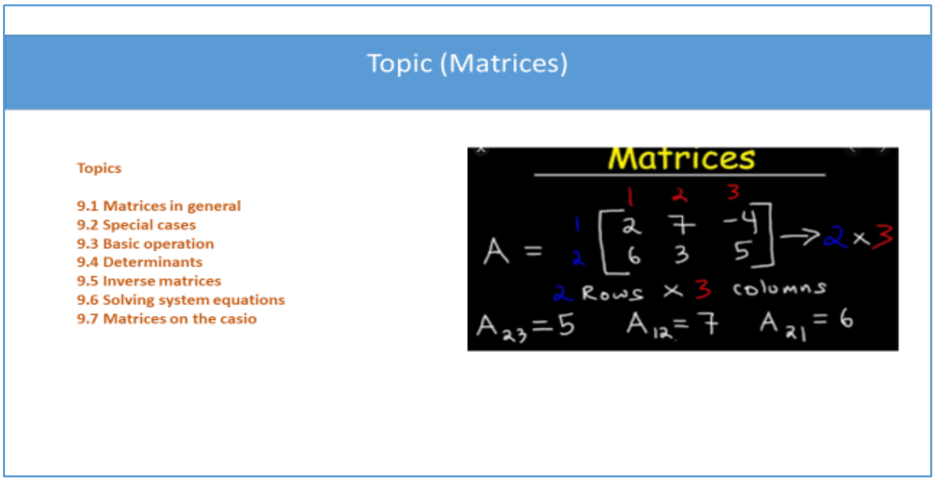
Mathematical concepts to be covered during Saturday classes.

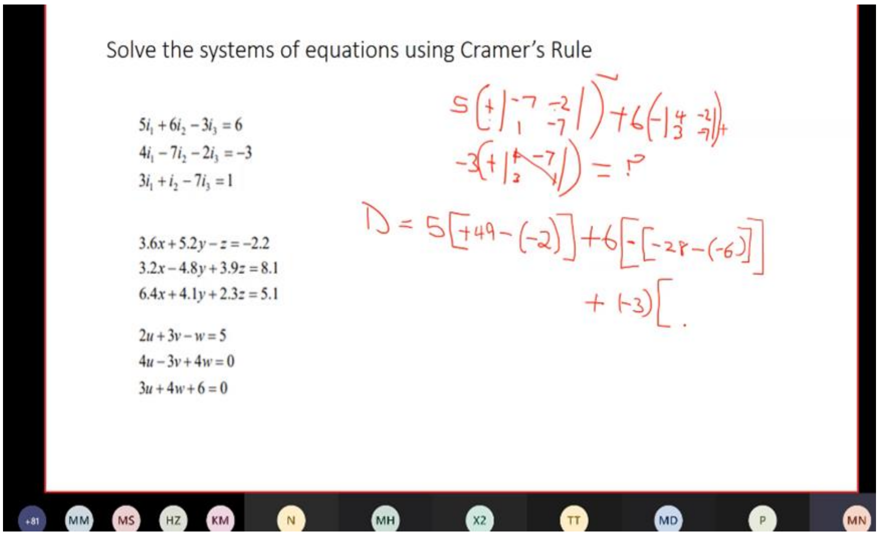
Table 9 shows TMA105C and EMA105B mathematical topics covered during the sessions. The offering of TMA105C Saturday classes started in May 2021 while for EMA105B in August 2021. Students participated in quizzes questions extracted from previous question papers and textbook exercises. The online quizzes, short tests data on their performance was collected for analysis. When students write summative assessments they do not attend Saturday classes since the assessments take place on Saturdays. However, the tutors assist students during the week in preparation for the summative assessments which is written face-to-face.

Table 9: Topics covered during Saturday Sessions

Month	Topics to be covered	
	Technical Mathematics (TMA105C)	Engineering Mathematics (EMA105B)
May	• Calculations with real numbers • Coordinate systems • Calculations with complex numbers • Angle units	
June	• Matrices in general • Special cases • Basic operation • Determinants • Inverse matrices • Solving system equations • Matrices on the Casio	
July	• Definitions and Notations • Vectors in 3 dimensions • Unit Vectors • Scalar and Vector Product • Variation-range, Standard deviation, variance	
August	• Basic functions • Composite functions • Inverse functions • Domain and range of function • Vertical and horizontal test lines • Rational functions. • Transformation • Even and Odd functions • Periodic functions	• Functions • Limits and continuity • Complex numbers • Matrices • Vectors • Inverses • Eigenvalues and eigenvectors • Matrix Diagonalization
September	• Composite functions and inverse functions • Decomposition of functions, Composite functions • Trigonometric functions (including inverse trig functions) • Sinusoids function-Amplitude phase form.	• Vector spaces • Subspaces • Spanning sets • Linear dependence and independence • Linear transformations • Limit as a derivative • Derivatives of transcendental functions • Differentiation techniques • Logarithmic Differentiation • Implicit Differentiation

The lecturers and tutors are provided with presenter's headsets and WACOM Creative Pen Tablets for remote multimodal teaching and learning. The WACOM Creative Pen Tablets are used to demonstrate mathematical concepts to students. For example, below are some of the mathematical concepts and exercises covered during the sessions.





4.2.2 Implementation of student-centered approach for support and care.

Each and every faculty at the university should have Academic Excellence Office (AEO) that deals with students' academic and social issues. Academic Excellence Office assists with data collection, problems identification, interventions, monitoring and tracking of students who missed assessments or class attendance. Currently, at the faculty of Engineering and the Built Environment (FEBE) the students were not assisted and monitored properly according to the mandate of the AEO. Students were only referred to Student Development Support (SDS) division but there was no proper structure of consultation records. For the Academic Excellence Office to function properly and efficiently, the recommended structure for FEBE 2021 Academic year is shown in figure 6. The Academic Excellence Coordinator oversee the office with the help of the Administrator. The Student Faculty Council (SFC) members deal with students' academic issues received from the departments. The SFC members are nominated and voted by students annually to serve the faculty for a year. Student assistants deal with students' enquiries regarding academic and social matters.

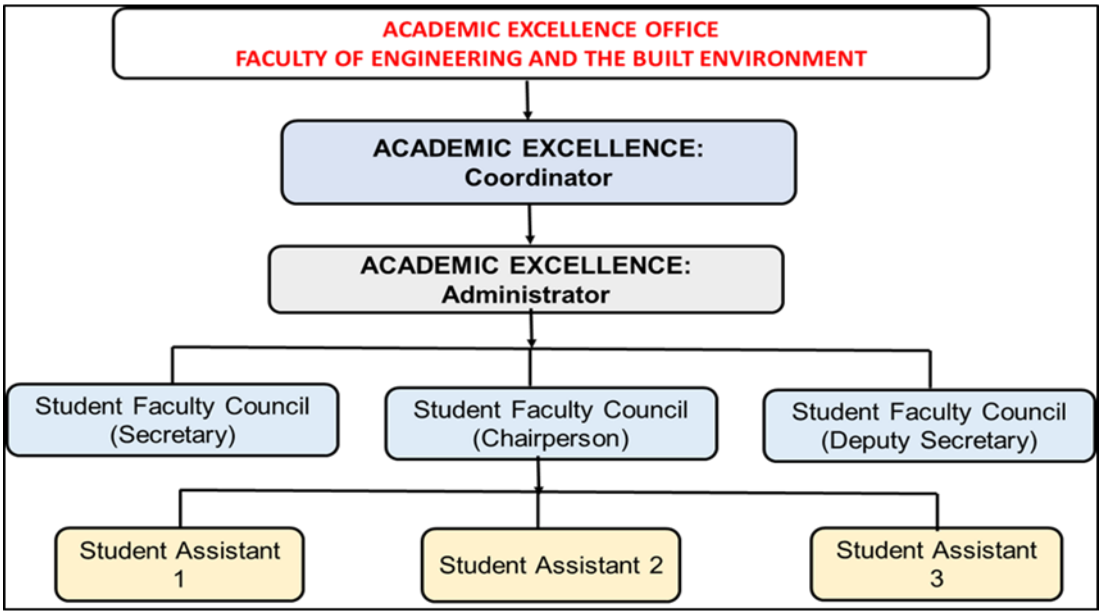


Figure 6: Academic Excellence Office structure

Normally, AEO work very closely with various departments within the FEBE. In this study the focus will be on first-time entering students who are doing mathematics modules. To further support outcome 1, the TMA105C and EMA105B students who performed below 50% after they have written the tests or missed class will be referred to AEO to established challenges that are affecting their academic performances. The logbook will be provided to the lecturers appointed to assist with Saturday mathematics classes to monitor the students' performance and identify students who are at high-risks. The students need to complete the following information on the logbook on a weekly basis for monitoring their academic performance:

- Personal details
- Qualification details and Registered modules
- Mentorship and Tutorship Consultations
- Student support interventions from Academic Excellence Office (Practitioner)

The Academic Excellence office is responsible for promoting holistic student development and academic excellence by facilitating the subsequent student support services as stated below and depicted in figure 7:

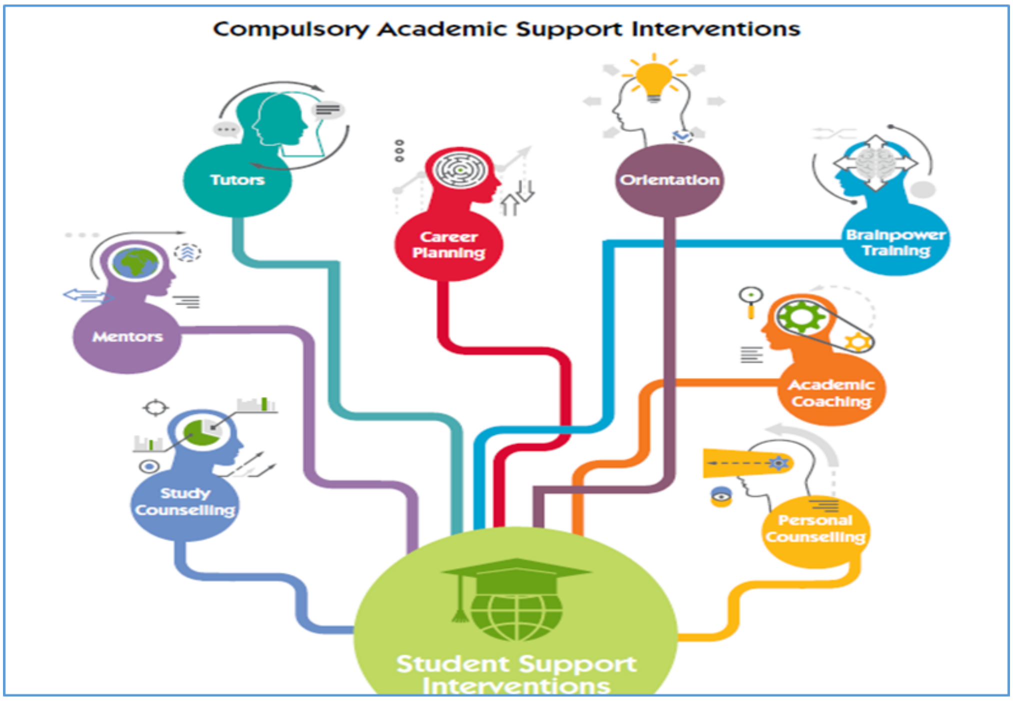


Figure 7: Compulsory Academic Support Interventions for first year high-risks students

The office has regular communication with the lecturers and the SDS for continuous students' support. The office serves as a partner in optimising students' potential for academic success and holistic development. Students are given the platform to discuss academic concerns, barrier to success and support needs. Table 10 below depicts the implementation plan for 2021 academic year to support first year students with academic and social challenges experiencing during their studies. The AEO provides support especially to students who are high-risks e.g. underperforming students. The AEO in collaboration with SDS look at high-risks students' academic records in order to make an informed analysis of the underlying factors impacting negatively on the students' performance. The resulting prescribed programme to be followed, a quarterly report by the student (which may include a report from SDS) must be submitted to the department.

Table 10: Students' support implementation plan for 2021 academic year.

Indicator of performance/ objective	Strategies / action plans	Timeframe
First years student support plan: first year experience (FYE) programme		
Explore student experiences of online classes	• Review and send out a survey which aims to gather students' experience of online classes, online challenges and support needs	Conducted during online teaching phase
Measuring of academic success: Continuous monitoring and evaluation of students' progress	• The AEO has made arrangement with MIS to provide 1st year students assessment report. • The report will be utilised to conduct performance analyses and identify students with unsatisfactory performance, in need of additional support and arrange coaching sessions. • Provide students with intervention LogBook which is used to monitor support service uptake	Continuous
Monitoring of student support service uptake	Utilise the subsequent resources to monitor student support uptake: • Monitoring intervention LogBook during Coaching sessions. LogBooks will be handed out to students in need of additional interventions • Monitoring support service uptake via SDS Student Tracking System and SDS service uptake reports	Subsequent to first assessment
Measuring of final academic success	• Conduct academic performance analysis of final assessment results to determine the impact AEO in contributing towards student success	Subsequent to final assessment
Coordinate tutorial programme		
Coordinate Tutor: Student activities	• Organise Ms Team training for Tutors • Assign Students (first years, probation and readmitted exclusion) to Tutors and encourage attendance • Evaluate the impact of Tutoring towards student success	July/August September 2021
Coordinate mentoring programme		
Coordinate Mentor: Mentee activities	• Organise training for newly appointed Mentors • Assign first years Students to Mentors and encourage attendance • Evaluate the impact of Mentorship towards student success	Depends on Mentor appointment period

4.2.3 Training of lecturers on technology for online teaching.

The university has identified four equally important pillars to support the strategy over the next six years. Focus will be only on two pillars that are relevant to connectivism. The first pillar is to produce future-ready graduates who make a positive societal impact. The main goals are:

- Deploy creative and innovative educational practices in our programmes.
- Deliver research-informed, high-quality teaching and learning experiences to our students.

Another pillar is to be a digitally advanced university. The main goals are:

- Deploy digital and smart technologies to enhance student-learning experiences, facilitate knowledge creation, increase engagement and accelerate technology.
- Deploy digital technologies to strengthen our internal capabilities to foster sound University governance and deliver effective services.

To achieve one of the aim to deploy digital and smart technologies to enhance student-learning experiences, facilitate knowledge creation, increase engagement and accelerate technology. The faculty has to ensure that training is provided to educators to enhance their technological-pedagogical skills. Educators require an understanding of pedagogical principles that are specific to the use of technology in an instructional setting to effectively align with what is to be learned. The university migrated from Blackboard (MyTUTor) Learning Management System to Bright Space (D2L) in 2021. The lecturers received training on how to use Bright Space platform as shown in Table 11. The faculty Instructional Designer provided training sessions as shown below. Some sessions, three different dates for each session were provided for the lecturers to choose the date that suit them to attend the training. Additional interactive discussion sessions were also provided to lecturers to focus on addressing specific problem areas and finding innovative solutions for design challenges.

Table 11: Bright Space training sessions for lecturers.

Date	Activity
08/02/2021 10/02/2021 11/02/2021	Communication and building Module Content • Creating announcements • Creating discussions • Video/audio communication • Create learning material by inserting files such as Notes, Videos, PPT/Video PPT, Audio files, PDF, etc.) • Activate Intelligent Agent for tracking and monitoring of learning content • Creating Assessment • Build Quizzes • Create test settings • Creating test restrictions & open assessment to students
15/02/2021 17/02/2021 19/02/2021	• Submitting an assignment as a student • Creating a Rubric • Creating Rubric Options • Creating an Assignment • Linking Rubric with Assignment • Grading an Assignment with the rubric created
08/03/2021 10/03/2021 12/03/2021	Assessments: • Creating an assessment in Bright Space • Export a question pool from Blackboard • Import a question pool into Bright Space • Set up an assessment with a question pool. • Export question paper from Respondus to Bright Space
13/05/2021 11/06/2021	• Creating an Assignment and Rubric • Linking Rubric with Assignment • Grading an Assignment with the rubric created
19/05/2021	• Fast Recording • Easy video editing • Streamlining the video teaching experience
25/06/2021	• Grade centre set up • Populating grade centre • Connecting grade centre to quizzes and assignments • Student grades view

	• Setting up of sectional questions – Main question with 'sub' questions • Grading and much more.
11/08/2021	How to manage your recorded videos. • Only 20 days of MS Teams recording • Uploading your MEGA Teams recordings • Editing MS Stream and how make it a usable tool for online teaching. • Linking the videos to your course content • Editing of MS Stream videos

4.2.4 Framework development for assessing mathematical competency for first-time entering students in 2022.

The interventions for outcomes 1 and 2 are being put in place because most of the first-time entering students are underprepared. Most students struggle with basic mathematical concepts and to close these gaps early interventions is required to be put in place. Currently, the first year students are already admitted to the Higher Certificate progammes with the following admission requirements:

*Applicants with a National Certificate (Vocational) at NQF Level 4, with a bachelor's degree or a diploma, or a higher certificate endorsement, issued by the Council for Quality Assurance in General and Further Education and Training (Umalusi), with at least **50% (APS of 4) for English and Mathematics**, and 50% for Life Orientation (excluded for APS calculation) and 40% (APS of 3) for Science, and any other three compulsory vocational subjects.*

Selection criteria: To be considered for this qualification, applicants must have an Admission Point Score (APS) of at least 20 (excluding Life Orientation).

For Bachelor of Engineering in Technology Degree programmes, the first year students are admitted to the with the following admission requirements:

*A National Certificate (Vocational) at NQF Level 4, with a bachelor's degree endorsement, issued by the Council for Quality Assurance in General and Further Education and Training (Umalusi), with at least a 50% (APS of 4) for English, 50% for Life Orientation (excluded for APS calculation), and **60% (APS of 5) for Mathematics** and Science, and **60%** (APS of 5) for any other three compulsory vocational modules. To be considered for this qualification, applicants must have an Admission Point Score (APS) of at least 28 (excluding Life Orientation).*

Potential students do not write any potential assessment before being selected for admission to these programmes to determine their numerical level of understanding and English proficiency. Furthermore, students' prior mathematical knowledge and skills are not assessed after being admitted to the programmes. Hence, the framework for assessing mathematical competency for first-time entering students is crucial. The development methods to assess the students' mathematical competencies are designed to address the research question in achieving future outcome 3 in 2022. The framework process for assessing mathematical competency for potential students will consists of 3 parts:

- Potential assessment – before admission to the programme
- Pre-Assessment – after being admitted to the programme
- Post-Assessment – after first summative assessment is being written

The plan shown in figure 8 will be implemented in 2022 because the first year students have already started with their classes.

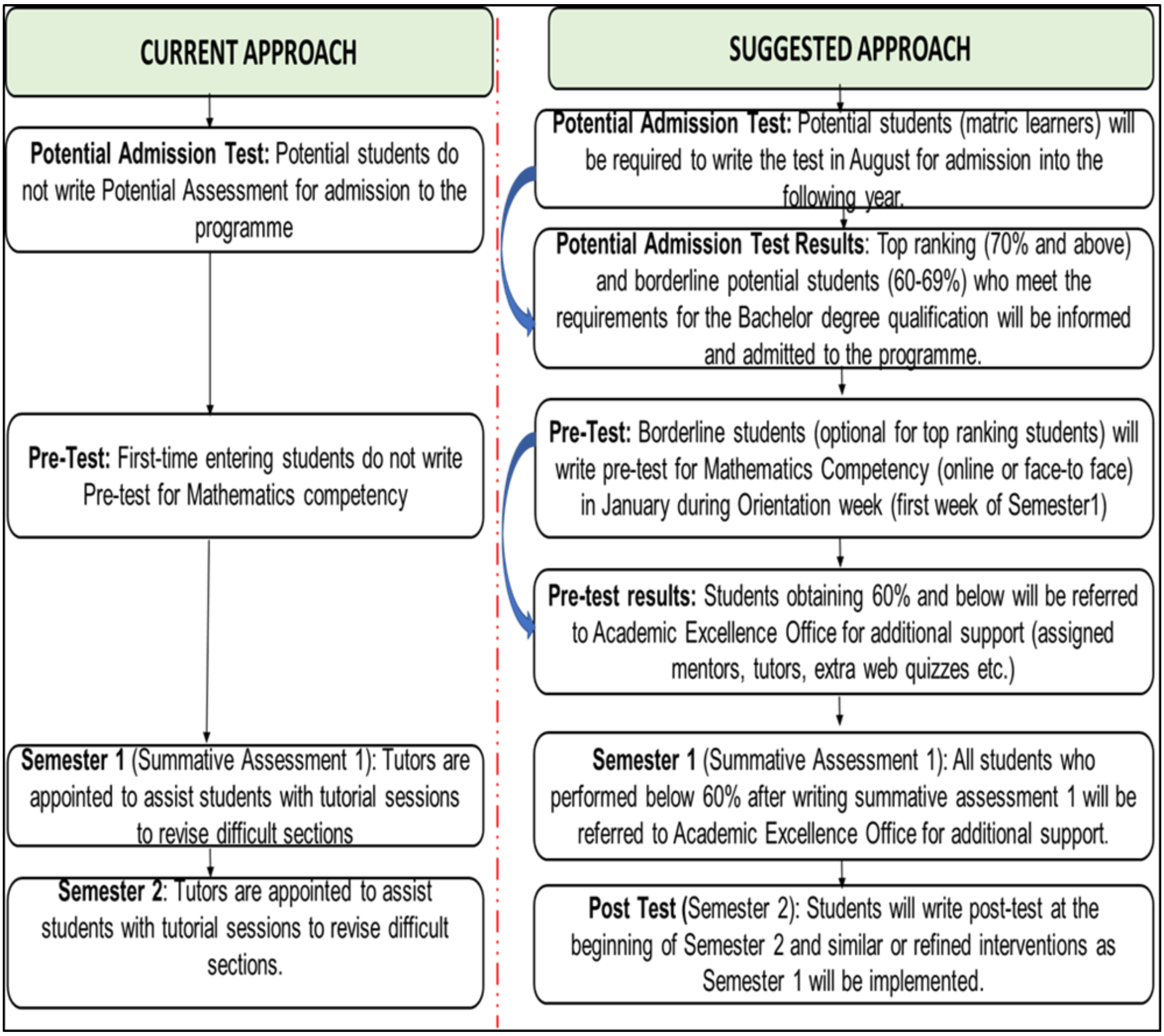


Figure 8: The framework process for assessing mathematical competency for potential students in 2022

5. Implementation and outcomes

This section provides a discussion of the proposed research questions and the envisaged outcomes. The section presents the findings in addressing the following objectives:

i. Implementation of interventions to increase students' participation in mathematical activities.

ii. Implementation of student-centered approach by strengthening educational support and care

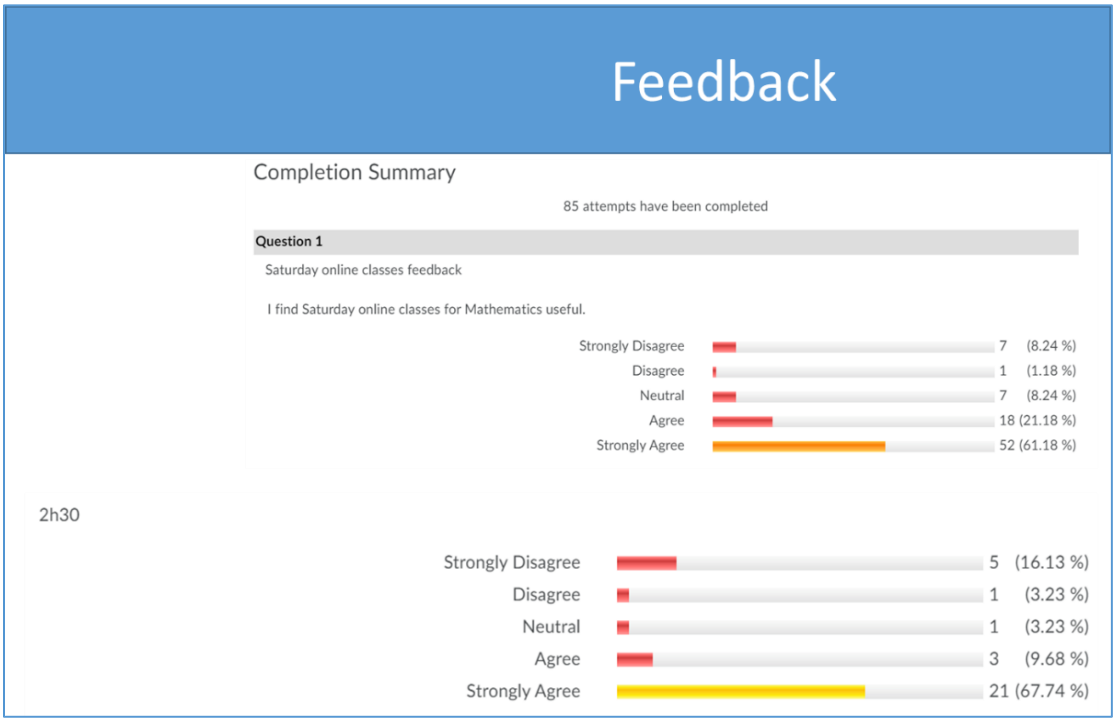
iii. Development of efficient pre- and post- assessment processes to assess mathematical competencies of first-time entering students in 2022.

5.1 Outcomes of improving students' participation in mathematical activities.

To address RQ1: How do we propose or plan to assist the students who are not coping well up to now? The implementation of interventions to increase students' participation in mathematical activities was designed. Below are the outcomes achieved in addressing RQ1.

5.1.1 Students survey to conduct TMA105C Saturday class

The students' survey showed that 61.2% of students find it useful to have additional online Saturday Mathematics classes as shown below. The outcome of the survey showed that 67.7% of students preferred to have Saturday class at 2H30. However, after having the first class at 2H30 and then requested the lecturers to move it to 9H00. Hence, the revised schedule was drafted to have classes in the morning. The outcome of the survey guided us to design the plan that would accommodate and have more students' participation.



5.1.2 Multimodal teaching and learning students' survey responses

The survey that was conducted by DQP was also taken into consideration to identify other additional needs of students. The survey was to investigate the needs of students in order to participate remotely on online teaching and learning activities. The students' feedback indicated some of the challenges that are listed below:

- No Laptops/PC to write assignments, they are mostly use their cell phones to manage their work or to visit Facebook, WhatsApp for announcements.
- Poor internet connectivity
- Difficult to understand mathematical concepts online
- No access to library material
- Majority students are using the I-Centres to access PC
- Only 9% of the students indicated that they are using a friend's computer.

The survey results show that 44.3% of students were trained on accessing activities using learning management system (LMS) while 42.5% did know how to do assessment online as shown below. Furthermore, 50.2% of the students indicated that they were trained on how to submit assessment online. The low percentages show that students are struggling on how to navigate through the blackboard platform. This shows that students want to participate but they need to be trained properly on how to use the university's learning management system.

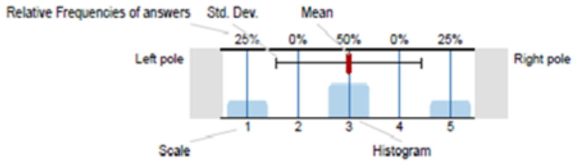
Engineering and the built environment with open ended questions

No. of responses = 2546

Survey Results

Legend

Question text



n=No. of responses
av.=Mean
dev.=Std. Dev.
ab.=Abstention

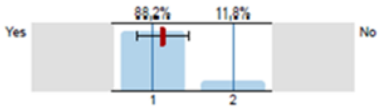
1. Dear Student,

1.1) I give my consent to take part in this survey

Yes	100%	n=2529
No	0%	

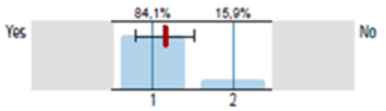
10. Orientation to remote multi-modal teaching and learning

10.1) I was informed of the emergency remote multi-modal teaching and learning



n=2527
av.=1,1
dev.=0,3

10.2) I was informed about the available options (ONLINE, hard copy printed material) of Teaching and Learning



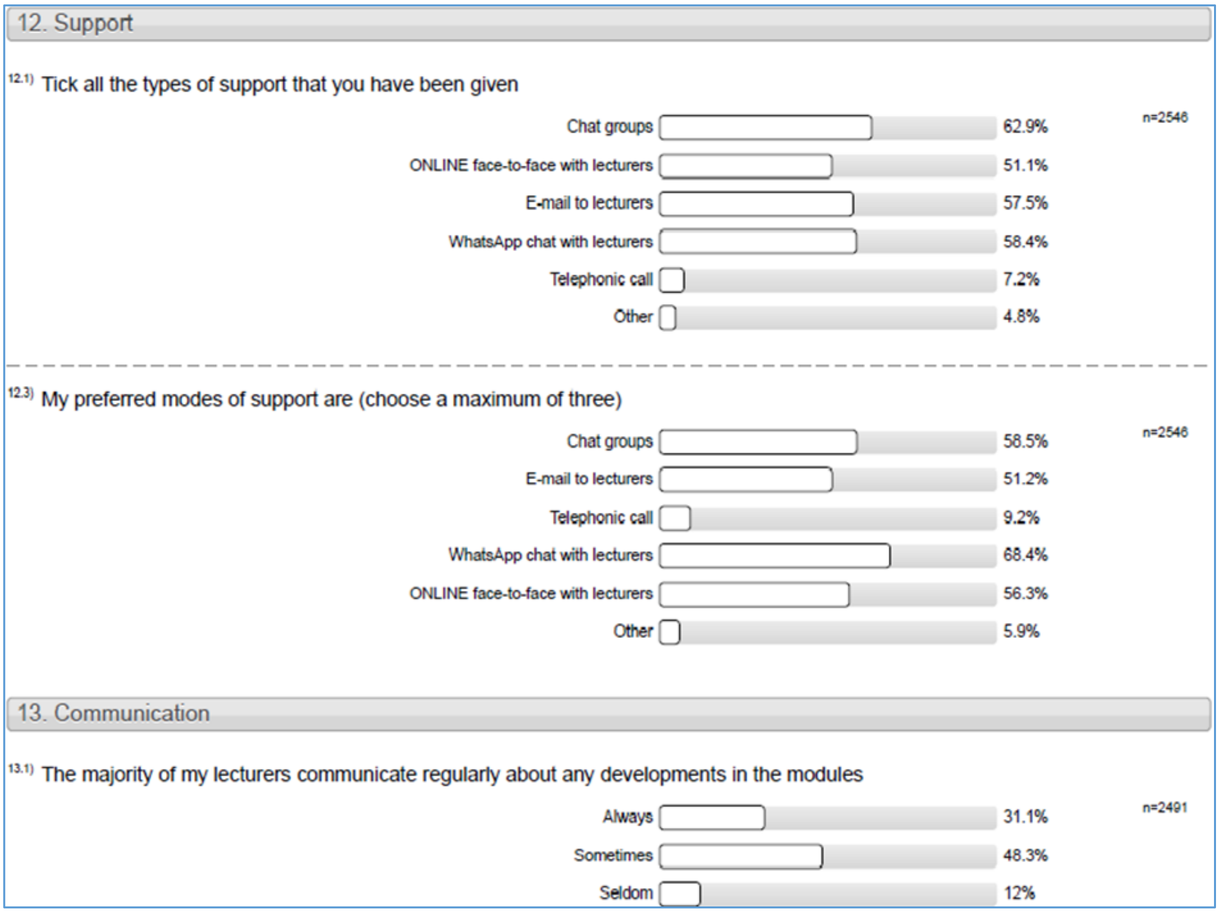
n=2520
av.=1,2
dev.=0,4

10.3) I study using paper-based remote option

Yes	50.8%	n=2472
No	49.2%	

10.4) I study ONLINE

Yes	75.5%	n=2472
No	24.5%	



5.1.3 TMA105C and EMA105B Saturday class attendance

There are about 550 students who registered for HC qualifications and about 700 students who registered for BEngTech qualifications. The Saturday classes were opened to all first year HC and BEngTech students to attend these additional classes voluntarily. However, these additional classes were targeting students who were lagging behind or struggling with certain mathematical concepts to catch-up and ask questions during sessions. The platform was aimed to provide students, to freely engage with peers and tutors to create student-tutor relationship where they can communicate using other social media platform such as WhatsApp at given time.

Figures 9 and 10 show the class attendance statistics and MS Teams online platform for TMA105C. It is clear from figure 9 that only few students attended the class. The results showed that the number of students attended class fluctuated with weeks. When the numbers dropped the lecturer will inform the Academic Excellence Office (AEO) to find out challenges experienced by students not to attend class. The AEO will also send message through TUT bulk SMS platform to remind them to attend class hence the fluctuation is observed. Most students preferred to watch the recorded sessions instead of attending live classes. This observation is expected especially when students are writing tests for other modules they have the tendency not to attend class and use the time to study for those tests.

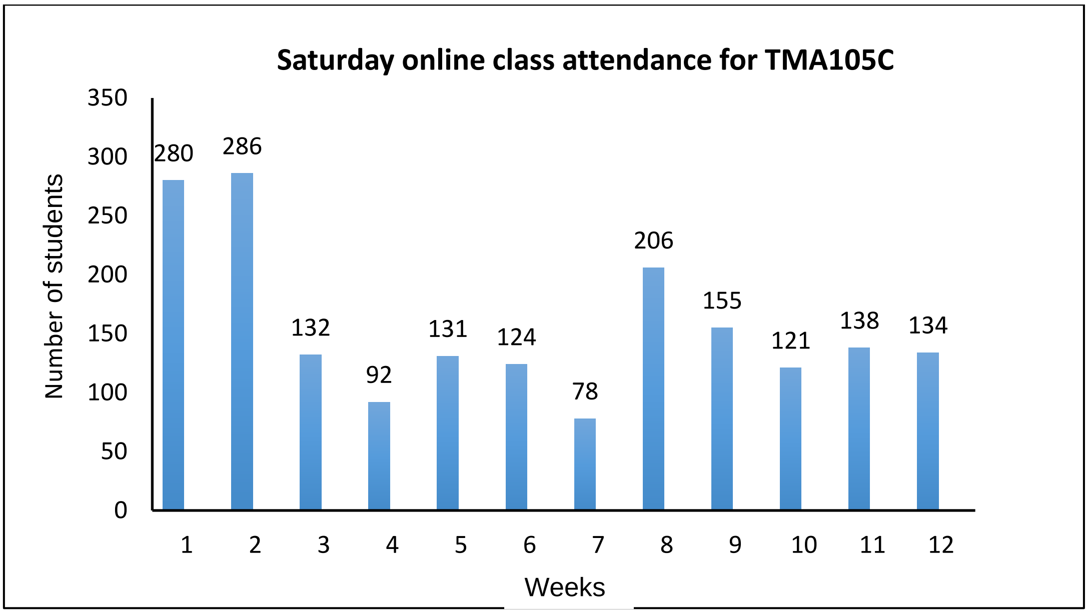


Figure 9: TMA105C Saturday online class attendance statistics

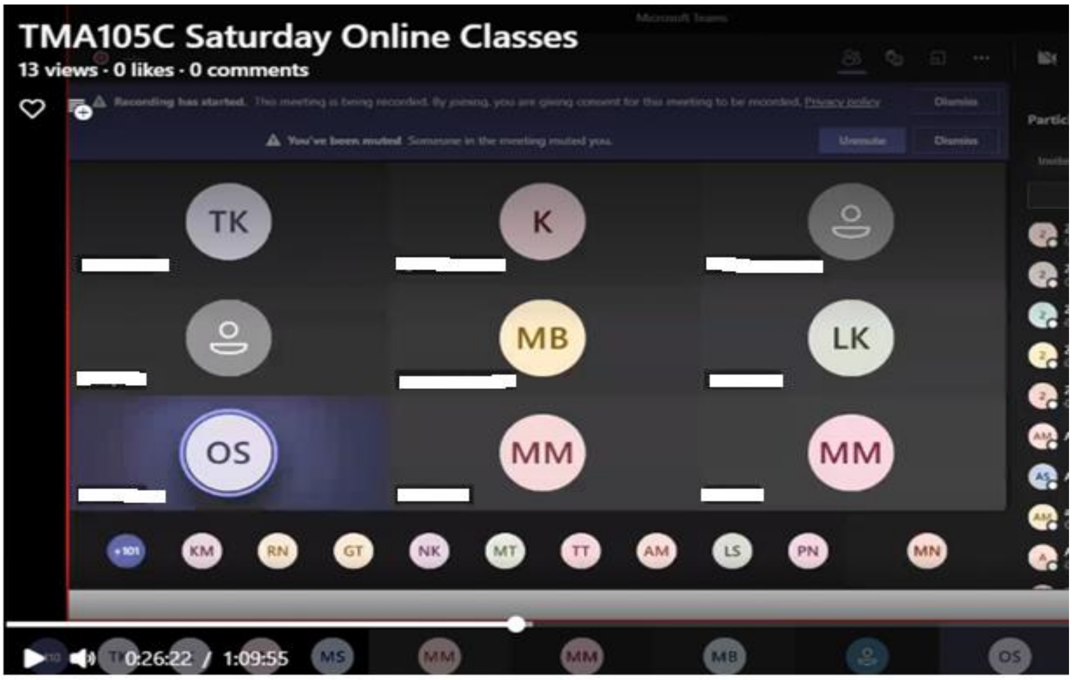


Figure 10: MS Teams TMA105C Saturday Online Class

Figures 11 and 12 show the class attendance statistics and MSTeams online platform for EMA105B. Figures 11 shows that the class attendance for EMA105B decreased gradually as the weeks progress. One of the major reasons was the country was moved to adjusted level 4 lockdown (Annexure 1) and sit-down assessments and practicals were suspended from June until mid-July 2021. The country then moved to adjusted level 3 lockdown (Annexure 2). The university made adjustments regarding assessments, examinations and practicals. Invigilated summative assessments resumed from 10 August 2021 and examinations commenced from 16 August 2021. The Saturday class started in August 2021 where most students were preparing for examinations, writing summative assessments and completing outstanding laboratory practical work for other modules. This observation is expected especially when students are writing summative assessments or examinations for other modules, class attendance is usually low because they use the time to study for those modules. When the numbers dropped the lecturer informed Academic Excellence Office to send message through TUT bulk SMS platform to remind them to attend class.

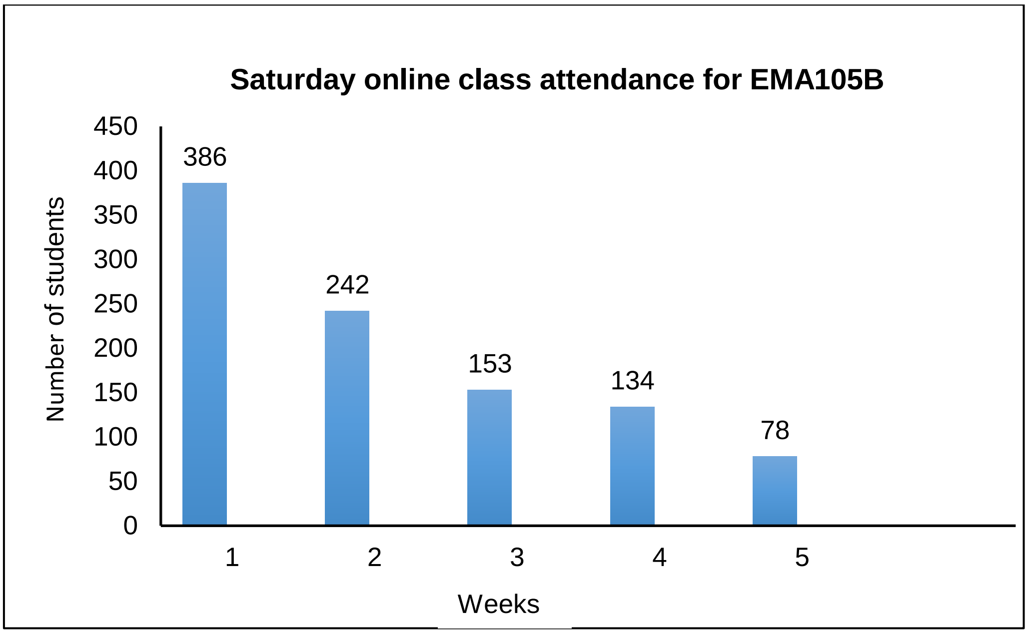


Figure 11: EMA105B Saturday online class attendance statistics

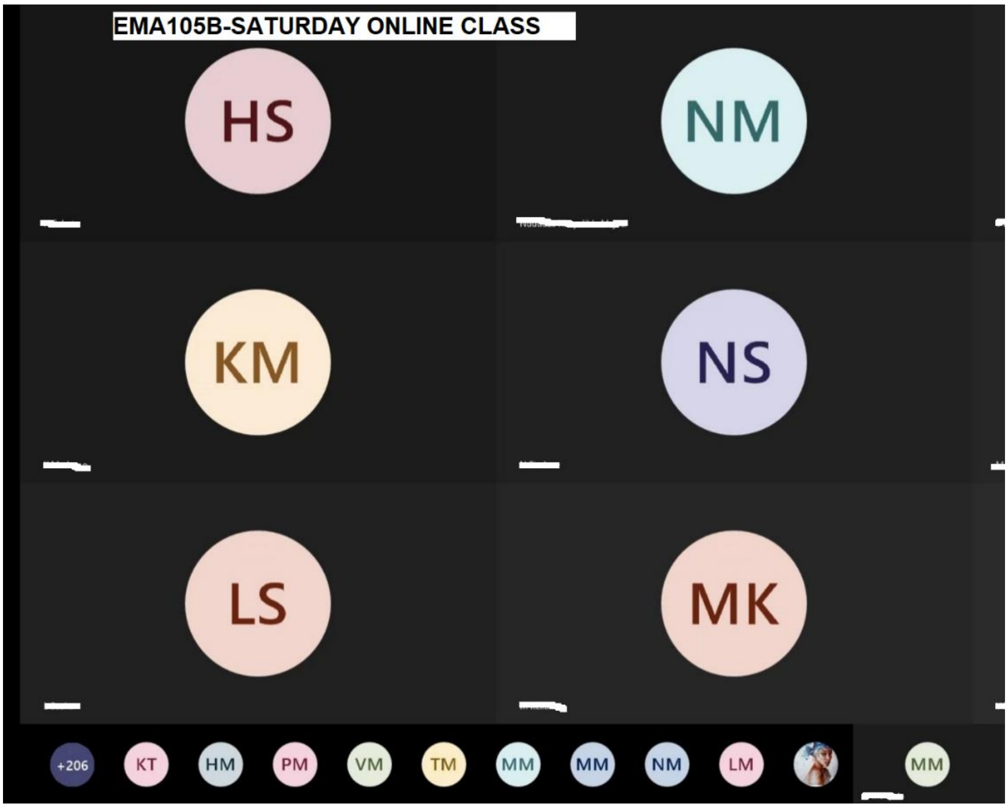


Figure 12: MS Teams EMA105B Saturday Online Class

Generally, some of the common reasons for students' low class attendance for both TMA105C and EMA105B are stipulated below:

- The data (10GB) provided to students by university was not sufficient to attend extra online classes.
- Students preferred to listen to recorded sessions at own time since the sessions are compressed and uploaded on TUT LMS which is zero-rated data.
- Connectivity was a serious issue especially from remote areas where internet connectivity is poor and national load-shedding affected network connectivity as well.
- Some students had limited space to work, privacy and silent work environment were sometimes impossible.
- Lack of laptops or appropriate devices for students to connect for online lecture sessions or type assignments.
- Some students registered late due to financial constraints
- NSFAS funded students were affected as well since the Department of Higher Education released the funds late students could not register on time to access learning materials through LMS-D2L Bright Space.

Based on the findings of this study about the low Saturday class or tutorials attendance by students prove that these sessions should be formalised and be made compulsory rather than voluntarily. Higgins & Read (2012, 35) reported that tutorial attendance and student engagement was very low for first year mathematics students since the tutorials was not structured and not monitored properly. Matsoso & Iwu (2017, 8) also reported that tutorial sessions should be structured in a formal time table to increase students' participation since tutorial attendance is crucial if supplemented by class attendance for students to perform well.

5.1.4. Online class and tutorial activities

Figures 13 and 14 show that TMA105C and EMA105B classes did take place and students were given exercises and quizzes to solve. Students were given opportunity to solve the questions and then the lecturers or tutors discuss them by demonstration using the WACOM tablet. Students were able to follow on how the solution to the exercise was obtained and were allowed to ask questions if they did not understand the process.

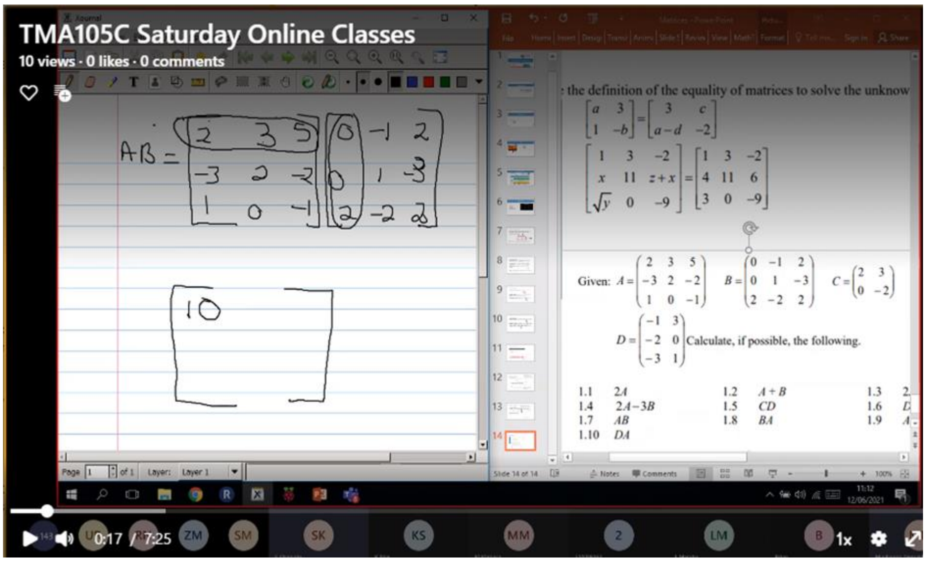


Figure 13: Mathematical activities during TMA105C class

For EMA105B, figure 14 depicts a Saturday session where the lecturer/tutors provide feedback on the exercises given. On the top right-hand side of the figure, it can be seen that the demonstrator recalls the product rule using the WACOM tablet. This is useful in a sense that it shows it is crucial for students to understand the theory. The lecturer reported that the session was quite interactive with students who had attended. The difficulties faced were students who were initially unsure of the notation used in higher order derivatives. Through discussions, the students demonstrated an understanding of tricky techniques of differentiation. Moreover, by the end of the session students were comfortable with different notations and how logarithmic differentiation applies even to hyperbolic functions and how other differentiation techniques can be extended to inverse trigonometric functions. Students who are performing well were grouped with struggling students to work together and assist each other during tutorials.

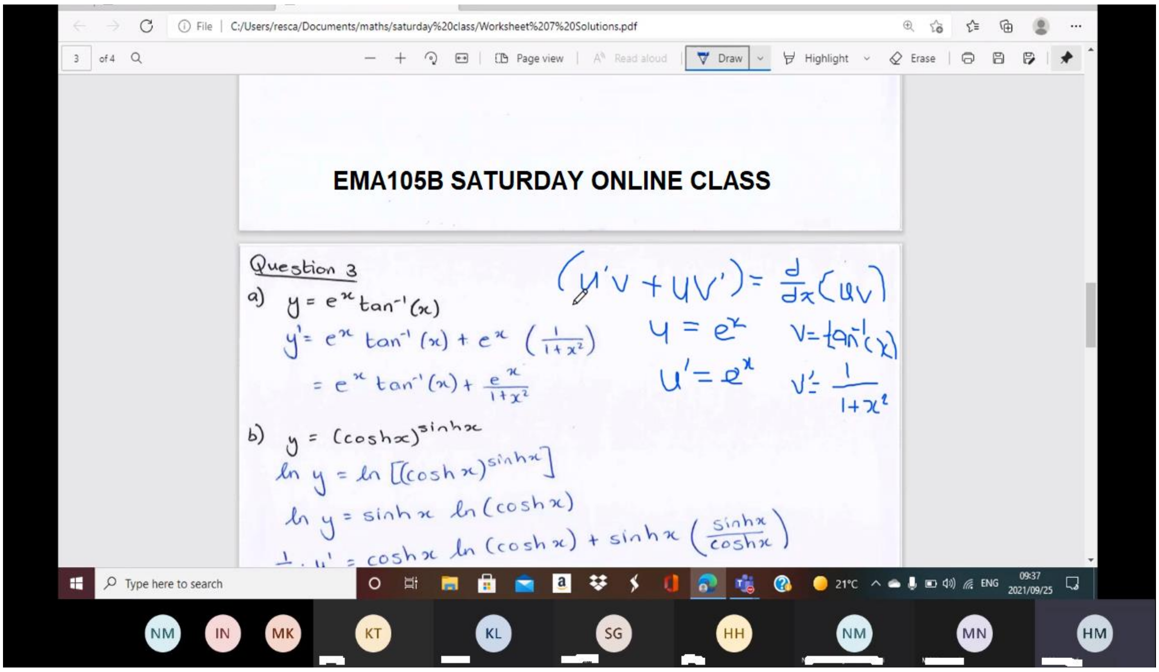


Figure 14: Mathematical activities during EMA105B class

Generally, WhatsApp groups for both TMA105C and EMA105B are used to communicate with students and identify sections that they struggling with and emphasize the sections during class.The students were even encouraged to compete amongst themselves to solve problems and share solutions in the group. Students who are afraid to ask questions in class not to appear being stupid they utilise the consultation times. Sometimes the lecturer will use the remaining 30 minutes of the class to release students who understand and allow those who do not understand to remain in class for further questions or explanations.

According Higgins & Read (2012, 35) reported that different strategies for teaching were introduced into tutorials to address students' low attendance and lack of participation challenges. Their findings showed that after implementation of monitoring systems the overall average tutorial attendance increased 30% to 78%.

5.1.5 Outcomes of TMA105C and EMA105B online test performance

Firstly, figure 15 shows the success rate of TMA105C and EMA105B modules for the last three years. It is clear that the success rate for TMA105C and EMA105B modules decreased steadily for the past three years and a sharp decline in 2020 for both modules was observed. The sharp decrease was due to the impact of COVID-19 pandemic and the following reasons contributed to low success rate:

- First year students were still adjusting to university activities and the country was put on hard Lockdown level 5 in March 2020.
- Students were not yet familiar with the usage of Learning Management System.
- Most students did not have proper devices (laptops, Desktops etc.) for teaching and learning and relied on the usage of their cell phones.
- Lecturers were trained on how to design the online content and teach at the same time. This caused stressed to lecturers to adapt to new mode of teaching and learning.

Based on above mentioned challenges experienced in 2020 due to the pandemic, interventions had to be developed to provide additional support to improve the pass rate and the success rate of Technical Mathematics and Engineering Mathematics I.

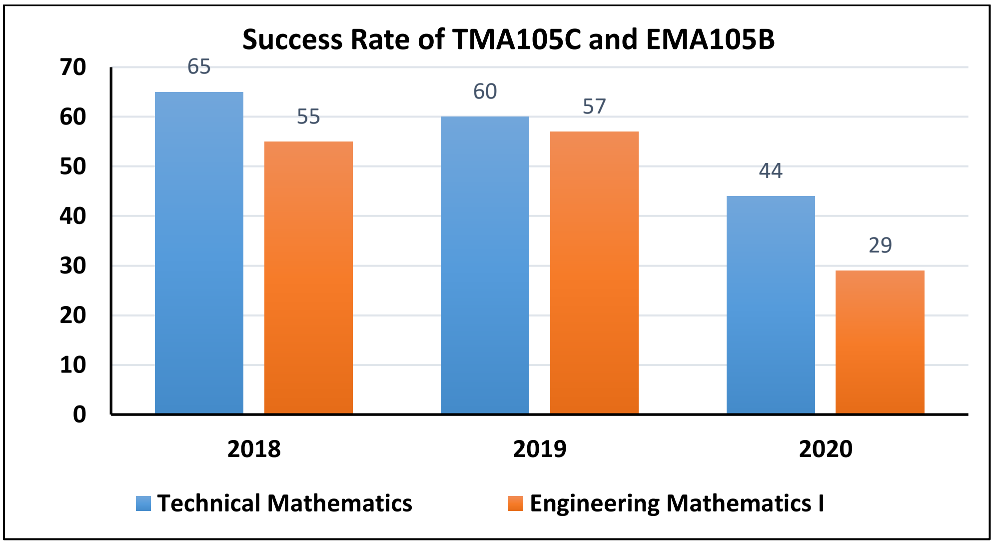


Figure 15: Success rate of TMA105C and EMA105C Mathematics

For TMA105C, figures 15 and 17 show tests 1 and 2 class average statistics. The test written covered the matrices chapter and 260 students wrote the test. It is clear from figure 15 that most students performed better after attending the Saturday class. Majority of the students (about 222) obtained above 50% which is the passing mark while 38 students obtained less than 50%. The class average percentage is 65.54% which is good especially for first test. The results show that additional support provided to students by introducing Saturday online classes to address mathematical gaps is crucially important. The lecturer took note of the questions that students find it difficult to answer and obtained low marks into consideration as well. The difficult sections will then be given more attention during class or tutorial sessions.

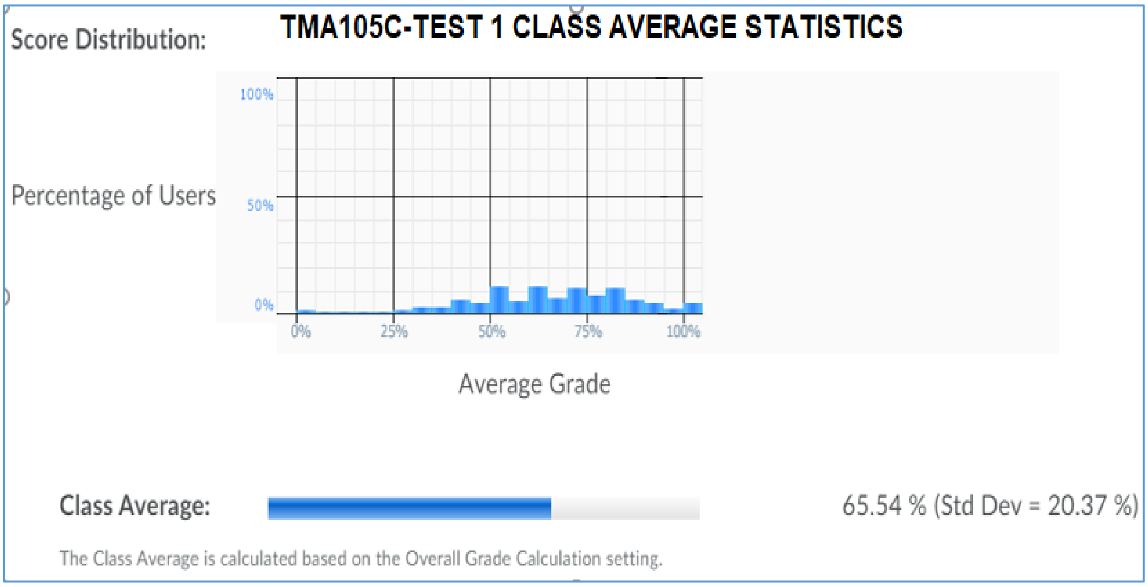


Figure 16: TMA105C test 1 class average percentage

Figure 17 indicates the level of difficulty of the questions and may be used to determine which sorts of questions/content are most challenging for students. Generally, question 6 was poorly answered by most students and it should be given special attention during review. However, question 12 was well answered by majority of students and indicating those questions will receive less attention. This trend of students answering other questions poorly is confirmed by Khashi'ie *et al* (2017, 87). They reported their findings that students failed to express and simplify the algebraic expression component given in the simplest way and mostly repeated the same error and more than half of the students answered the questions incorrectly for both in pre- and post-tests. The students were also divided into small collaborating groups and they were left to work alone on the previous examination papers to find solution for the questions.

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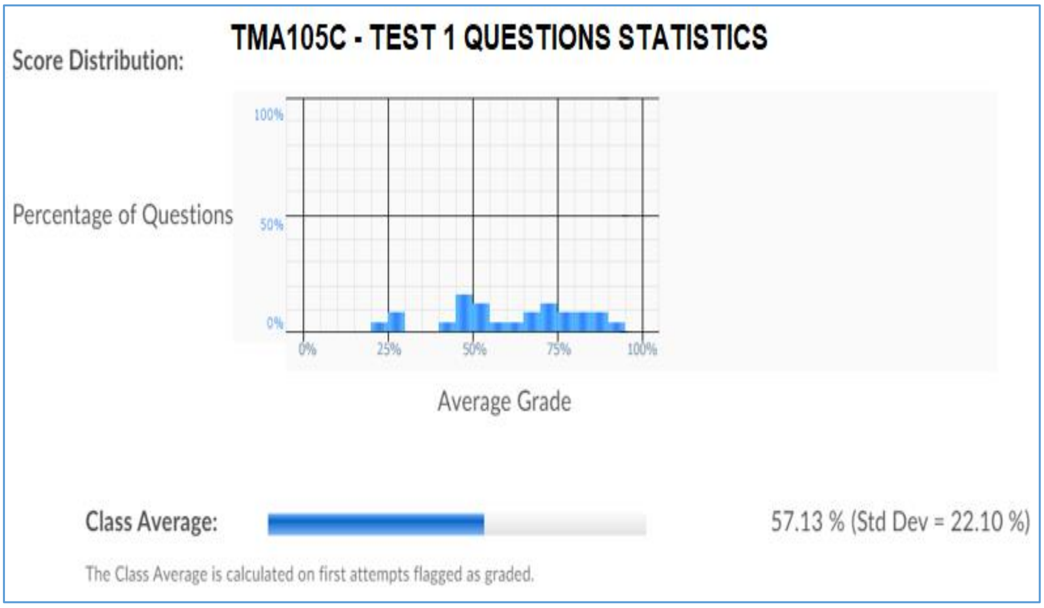

Figure 17: TMA105C Test 1 Questions class average

Figure 18 shows class average percentage for test 2 that students wrote. The test set covered the Vector Chapter dealt during the class and tutorial sessions and there were 260 students who wrote the test. The results showed in figure depicts that 221 students obtained above 50% while 39 students obtained less than 50%. The class average percentage is 57.84% which is still good but less than test 1 class average percentage. The decline in the percentage showed that there were few students who obtained between 75 and 100% when compared to test 1 where more students were in that region as shown in figure 16. It shows that most students find the vector section difficult and the lecturer will revise the section in class and during tutorial sessions.

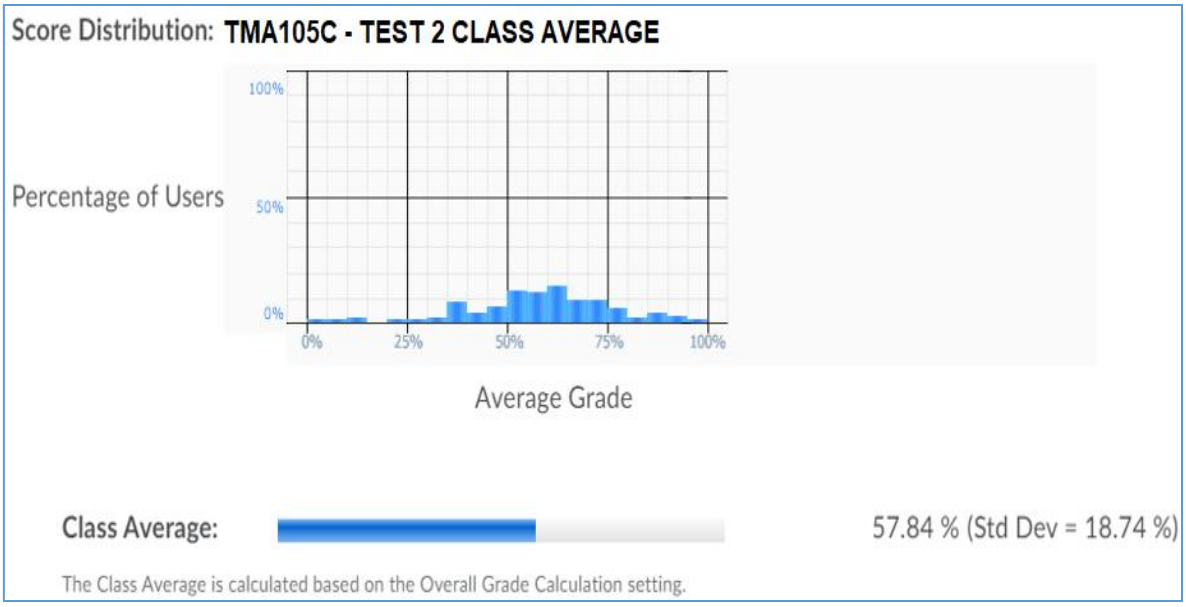

Figure 18: TMA105C Test 2 class average percentage

Figure 19 shows the level of difficulty of the questions that may be used to determine which questions or learning content most students challenging. It was observed that question 18 of the paper was not attempted or poorly answered. The question or learning content related to the question will be revised and given special attention during class. However question 14 was well answered and hence the average questions percentage is 51.5%.

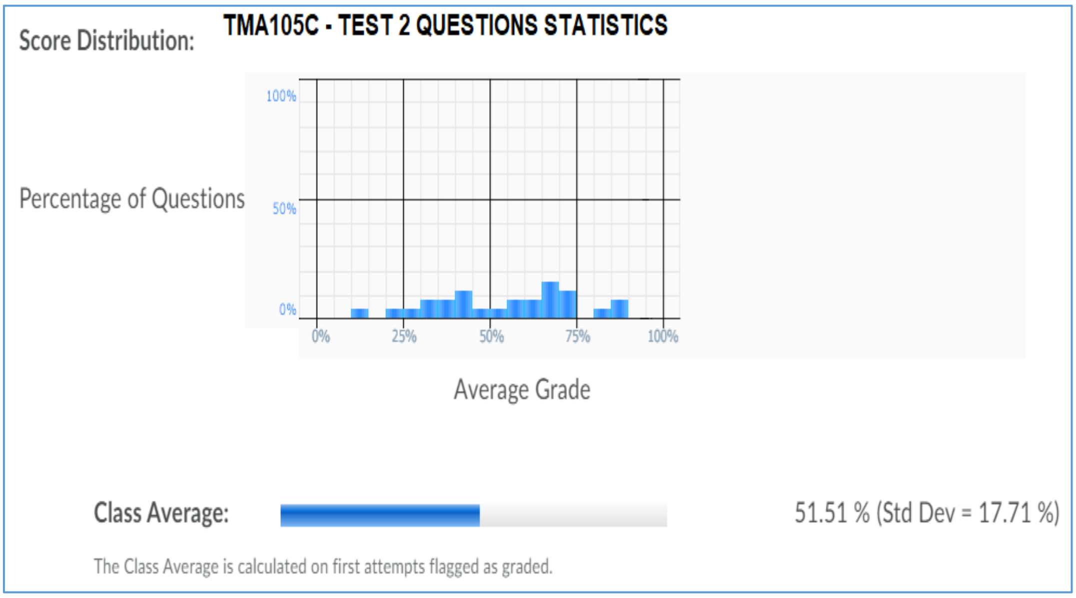

Figure 19: TMA105C test 2 questions average percentage

For EMA105B, the Saturday online class sessions started in August 2021 as stated previously. Figure 20 shows the results of the quiz undertaken by students. The students only did the quiz and were assessed on functions, limits and continuity, complex numbers and vector algebra. There were 146 students who completed the quiz and 104 students obtained 50% and above while 42 students obtained less than 50%. The class average percentage was 54.73% and few students obtained above 75% passing marks. The class average percentage is slightly above the passing mark even though more students pass the quiz.

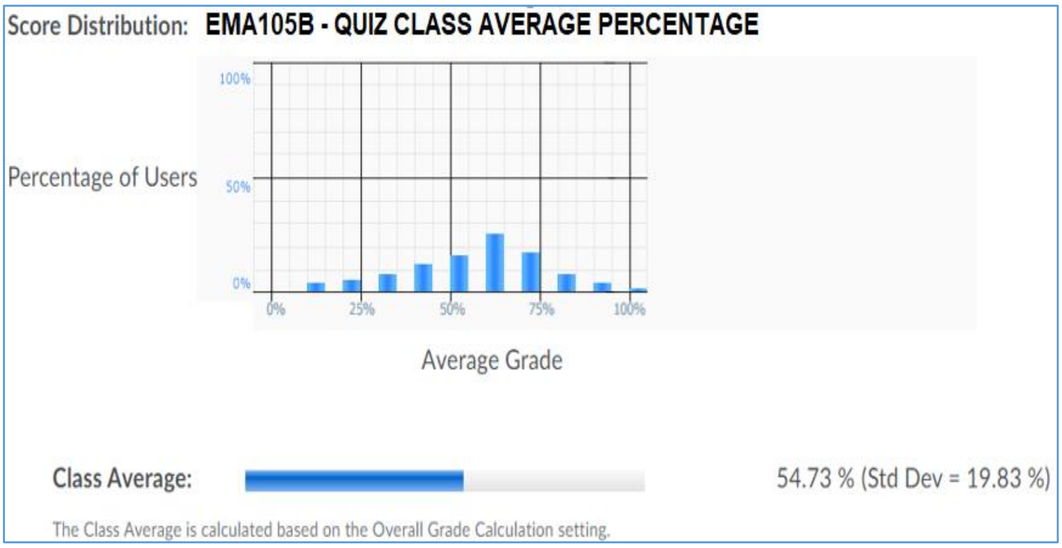

Figure 20: EMA105B quiz class average percentage

5.1.6 Outcomes of TMA105C and EMA105B summative assessment performance

The students have written two summative tests to date. Figure 21 and 22 show the class average percentage for TMA105C and EMA105B summative tests written by students. It is clear from figures 21 and 22 that students did not do well with the written summative test 1 (WR1) but a slight improvement was observed with written summative test 2 (WR2). This confirms that students are now grasping mathematical concepts hence a slight pass rate improvement was observed with WR2. For EMA105B, the departments that did not show improvement or was a slight decrease with written assessment two are Civil Engineering and Geomatics, respectively.

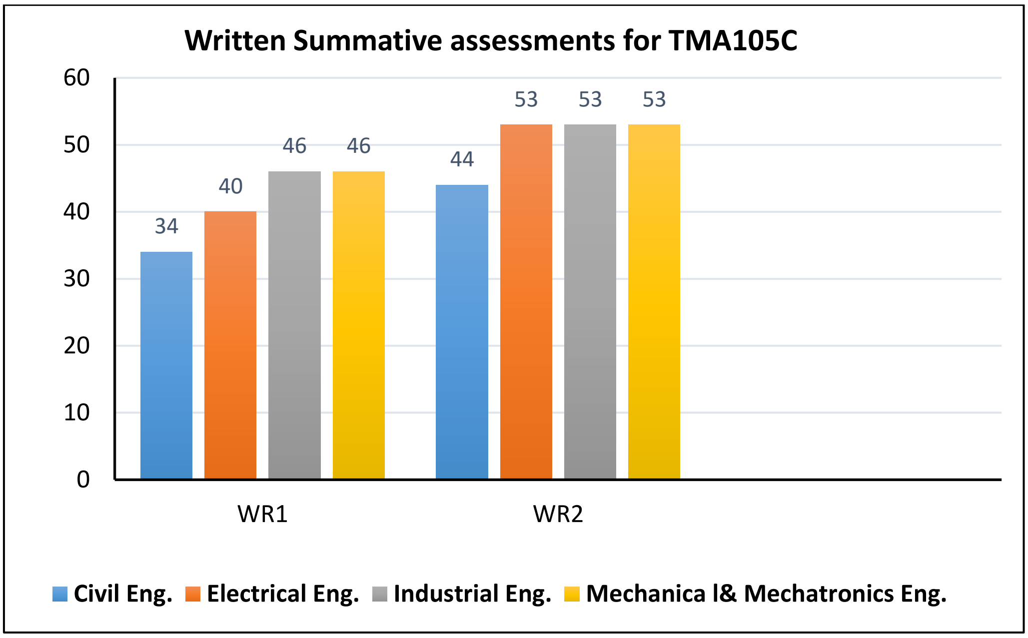

Figure 21: Written summative assessments for TMA105C

However, most students did not attend the Saturday class as expected but those who participated in class activities did well. The results are in support of Engelbrecht *et al* (2010, 72) findings where students' performance improved from semester test 1 to test 2 after attending the fresher's intervention course.

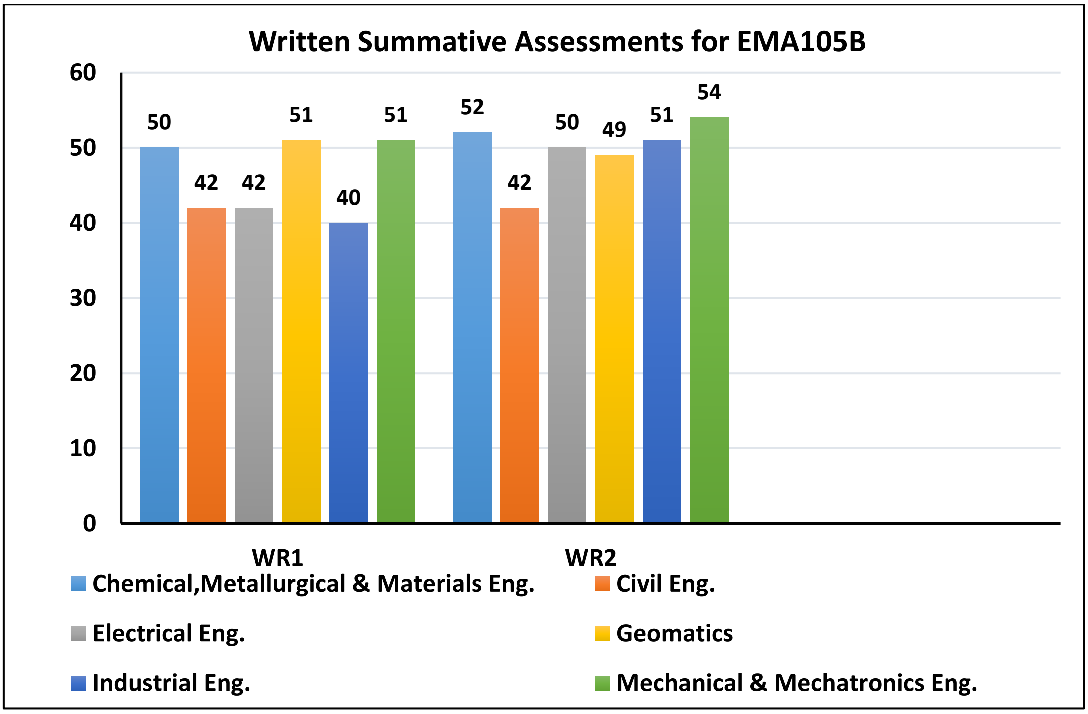

Figure 22: Written summative assessments for EMA105B

5.1.7 Students' feedback on Saturday online classes

Figure 23 depicts the survey that was conducted through D2L Bright Space platform. It is clear from figure 23 that almost 60% strongly agreed that Saturday online classes for mathematics are useful. Student's survey is crucial because it assists the lecturer to be encouraged and improve the teaching skills as reported by Oahada (2019, 9).

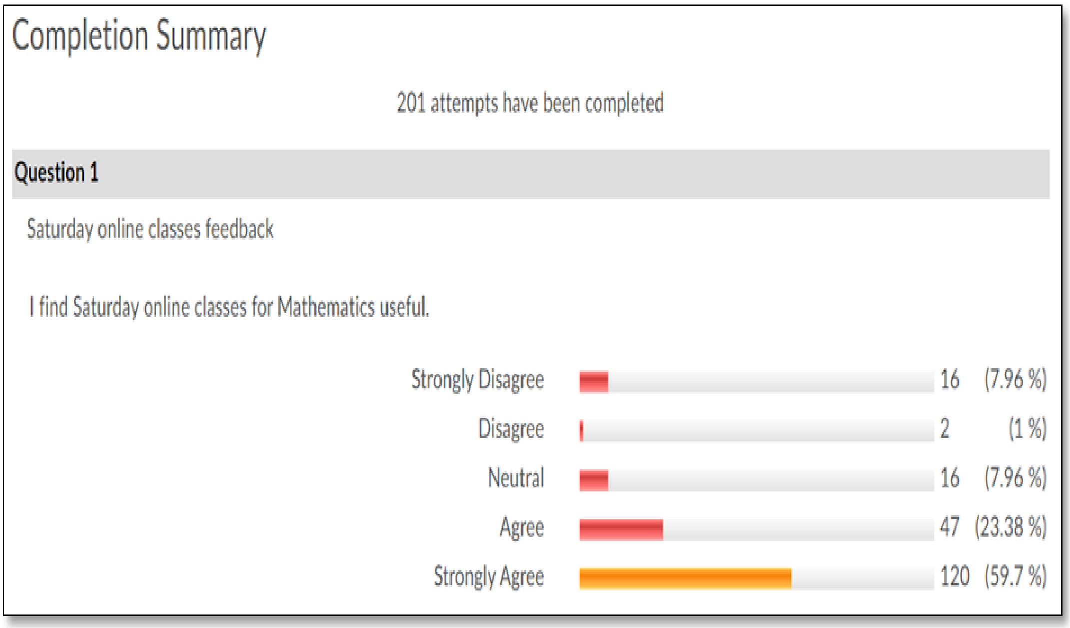

Figure 23: Students' feedback on TMA105C Saturday online class.

5.2. Outcomes of academic and social services offered to students

Most of the students are from poor and disadvantaged environment. Students relied on university resources such as i-Centres and Desktop laboratories computers to do their academic work. Despite the university's efforts to ensure equitable access to learning by providing data and poorer students have been disadvantaged by shifting to online teaching during national lockdowns. Students were forced to return home during lockdowns where they were faced with unconducive environment for studying. Most students used their cell phones for teaching and learning due to lack of laptops or appropriate devices to view lecture sessions or type assignments. Some students had to look after families and space to work was very limited. Privacy and silent work environment were sometimes impossible for students. The stress in writing an assessment at home and the fear of not being able to submit on time due to possible connectivity problems or load shedding. Harassment within the academic environment and family challenges due to deaths in the family due to COVID-19 and financial constraints affected their academic performance. Figure 24 shows the services provided by Academic Excellence Office in collaboration with Student Development Support (SDS) and the number of students who received academic and social support. The record of students consultations are recorded in a logbook (Annexure 3). The advantages of the initiative were to make students aware of or to encourage them to use the support available at the institution. The services provided indicated that students were able to cope after attending consultations at SDS and AEO with councillors/coachers or psychologist's.

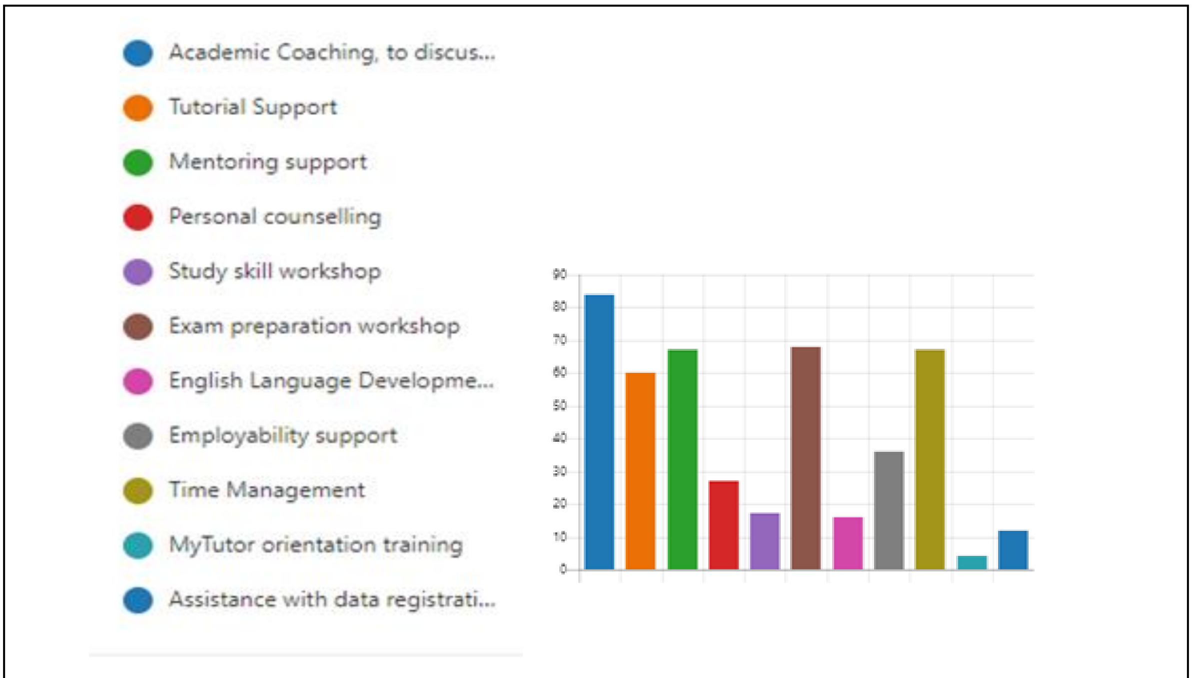

Figure 24: Services students received from Academic Excellence Office

Figure 25 shows the intelligent agent system used as one of the tool on D2L Bright Space for lecturer to track students who are not or seldom participating on class activities. It shows the number of times students login in the learning management system. It shows that out of 9 activities some students have completed 0 tasks and the poor performing students will be contacted and referred to Academic Excellence Office for further academic and social support.

Figure 25: Intelligent tracking system to identify students at risks.

Table 12 shows the suggested guidelines for mathematics lecturer-tutor. Tutors know what is expected from them and the students know tutors who are responsible for the modules. The tutorial guidelines are in line with Matsoso & Iwu's (2017, 8) findings that tutorials are introduced as support mechanism to assist struggling students to improve their mathematics marks.

Table 12: Lecturers responsibilities toward a tutor

Lecturers responsibilities towards a tutor
• Lecturer should introduce tutor and tutor introduce him/herself and remind students of his/her accessibility in the Learning Centre, classroom and online platform. • Tutors must at all-time be informed about content that the Lecturer will teach. If needed the lecturer must do preparations in collaboration with the Tutor. • Ensure that Tutors should be present during class and tutorial sessions. • Communicate with the tutor via e-mail before or after class and ask for feedback. Feedback can help to determine whether the students have clear understanding of the learning content or module. • Encourage open communication with tutor since students tend tell tutors things they may not tell you. The tutor may disclose general and even specific information, because of the confidential nature of tutoring. Student names and information may not be part of this feedback. • Provide the tutor with a copy of the syllabus, weekly schedule, assignments, and hand-outs. Explain the teaching method. • Discuss the content of the lesson. Make sure that the tutor is able to help with problem solving and solutions to difficult areas in the lesson. • Demonstrate problem solving solutions to enable the tutor to support the students in the learning area. • Remember that your students may be disinclined or too shy to ask for clarification about a lesson or an assignment you give. You could ask the tutor if your instruction is clear which might encourage the students to ask questions they may have. • The tutor might be open to giving a mini-presentation on some aspect of your instruction. Encourage him/her to be involved this way. • Ask the tutor if he/she has any suggestions for other ways to utilise his/her presence in the online class • Encourage your students to consult the tutor on time for more clarity on the learning content or practical/experiments in the laboratories for example.

5.3 Assessment processes for mathematical competencies of 2022 first-time entering students.

The plan will be implemented in 2022 because the first year students have already started with their classes. Currently, the students are randomly put in different groupings according to the qualification registered as shown in Table 13. To implement the plan in 2022, the students will still be grouped according to the qualification groupings. However, the groupings will consist of students who performed above 70% and the other group students who obtained below 70% pre-assessment marks. The groups will be assigned different lecturers based on their expertise and character. If there are few students who obtained 70% and above then the allocation will be revised to balance out the numbers. The reason being that more attention can be given to struggling students and also to allocate the lecturer who is passionate, good and patient with students to address the identified mathematical gaps in students. Students who are not coping need a lecturer who will provide the necessary support and adjust the pace to accommodate those students.

Table 13: TMA105C and EMA105B mathematical groupings within the faculty

Higher Certificate Groupings		Bachelor of Engineering in Technology
Civil Engineering	C1-HCCM18	C1 – Civil Engineering (Group A)
	C2-HCCM18	C2 – Civil Engineering (Group B)
	C3-HCCM18	
	W1-HCCW18	
Electrical Engineering	E1-HCEE18	E1 – Electrical Engineering
	E2-HCEE18	
	E3-HCEE18	
	E4-HCEE18	
Industrial Engineering	I1-HCIE18	I1 – Industrial Engineering (Group A)
	I2-HCIE18	I2 – Industrial Engineering (Group B)
Mechanical and Mechatronics Engineering	M1-HCME18	M1 – Mechanical Engineering (Group A)
	M3-HCME18	M2 – Mechanical Engineering (Group B)
	M4-HCME18	M3 – Mechatronics Engineering
		B1 – Chemical Engineering
		B2 – Metallurgical Engineering
		B3 – Materials Engineering
		G1 – Geomatics

6. Conclusion

Firstly, the section provides an overview of the study and the achieved and/or anticipated outcomes of the implementation of the project. Finally, conclusions and recommendations for further development.

To support outcome 1, implementation of interventions to increase students' participation in mathematical activities was achieved by implementing Saturday mathematics online classes even though it is an on-going process. It is clear that there is low class attendance and students preferred to listen to recorded sessions. The summative assessments results showed that there is a gradual and significant improvement in mathematics pass rate. The pass rate could have been improved if most students were attending Saturday classes and tutorial sessions. The test results showed that students who attended the sessions performed well even though the numbers are still low.

To support outcome 2, implementation of student-centered approach by strengthening educational support and care. The interventions implemented to support the students in terms of their academic and social challenges were achieved by re-structuring the Academic Excellence Office. There was a significant improvement observed with academic coaching, tutoring, mentoring and examination preparation services provided to students. The office is constantly communicating with the lecturers to track students at risks who were not attending either structured or Saturday online classes. This shows that the office should work closely and efficiently with the departments and mitigate challenges experienced by students on time rather than late.

To support outcome 3, to implement pre- and post-assessment processes for mathematical competencies of first-time entering students in 2022. It is clear from findings of outcomes 2 and 3 that a quick screening assessment should be conducted to prior admission to the programme to establish their mathematical competencies to place them on the relevant groupings programme.

7. Recommendations

The faculty of Engineering and the Built Environment should engage with the service faculty, the faculty of Science to come up with plans on how to motivate and encourage students to attend additional Saturday classes. The lecturers reported that most students were demotivated since Saturday online assessments do not contribute towards their final predicate marks. The lecturers who teach mathematics Saturday classes recommended that online tests conducted during sessions should contribute at least 5% towards their predicate marks. Based on the findings of this study to reach an overall faculty target percentage for success rate the faculty should commit to engage with the Faculty of Science as a starting point to identify students at high-risks prior to entry rather than at the end of the first term.

8. Personal Reflection

Reflecting on a personal journey of writing this thesis was a mission because the structure and approach was outside my field of expertise as a Scientist. The thesis write-up journey has taken me out of my comfort zone. The main challenge was having too much information and had to narrow it down to specifics and place it at relevant sections of the thesis. I really enjoyed the ride with few speed bumps and humps on the road and few tyre punctures. Fortunately, when I experienced few tyre burst and speed bumps and humps, my family, colleague (Mxolisi Shongwe), friend (Ingrid Mokgobu) and supervisor were always there to help me put a new tyre and continue the journey. I really want to thank my supervisor for her endless kindness and patience, she is the best supervisor I ever had in my academic journey.

I really stretched myself by choosing the high-risk subject that is not being offered in the faculty of Engineering and the Built Environment that was really challenging. The challenge now is to present the development plan to the department of Mathematics and Statistics (Faculty of Science) to implement the plan within their environment. If the faculty of Science is not willing or ready to adopt the plan then the faculty of Engineering and the Built environment will continue with the intervention already in place. Generally, the whole process of thesis write-up was very intriguing and exciting because I had to come up with a plan that has been bothering me for years on how to assist the first year students to improve their mathematical competencies. I liked the learning path and find this topic as an ongoing challenge, nationally if not globally. I intend to write a paper about the outcomes of the development plan to be published in an accredited journal.

Lastly, what was so interesting for me was the Haaga-Helia coordinators who were so thoughtful in arranging the thesis workshop to assist in finalising the thesis write-up. I wished the workshop could have been split into 3-parts i,e proposal stage, the draft thesis stage and final thesis stage.

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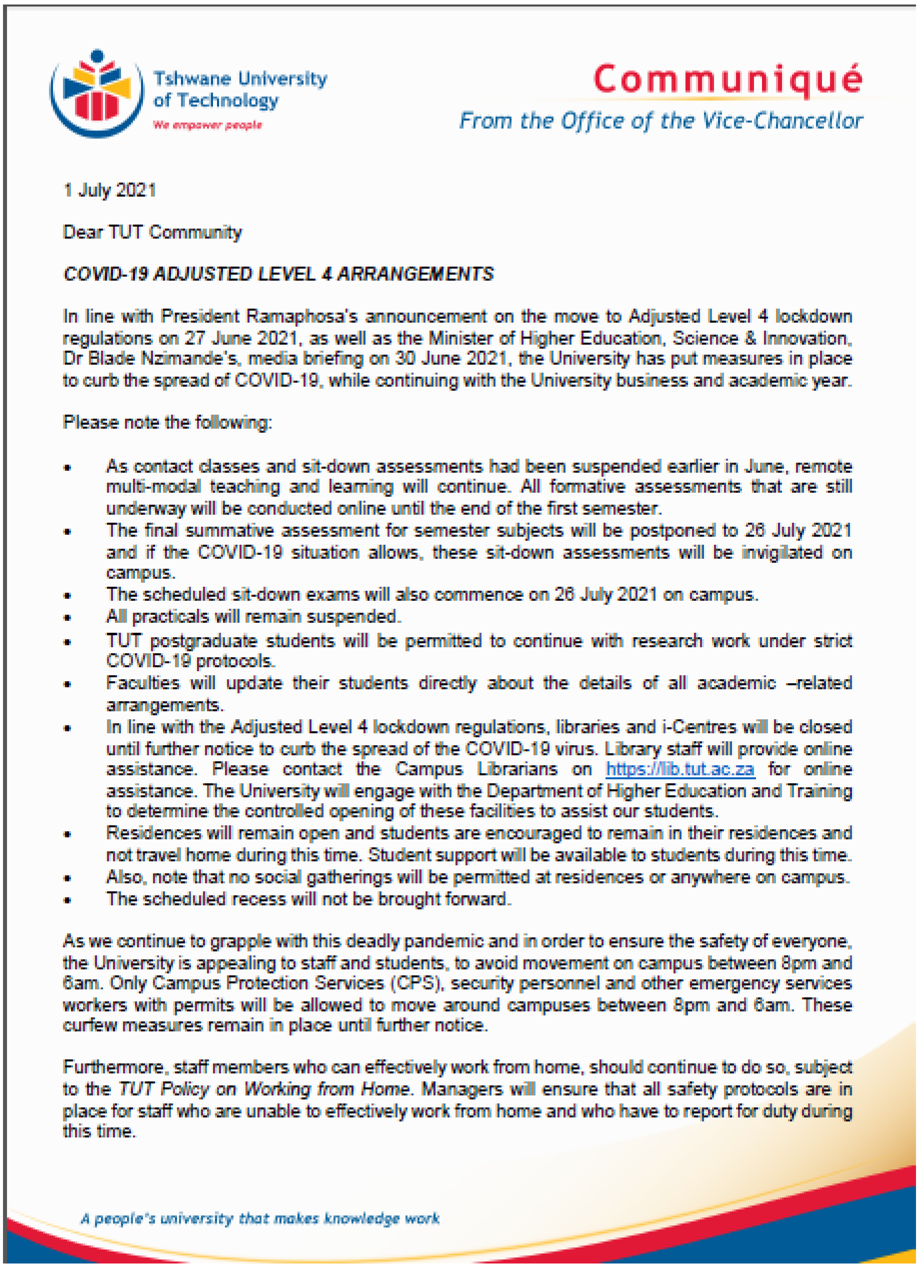
ATTACHMENTS:

Annexure 1: TUT COVID-19 adjusted level 4 arrangement communiqué



Tshwane University of Technology
We empower people

Communiqué
From the Office of the Vice-Chancellor

1 July 2021

Dear TUT Community

COVID-19 ADJUSTED LEVEL 4 ARRANGEMENTS

In line with President Ramaphosa's announcement on the move to Adjusted Level 4 lockdown regulations on 27 June 2021, as well as the Minister of Higher Education, Science & Innovation, Dr Blade Nzimande's, media briefing on 30 June 2021, the University has put measures in place to curb the spread of COVID-19, while continuing with the University business and academic year.

Please note the following:

- As contact classes and sit-down assessments had been suspended earlier in June, remote multi-modal teaching and learning will continue. All formative assessments that are still underway will be conducted online until the end of the first semester.
- The final summative assessment for semester subjects will be postponed to 26 July 2021 and if the COVID-19 situation allows, these sit-down assessments will be invigilated on campus.
- The scheduled sit-down exams will also commence on 26 July 2021 on campus.
- All practicals will remain suspended.
- TUT postgraduate students will be permitted to continue with research work under strict COVID-19 protocols.
- Faculties will update their students directly about the details of all academic –related arrangements.
- In line with the Adjusted Level 4 lockdown regulations, libraries and i-Centres will be closed until further notice to curb the spread of the COVID-19 virus. Library staff will provide online assistance. Please contact the Campus Librarians on https://lib.tut.ac.za for online assistance. The University will engage with the Department of Higher Education and Training to determine the controlled opening of these facilities to assist our students.
- Residences will remain open and students are encouraged to remain in their residences and not travel home during this time. Student support will be available to students during this time.
- Also, note that no social gatherings will be permitted at residences or anywhere on campus.
- The scheduled recess will not be brought forward.

As we continue to grapple with this deadly pandemic and in order to ensure the safety of everyone, the University is appealing to staff and students, to avoid movement on campus between 8pm and 6am. Only Campus Protection Services (CPS), security personnel and other emergency services workers with permits will be allowed to move around campuses between 8pm and 6am. These curfew measures remain in place until further notice.

Furthermore, staff members who can effectively work from home, should continue to do so, subject to the *TUT Policy on Working from Home*. Managers will ensure that all safety protocols are in place for staff who are unable to effectively work from home and who have to report for duty during this time.

A people's university that makes knowledge work

Annexure 2: TUT COVID-19 adjusted level 3 arrangement communiqué

Tshwane University of Technology
We empower people

Communiqué
From the Office of the Vice-Chancellor

27 July 2021

Dear TUT Community

COVID-19 ADJUSTED LEVEL 3 ARRANGEMENTS AND ASSESSMENTS

In line with President Ramaphosa's announcement on the move to Adjusted Level 3 lockdown regulations on 25 July 2021, the University has made a few adjustments regarding practicals and assessments.

Please note the following important adjustments:

- All practicals will resume with immediate effect and postgraduate students will continue with research work under strict COVID-19 protocols.
- Remote multi-modal teaching and learning will still continue. Invigilated summative assessments will resume from 10 August 2021.
- Examination will commence from 16 August, particularly for engineering related and ICT programmes. Faculties will update their students on further details.
- In line with the Adjusted Level 3 lockdown regulations, libraries and i-Centres will be opened from 08:00 to 16:00 Monday to Friday. Library staff will additionally provide online assistance to students. Please contact the Campus Librarians on https://lib.tut.ac.za for online assistance.
- Also, note that social gatherings are still not permitted at residences or anywhere on campus.

Furthermore, staff members who can effectively work from home, should continue to do so, subject to the *TUT Policy on Working from Home*. Managers will ensure that all safety protocols are in place for staff who are unable to effectively work from home and who have to report for duty during this time.

Students and staff must remember the first step is to avoid the three C's – closed spaces; crowded places; and close contact settings. The other important COVID-19 protocols to follow are to wear a mask when in public or among other people at all times and to wash or sanitise your hands regularly.

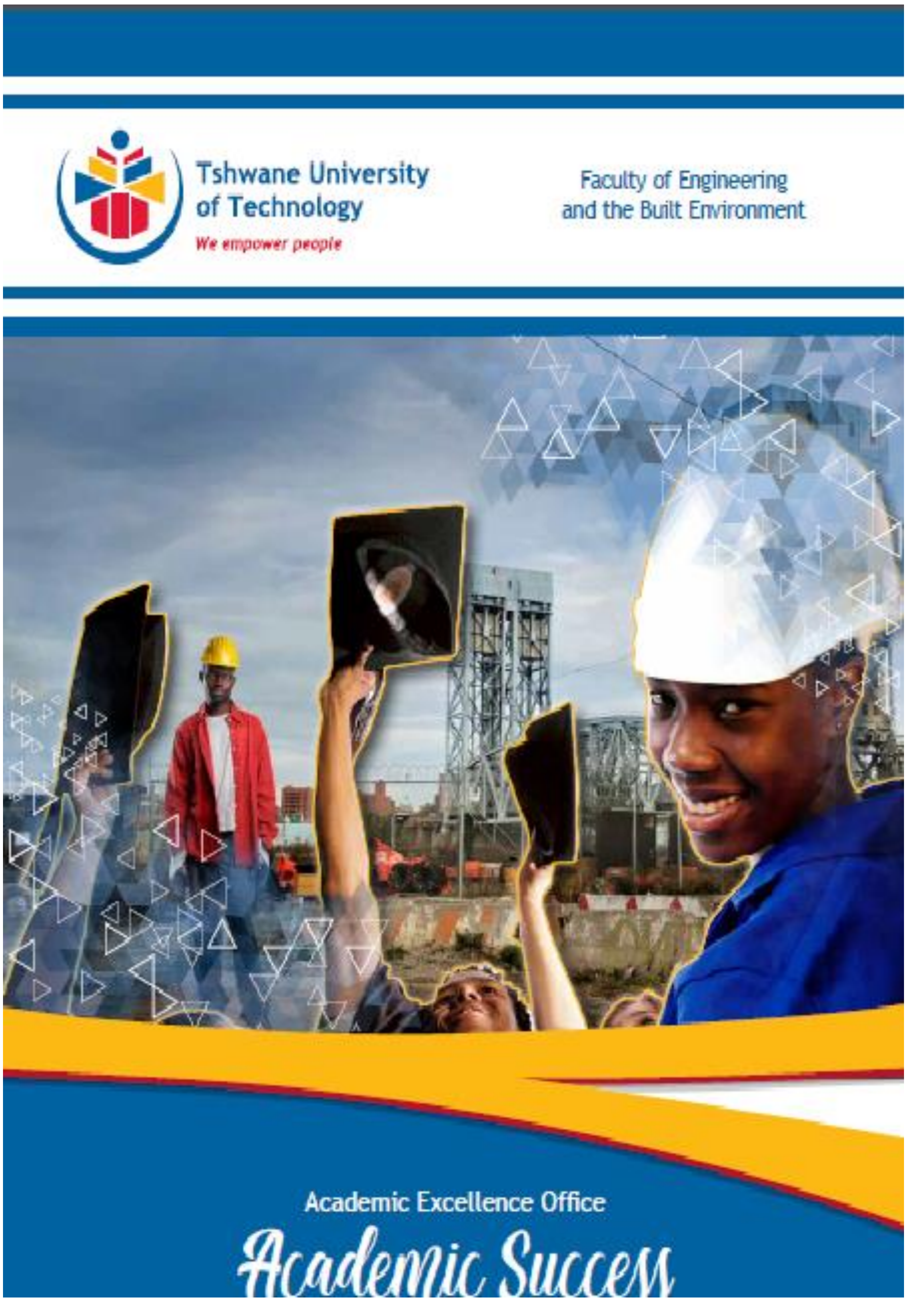
If we all adhere to the protocols and work together we can curb the spread of this deadly disease.

Kind regards

PROF LOURENS VAN STADEN
VICE-CHANCELLOR & PRINCIPAL

A people's university that makes knowledge work

Annexure 3: Faculty of Engineering and the Built Environment Logbook



Academic Excellence Office

Welcome to the Faculty of Engineering and the Built Environment.

The Academic Excellence Office is the centre for Student Support within the Faculty.
The office serves as a partner in optimising students' potential
for academic success and holistic development.
You are most welcome to visit the office to discuss
academic concerns, barrier to success and support needs.

Remember one of the keys to success is consistent attendance of support interventions.

All the best with your studies!

Contact Staff

Academic Excellence: Coordinator	Academic Excellence: Administrator
Tell: 012 382 5823 Office: Building13: 240	Tell: 012 382 5823 Office: Building 13:240

Student personal details

Name(s)		
Surname		
Student number		
Gender		
First generation	YES	NO
Residence (Res, Flat, Family)		
Mobile number		
E-mail		

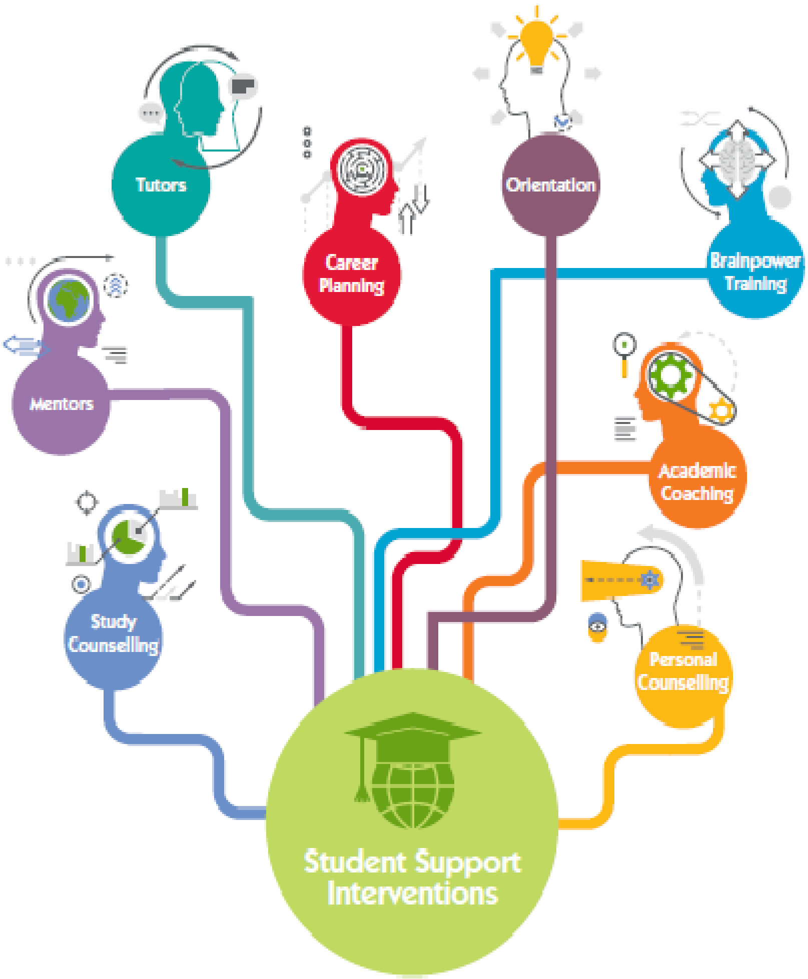
Qualification details

Department	
Course name	
Course code	

I, ____ declare to participate and commit to intervention programmes as part of my academic progress and success. I understand that I am required to request the support staff to sign this ***Success Log Book*** after every support session attendance.

Signature: ______________________________ Date: __________________________

Compulsory Academic Support Interventions



Where to find the Services at Pretoria Campus

Student Development and Support (SDS) Building 6-361/352 Tel: 012 382 5010/4826	Academic Excellence Office Faculty of Engineering and the Built Environment Building 13:240 Tel: 012 382 5823

Registered Subjects

No	Subject code	Test 1	Test 2	Test 3	Test 4	Assignment 1	Assignment 2	Predicate	Final Exam
1.									
No	Subject code	Test 1	Test 2	Test 3	Test 4	Assignment 1	Assignment 2	Predicate	Final Exam
2.									
No	Subject code	Test 1	Test 2	Test 3	Test 4	Assignment 1	Assignment 2	Predicate	Final Exam
3.									
No	Subject code	Test 1	Test 2	Test 3	Test 4	Assignment 1	Assignment 2	Predicate	Final Exam
4.									
No	Subject code	Test 1	Test 2	Test 3	Test 4	Assignment 1	Assignment 2	Predicate	Final Exam
5.									
No	Subject code	Test 1	Test 2	Test 3	Test 4	Assignment 1	Assignment 2	Predicate	Final Exam
6.									
No	Subject code	Test 1	Test 2	Test 3	Test 4	Assignment 1	Assignment 2	Predicate	Final Exam
7.									
No	Subject code	Test 1	Test 2	Test 3	Test 4	Assignment 1	Assignment 2	Predicate	Final Exam
8.									
No	Subject code	Test 1	Test 2	Test 3	Test 4	Assignment 1	Assignment 2	Predicate	Final Exam
9.									
No	Subject code	Test 1	Test 2	Test 3	Test 4	Assignment 1	Assignment 2	Predicate	Final Exam
10.									

Student Support Interventions

Academic Excellence Office

Date	Practitioner	Signature	Details/Comments

Mentorship

Consultations

Date	AEO Practitioner	Signature	Details/Comments

Tutorship

Consultations

Date	AEO Practitioner	Signature	Details/Comments