Gamification and simulation teaching – a system created to improve the depth of knowledge and knowledge retention of engineering students

by

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Declaration

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Abstract

This study presents research done on the possibilities of implementing an improved method of education in some of the modules in the industrial engineering programme at Stellenbosch University. The focus is specifically on selected modules of the final year. A literature study on the history of education was done which describes the evolution of education from its start to its current state, as well as different modern teaching and learning styles. Also found in the literature study is research done on gamification, which is the proposed education method for implementation. A survey was used to extract information from a final year group of students to determine their preferred learning methods and teaching styles, among other learning and teaching considerations. From the observations, the elements of gamification most suitable for implementation were determined and an architectural design was developed on how gamification can be implemented in a selected final year module. Students voluntarily signed up to participate in the gamification model created as a new teaching method in the selected module. Statistical analysis was done on the academic performance of the students before and after they participated in gamification to determine any improvement as a result of the new teaching method. Conclusions and recommendations based on the outcomes of the statistical tests followed with a brief explanation on certain pitfalls to avoid when implementing a gamification strategy.

Opsomming

Hierdie tesis doen verslag oor navorsing wat gedoen is oor die moontlikheid om ‘n verbeterde metode van onderrig in sekere modules van die bedryfsingenieursprogram by Stellenbosch Universiteit te implementeer. Die fokus is spesifiek op geselekteerde modules van die finale jaar. ‘n Literatuurstudie oor die geskiedenis en demografie van onderwys word aangebied. Hierin word die evolusie van onderwys beskryf van waar dit begin het tot wat dit vandag is, asook verskillende onderrig- en leerstyle wat hedendaags voorkom. In die literatuurstudie kom navorsing oor “gamification” ook voor, wat die voorgestelde onderrigmetode vir implementering is. ‘n Opname was uitgestuur aan finale jaar studente om hulle verkose leer- en onderrigstyle vas te stel. Van die terugvoer is die elemente van “gamification” wat die meeste geskik is vir implementering bepaal. ‘n Argitektuurontwerp volg oor hoe “gamification” geïmplementeer sou word binne ‘n gegewe module in die bedryfsingenieurs program. ‘n Groot aantal studente in die finale jaar klas van 2020 het vrywillig deelgeneem aan die “gamification” model wat opgestel is as ‘n metode van onderrig vir die gekose module. ‘n Statistiese analise van die akademiese prestasies van die studente voor en na deelname is gedoen om enige verbetering as gevolg van die model te bepaal. Gevolgtrekkings en aanbevelings op grond van die statistiese resultate volg met ‘n kort verduideliking van moontlike struikelblokke om te vermy rakende ‘n “gamification” strategie in onderrig.

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Nomenclature

Acronyms

CET	Cognitive Evaluation Theory
CLE	Constructive Learning Environments
EA	Electronic Arts
EBT	Evidence Based Teaching
ECSA	Engineering Council of South Africa
EXP	Experience Points
FCM	Flipped Classroom Model
GI	Group Investigation
IEA	International Engineering Alliance
iRAT	Individual Readiness Assurance Test
JG	Jigsaw Grouping
LT	Learning Together
PBA	Problem-Based Learning
RAP	Readiness Assurance Process
RAT	Readiness Assurance Test

SDT	Self-Determination Theory
SGD	Small-group discussions
STAD	Student Teams Achievement Division
STEM	Science, Technology, Engineering, and Mathematics
STH	Six Thinking Hats
TAI	Teams Accelerated Instruction
TBL	Team-Based Learning
TGT	Team-Games-Tournaments
tRAT	Team Readiness Assurance Test

Chapter 1

Project Proposal

1.1 Background

Education first started informally in a hieroglyphic form by learning to read and write languages in about 3500 BC in Egypt (Fischer, 2004). It is estimated that the first formal school was developed in the Egyptian Middle Kingdom under the direction of Kheti, around 2100 BC (Eugen Strouhal, 1992; Janssen and Janssen, 1996).

Education in Ancient Greece was vastly introduced in the 5^{th} century BC. Education was private in most of Ancient Greece except for Sparta. Most parents could send their sons to school from around the age of seven to fourteen, learning gymnastics (including athletics, sport and wrestling), music (including poetry, drama and history) and literacy. At writing school, students first learned the alphabet by song and later by writing the shapes on a waxed wooden tablet. By 350 BC it had become common for scholars to also learn various forms of art, such as drawing, painting and sculpting. It was mainly the students of the richest families that furthered their studies in subjects such as rhetoric, mathematics, geography, natural history, politics and logic. Education in Sparta was approached very differently, where all students were from a young age trained to be warriors with complete obedience, courage and physical perfection and taught little else. For this reason, most of the population was illiterate (Coulson, 1999).

The first schools in Ancient Rome came into existence mid 4^{th} century BC. The schools were focused on basic socialisation and rudimentary education of young Roman children (Chiappetta, 1953). During the Roman Republic and later the Roman Empire, the educational system of Rome was finalised. Roman children were encouraged to attend school as early as possible as they realised that "memory" already exists in small children and is especially retentive at that age. Progression through school happened the same as in modern times, however, it depended more on ability than age. At the time, only the Roman elite would expect to complete formal education and go on to higher levels, as it was considered more of a status symbol than a practical concern (Walcot, 1997).

In China, the early Chinese state depended on literate, educated officials for operation of the empire and in 605 AD for the first time during the Sui dynasty, an examination system was explicitly instituted for a category of local talents (Tom, 1989). Modern education systems in Europe derive their origins from the High Middle Ages, with the institutions being founded on religious principles and the primary purpose of training the clergy (Orme, 2006). It was between the 16^{th} and 18^{th} century that education became significantly widespread (Boyd and King, 1966).

Al-Qarawiyin University in Fez, Morocco is known as the world's first modern university, founded by Al-fihri. It was originally a mosque built in 859 AD (Al-Hassani, 2011). Formal education in the Middle Ages stretches from 500 to 1500 AD. The first institutions generally considered to be universities in medieval times were established in Italy, France and England in the 11^{th} and 12^{th} centuries for the study of arts, law, medicine and theology. It is difficult to define when these institutions became true universities, as they were modified from older Christian cathedral and monastic schools (Gray, 2008). By the 18^{th} century, universities started to publish academic journals. In the 19^{th} and 20^{th} centuries it concentrated on science and served an upper–class clientele. Science, mathematics, theology, philosophy and ancient history comprised the typical curriculum (Carline, 1968). Most of West, Central and parts of Eastern Europe in the late 19^{th} century began to provide elementary education in reading, writing and arithmetic,

partly because politicians believed that education was needed for orderly political behaviour (Kagan et al., 1998).

In the 20^{th} century, two revolutionary education models were created in Italy and Germany (Kagan et al., 1998). The Montessori schools model was developed in Italy, with the focus of viewing children as people naturally eager for knowledge and attempting to develop children physically, socially, emotionally and cognitively. Waldorf education (also known as Steiner education), is the German model and strives to develop pupils' intellectual, artistic and practical skills in an integrated and holistic manner, cultivating the imagination and creativity of the pupil.

Since the mid-20^{th} century, societies around the globe have undergone an accelerating pace of change in economy and technology. Its effects on the workplace, and thus on the demands on the educational system preparing students for the workforce, have been significant (Graham, 2015; Insa et al., 2016).

Education exists in three forms namely: formal, informal and non-formal. Each of these education forms has different characteristics associated with it, such as:

1. Formal:
    - Planned with a particular end in view
    - Limited to a specific period
    - Well-defined and systematic curriculum
    - Given by specially qualified teachers
    - Include activities outside the classroom
    - Observes strict discipline

2. Informal:
    - Incidental and spontaneous
    - Not pre-planned
    - Not imparted by a specialist agency

- No prescribed time-table or curriculum
- Utilised techniques may be ineffective

3. Non-formal:
    - Derived from the expression of 'formal education'
    - Outside the realm of formal education
    - Conscious and deliberate
    - To be organised for a homogenous group
    - Serving the need of the identified group

Along with education, there are a few other terms of importance which will be elaborated on now. These terms are epistemology, pedagogy, andragogy and knowledge and their descriptions can be found in Table 1.1.

Engineering Education (EE) is the term used for the numerous forms used for training students in the profession of engineering. The different engineering education programmes that are accredited by the Engineering Council of South Africa (ECSA) and agreed on by international education institutions are:

- BEng, BSc(Eng) and BIng Programmes
- B.Eng Tech Programmes
- National Diploma Programmes

The international institutions in agreement with ECSA are:

- Washington Accord and recognition of BEng-type Programmes
- Sydney Accord and recognition of BTech Programmes
- Dublin Accord and recognition of National Diploma Programmes

These programmes each represent a certain qualification attained upon completion. A BEng is a four-year programmes which carries the most merit as it meets the initial academic requirements for registration as a Professional Engineer in

Table 1.1: Terms in education

Educational Term	Description
Epistemology	The philosophical study of the nature, origin, and limits of human knowledge. The term is derived from the Greek epistēmē ("knowledge") and logos ("reason"), and accordingly the field is sometimes referred to as the theory of knowledge (Martinich and Stroll, 2020).
Pedagogy	Often confused with curriculum, which is the content being taught, while pedagogy refers to the method used to teach the content - the theory and practice of educating. Pedagogy is the relationship between learning techniques and culture, and is determined based on an educator's beliefs about how learning should, and does, take place (Persaud, 2019).
Andragogy	Malcolm Shepherd Knowles defined andragogy as the art and science of adult learning, thus andragogy refers to any form of adult education. Andragogy in Greek means man-leading in comparison to pedagogy, which in Greek means child-leading (Pappas, 2013).
Knowledge	Knowledge is a highly valued state in which a person is in cognitive contact with reality. It is, therefore, a relation. On one side of the relation is a conscious subject, and on the other side is a portion of reality to which the knower is directly or indirectly related (Greco and Sosa, 2017).

South Africa. The Washington Accord recognising these programmes were signed in 1989.

B.Eng Tech programme is a full three-year degree which supports the expanded access, improved quality and increased diversity of provision, which reinforces a stronger and more co-operative relationship between Higher Education and training institutions and the workplace. These programmes provide for improved articulation towards postgraduate qualifications and exit-level outcomes are aligned with those of ECSA, a signatory of accords associated with the International Engineering Alliance (IEA).

The National Diploma is a three-year programme consisting of two years of academic study and one year of experiential training. According to the Dublin Accords signed in 2002, these programmes are recognised as meeting the initial academic requirements for registration as a Professional Engineering Technician in South Africa.

1.2 Problem Description

In the engineering education sector today, numerous uncertainties arise when comparing the way in which engineering lecturers give education and how their students best consume knowledge. The current system for engineering education is perceived to be flawed since it does not cater to the needs of the different engineering student profiles. It is conjured by the researcher that many students at present, often do not attend class anticipating they will not understand the content, while others attend class and understand the content, but forget what they learned only days later. This can be the result of a conventional method of education currently not accommodating the different learning styles in existence. As yet, there has not been a system developed which can differentiate between the different learning styles and how students acquire knowledge. For this reason, it is needed to design a model for education that lecturers may adopt to improve the exit state of their students' competence (depth of knowledge and knowledge retention) level. There are various different personality profiles amongst people,

which means students consume knowledge differently from their peers; thus it is necessary to equip lecturers in the various ways these profiles best function.

The need for an education system which treats engineering students differently and not in a conventional way is becoming more relevant as more companies are complaining that the newly employed graduates lack the necessary skills to function in the working environment (MIT, 2018). When looking at the method currently used, it seems a very standard and conventional method is used not very different from other education forms. In most industries and departments, education is still received by seeing information on a blackboard, or in recent times, screens. The way knowledge is consumed differs for everyone, and using the conventional method for teaching in the 21^{st} century might not always be the best strategy.

Each industrial revolution has brought in a new age of technological advancement and with the rapid pace at which technology is advancing, it is necessary to adapt our teaching methods with the leaps technology is taking. Students 100 years ago had a very rigid and conformed education system where they mostly only had libraries to attain information from. 50 years ago the internet came into existence and the world of information became somewhat bigger and more accessible. Of course this was a more basic form where research was shared between computers at ARPANET, with the more modern form of the internet we know today began in about 1980. The "chalk-and-talk" method of teaching has been used for more than 70 years, since it was around that time that learning institutions in Western cultures began to look for other teaching methods, while Eastern countries continued with this age old approach (Donnelly, 2014). The students of the 21^{st} century have a far more open world for gathering knowledge from various information platforms like; the internet, libraries, smartphones, personal computers, e-books and more, all which are accessible at any time and at any place. However, all these information platforms could complicate learning and needs to be exploited correctly through a correct form of education.

Lecturing has been the predominant form of instruction since the founding of universities in Western Europe almost a millennium ago. Although theories of learning that emphasise the need for students to construct their own understanding have challenged the theoretical underpinnings of the traditional, instructor-focused, "teaching-by-telling" approach, to date there has been no quantitative analysis of how constructivist *vs.* exposition-centred methods impact student performance in undergraduate courses across science, technology, engineering and mathematics (*STEM*) disciplines. It is necessary to discover whether we should ask or tell in the STEM classroom (Jordt et al., 2014).

1.3 Research Objectives

The objectives of this research project is to investigate a new approach to engineering education. It will be impossible to attend to each student personally. The aim is to group students according to their most dominant attribute in consuming and remembering knowledge and information, based on their learning profiles and to train lecturers to be equipped to educate the students in this form of teaching.

The main objective for this perceived improved approach is to help engineering students to improve their depth of knowledge and knowledge retention of different modules they completed. Instead of having to reference this information from the internet whenever it is needed, it will already be in the memory of the person which can be accessed at any time.

The researcher surmises that the results which prevail from this research are: the students who experience the "improved model" will induce a more proficient understanding of the work covered during the engineering courses and knowledge will be retained for longer periods of time. This could improve the standard of engineers entering the work environment with skills and knowledge of their field accessible to them at all times, since it will be implanted in their memory.

1.4 Methodology

The methodology will follow a sequential, step-wise process. The steps, with their motivation, are as follows:

1. A brief study of the history of education will be done to become familiar with its roots and how it became what it is today.
2. Study the elements of teaching and learning approaches, for the way students learn and lecturers teach, do not always align.
3. Case studies on the demographic of study methods will be looked at, to determine if there is merit in specialising teaching specific to the students' learning styles.
4. The workings of knowledge retention will be studied to establish if it improves using certain teaching methods.
5. Data will be collected via a survey sent to students in their final year (2020) in the industrial engineering programme, to establish how students view their current form of education and their opinion on any shortcomings.
6. Data will be gathered on the students' abilities to understand new work in depth and for how long that information can be retained.
7. An in-depth study will be done on modern teaching methods, specifically gamification and how it can benefit in the modules at the disposal of the study leader.
8. A gamification platform will be chosen and implemented to determine the positive contribution of gamification on engineering modules.
9. After the implementation has been completed, results will be analysed based on the outcomes of the students who participated in the proposed implementation and those that did not.

Validation cannot be done with a single test. It is therefore necessary for several iterations of the study, which will ensure reliable results to draw conclusions from. These future iterations will be done in years to come one more modules than the one used in this study by students who will continue with this study.

1.5 Scope

1.5.1 Inclusions

1. The focus will be on the method used to educate students; thus more focused on lecturers than on students.
2. The scope of this project will focus on the 4^{th} year group of the industrial engineering undergraduate education sector.
3. It is necessary to discover the type of student profiles found under engineering students as well; whether they learn better by being taught, seeing information, hearing it or by figuring it out for themselves and so forth.

1.5.2 Exclusions

1. This project will exclude the broader approach of all education disciplines.
2. It will also not focus on the content of the engineering curriculum.

1.6 Timeline

Included in Appendix A.

Chapter 2

Literature Study

Marcus Tullius Cicero, the Roman Statesman in 63 BC, said: "The authority of those who teach is often an obstacle to those who want to learn."

An unfortunate truth is that a great deal of academics teach students without having much formal knowledge of how students learn. Many of them know how they learnt/learn best, but do not necessarily consider how their students learn or if the way they teach is predicated on enabling learning to happen. Learning is about how we perceive and understand the world, about making meaning. It is not a single thing; it involves mastering abstract principles, understanding proofs, remembering factual information, acquiring methods, techniques and approaches, recognition, reasoning, debating ideas, or developing behaviour appropriate to specific situations; it is about change (Fry et al., 2009).

2.1 Views of Learning

In psychology, there are several schools of thought on how learning takes place and the various categorisations of these, categorised in Table 2.1:

Table 2.1: Schools of thought in learning methods (Fry et al., 2009)

Name	Description
Rationalism	Based on the idea of a biological plan being in existence which unfolds in very determined ways
Associationism	Centres on the idea of forming associations between stimuli and responses
Social-cognitive theories	Learning is achieved by simply observing others

Learning is said to involve a process of individual transformation, whether of the cognitive, affective, interpersonal or psychomotor domain. In essence, people actively construct their own knowledge. The social-cognitive theory is the most known pole of the 21^{st} century with **constructivism** being the most familiar. The focus in this structure of learning, called the *schemata*, is the notion of continuous building and amending structures in the mind which "hold" knowledge. It rests on the idea that as new understandings, experiences, actions and information are assimilated and accommodated, the schemata changes, and unless it does, then learning will not occur (Biggs, 1993).

Often, learning is thought in terms of only adding more knowledge, whereas teachers should be considering how to bring change/transformation to the pre-existing knowledge of their students. Knowledge addition in the sense of accumulating "facts" may sometimes be possible without substantial transformation, but any learning of a higher order involving understanding and creativity, can usually only happen when the underlying schemata are themselves changed to incorporate a new and more refined understanding and linkages. It is likely that such a change will facilitate the retention of facts for the longer term (Mezirow, 1991).

There are various approaches to studying as well as teaching. With a combination of these approaches and techniques, it might just be what is necessary to accomplish the task of aiding undergraduate engineering students with understanding the work they study more in-depth and for longer periods of time. Some of the

most common and most useful approaches and techniques are discussed further in this report. After they have been studied and discussed, an attempt will be made to design a possible "model / approach" to education.

2.1.1 Study Approaches

The approaches to learning identified as the most dominant are: **deep** and **surface**. These approaches determine the extent to which students engage with the subject at hand, which in turn, affected the quality of the outcome. The **deep approach** to studying typically entails an intention to understand the work and seek meaning from it. Students who use this approach tend to link concepts to each other and to existing knowledge, to distinguish between new ideas and existing ones, to critically evaluate the key themes and concepts. This approach is a result from the students' intention to gain maximum meaning from their studies, which can only be achieved from high levels of cognitive processing during studying (Prosser, Michael and Trigwell, 1999). The **surface approach** to studying is centred around the intention of completing a task, to memorise information and make few to no distinction between new and existing knowledge/ideas; treating the task as externally forced. The typical form of the surface approach is **Rote learning**. It creates the impression that maximum learning has taken place and is displayed through superficial levels of cognitive processing. "Facts" are memorised without understanding its meaning (Fry et al., 2009).

Through further research by Biggs (1987) and Ramsden (1988), the concept of these study approaches have become more sophisticated. After they approached the students themselves rather than looking at the research of philosophers and cognitive psychologists for a distinctive perspective, the theory of learning was turned on its head. Ramsden (1988) noted that the learning approaches are not implicit in the make up of students, but rather both personal and situational due to the combination between the student and the task. He came to the conclusion that a learning approach therefore, should not be seen purely as an individual characteristic, but as a response to the teaching environment of students.

A third study approach was identified by Biggs (1987) – the **strategic and achieving approach**, associated with assessment. This is when a high examination grade is desired and the emphasis of the approach is placed specifically on organising learning to achieve it. Students prone to using the deep approach can sometimes inherit certain techniques of the surface approach only to meet specific requirements for an activity, such as a test. Approaches do not need to be a fixed arsenal to work with, in fact, it is better for students to have a collection of approaches to choose from.

Although this information is more focussed on the student side of education, it is important for lecturers to understand the ways in which their students best consume knowledge, to challenge them out of the misconception that higher education only involves the memorising of factual information with no conceptual understanding at all. To encourage them to become an expert in their field by ensuring the designed curricula, their teaching styles and the assessments they create push them toward critical thinking, creativity and innovation.

2.1.2 SOLO taxonomy

Taxonomy is the term used in biology for the scientific naming, defining and classifying groups of biological organisms based on shared characteristics. However, in the educational sense, taxonomy is a classification system used to define and distinguish different levels of human cognition – i.e. learning, thinking and understanding (Bloom, 1956; Ferris and Aziz, 2005). There is a taxonomy called **SOLO**, an acronym for **S**tructure of the **O**bserved **L**earning **O**utcomes. It is based on the principle that as students progress in their studies, the outcomes of the content they learn progresses through increasing stages of complexity (Biggs, John B. (John Burville) and Collis, 1982). Changes occur in the quantity of the work and then the quality of studying. First the detail of the work changes quantitatively, and then change to learning occurs qualitatively. The SOLO taxonomy is classified as a hierarchy where each level is built on the previous as a foundation, the descriptions of each platform are displayed in Table 2.2:

Table 2.2: Hierarchy of the SOLO taxonomy (Biggs, John B. (John Burville) and Collis, 1982)

Name	Description
Pre-structural	Understanding only shown at the individual word level. Students often miss the point of the content or use tautology in lack of understanding and little to no evidence of learning is displayed. It is considered uncommon in the higher education.
Uni-structural	Terminology is the focus of responses. Crucial features are missed as only part of the task is met.
Multi-structural	Learning of facts occur, but with no structure and failing to address key issues.
Relational	Addresses the point and makes sense as a whole, as it contains more than a list of details. As it involves a conceptual restructuring of components, this is the first level at which understanding occurs.
Extended abstract	At this point a breakthrough has occurred, changing the way issues are approached, contributing to a high level of understanding.

2.2 Views of Teaching

2.2.1 Traditional View

Traditional views of teaching regard the teacher as being the actuator of the learning experience. Power and responsibility are considered to be held by the teacher, as they instigate the position of instructor and decision maker. Students are viewed as having "knowledge holes" to be filled with information. Put simply, teachers act as if it is them causing learning to occur.

Traditional methods of teaching still being adhered to:

1. Teacher-centric classrooms
   In these types of setups, the teacher is the centre, where a great deal of control is exercised over the work covered and learning activities that the students obtain (Garrett and Shortall, 2002).

2. Teachers as knowledge dispensers rather than facilitators
   This is a term used for when educators assume a position in which they disseminate knowledge they see useful in a way they see fit. The opposed position of this is when educators facilitate the learning of students in ways that students best learn (Stewart, 2006). There are polls that stand for both positions of this comparison which will be discussed later in this study.

3. Chalk-and-talk method
   Probably the most original form of teaching where teachers write information on a board and students are expected to copy onto notes (Becker and Watts, 2018; Becker et al., 2009).

4. Regimented classroom
   Classrooms become regimented due to strict timelines and schedules, in which case more focus is placed on covering as much information as possible in the given time-frame than to work through a topic in detailed precision. Because of this, it is presumed that a deep understanding of the work covered is more difficult to accomplish (Vaughan, 2013).

5. Lack of collaboration and group learning
   This refers to the opportunity for students to work in a group format to collaborate with each other in order to attain knowledge and skills first hand for themselves. There has been an increase of implementation of this method of education, however, some are of the impression it is not yet enough (Elrod et al., 2003; Oliveira et al., 2011).

6. More emphasis on examinations and results than an understanding of concepts
   This can be linked to the regimented classrooms having a profound effect on the well-being of the students, as they are placed under immense pressure to keep up with the intense work load and to pass with high grades (Vaughan, 2013).

7. Improper alignment between objectives, activities and assessments
   Constructivism, which was mentioned earlier, has many theories related to it with all of them having in common the centrality of creating meaning from one's studies. To do this, emphasis is placed on the alignment between the objectives of a course and the targets of assessments (Biggs, 1996).

Clearing each semester with a good percentage is every student's dream and it is highly dependent on how well a subject is understood. If there is no in-depth understanding of the subject, it is impossible to succeed in a degree. Each student finds it easier to learn the material in a specific type of learning. Some might regard lecturing as the proper way of learning, while others would not consider it as such.

Traditional Teaching methods: The traditional, but at the same time the most important and effective, tool of teaching is lectures. Many students adopt this view of learning. Professors condense a vast expansion of study material and deliver it in a reduced and organised way, taking the burden off the students. Some pros and cons relating to lectures are displayed in Table 2.3:

Table 2.3: Advantages and disadvantages related to traditional lectures (Shivaramaiah, 2018)

Advantages	Disadvantages
• Used to condense a large amount of information and presented to a large audience • Can be used to meet the specific needs of the audience • Can appeal to the students who learn best by listening	• Suitable only for effective communicators • Reading information from slides is not effective in lectures • Students become passive and often cannot give feedback • Teachers assume all students learn at an equal pace with the same level of understanding

2.2.2 Modern View

The early 21^{st} century has shown major advances in various areas, including technology, economy and culture which have radically reshaped the foundation of traditional educational models, as educators attempt to address the issue of meeting the needs of students in personalised, meaningful and timely ways.

Certainly, it is irrational to suggest that traditional systems of education still apply to students today. Fifty to 100 years ago, class management was simpler, students were probably, due to the small workload and content size at the time, at the same level of intellect being able to follow the work at the same pace, making similar progress. In modern times there are many more factors to take into account, such as: the incorporation of technology, various cultures of students, the skill levels of the students as well as the teachers, and the difficulty of the course content, to name a few. Some frameworks of modern teaching, comprising of various principles of teaching methods considered to be newer and more

effective, are highlighted next. These are incorporated into the frameworks where a combination of these can create a suitable environment for optimal learning.

Modern methods in use in teaching:

1. Technology-driven classroom
   This includes the use of computer-based technology to include visual presentations, simulation, accessing course material, using the internet and interactivity. They also provide new learning strategies in the event of students who struggle with traditional teaching methods (Debevec et al., 2006).

2. Continuous comprehensive evaluation
   Assessments with the predominant nature of being summative, cannot by itself yield legitimate measures of a student's growth. At best, it only certifies an achievement level at a certain point in time. Not only is it an unfair assessment of a student, but exclusively relying on it to decide the development of students is unscientific, which will be explained later. It is thus needed to evaluate students in a more continuous and comprehensive manner (Singhal, 2012). This would include setting a scheduled time at which the progress and development of the students will be measured to track their growth and do analysis on the effectiveness of the teaching methods.

3. Cross-curricular connections
   The integration of content and skills across courses. Different modules are linked through concepts shared and built on, which creates fundamental building blocks for education, as these concepts help understand different modules, and understanding the concept in one module can aid performance in another module using the same concepts (Hall and Hudson, 2006).

4. Inquiry-based learning
   A learning approach placing emphasis on the student's role in the process of learning. In this approach students are encouraged to actively engage in

the learning process by reading the material, asking questions and sharing ideas, instead of being told what to learn by the teacher. This is especially popular among education fields where science plays a big role (Gormally et al., 2009).

5. Emphasis on understanding of concepts
   The reason why some students struggle with particular concepts in a curriculum while others grasp it within no time at all has been explored in certain studies. Meyer and Land (2006) proposes a "threshold concept" method arguing that in certain curriculums there are "conceptual gateways" which create a pathway to previously unreachable, or troublesome ways to to think about something. A rise of new ways to interpret, understand, or view a topic may occur.

6. Collaborative learning
   Its broadest, but incomplete description is: Instances where two or more people learn or aim to learn a subject together (Dillenbourg, 2007). This is not a sufficient description due to the different ways each element can be interpreted. "Two or more" can be people from as many as two to hundreds, "learn a subject" can mean to "follow a course", "study material" or "perform learning activities" and "together" can be interpreted as "face-to-face", "computer mediated", or "joint effort"/"divided labour". This topic will be expanded on later in this thesis document.

7. Differential learning
   The learning in different environments can yield different learning experiences with various achievement goals (Rosen and Salomon, 2007). There are two distinct environments which will be explored later in the paper, namely "Technology-intensive, constructivist-oriented mathematics learning environments" and "traditional".

8. Activity-based learning used to design constructivist learning environments
   The presumptions of constructive learning are vastly different from traditional instruction, hence traditional approaches of analysing needs and tasks are unfitting for the design of constructivist learning environments (CLE). It is argued by Johassen and Rohrer-Murphy (1999) that activity theory issues an acceptable platform for analysing needs, tasks and outcomes for designing CLE's.

9. Interdisciplinary learning
   Characterised by integrating knowledge from multiple disciplines across a central theme. Learners are able to develop more advanced epistemological beliefs, improve their critical thinking abilities as well as their metacognitive skills and increase their understanding of relations among perspectives derived from differential disciplines by experiencing repeated exposure to interdisciplinary thought (Ivanitskaya et al., 2002).

10. Flipped classroom
    A pedagogical approach to teaching where the traditional environment and its activities are reformed. Where traditional methods call for lecturers to stand in front of the class and give the information, "flipped classrooms" call for course material to be given online prior to the class, with in-class activities focussing more on group work and collaboration (Awidi and Paynter, 2019).

While there are numerous positives to adopting modern methods of teaching, it is not logical to simply go ahead and adjust all elements to modern methods. There are more things to consider than just the fact that individually, most modern methods outclass traditional methods, though it does not mean traditional methods in and of itself are worthless. Some advantages and disadvantages of modern teaching methods are highlighted in Table 2.4.

Table 2.4: Advantages and disadvantages related to modern methods (Shivaramaiah, 2018)

Advantages	Disadvantages
• Very effective learning tools for participating active learners • Lead to long-term knowledge retention • Very effective for students who do not excel at working alone • Develop teamwork and interpersonal communication skills	• Expect students to come prepared on the subject (unpreparedness is a big hindrance) • Not effective for large groups • May create a learning imbalance among students due to the participation of the academically strong

A more in-depth look at the frameworks and their contents will be done further in this thesis document.

2.2.2.1 Problem-Based Learning (PBL)

Especially in the higher education environment, PBL represents an intricate and extensive change in the practice of education. Four modern insights of learning compose the central argument for PBL, namely **constructive**, **self-directed**, **collaborative** and **contextual** (Dolmans et al., 2005). It is a form of learning where students define their own learning objectives using "prompts" from the various case scenarios. Students do individual self-study beforehand to only refine their knowledge in group discussions (Wood, 2012). These will be explained now.

1. **Learning should be constructive**

   Since learning is considered to be an active process in which students are constantly busy building or rebuilding their knowledge structures, the constructive part of learning is emphasised. It was mentioned earlier in this chapter that learning is about creating meaning from the knowledge one acquires, linking it to previously acquired knowledge, creating fundamental platforms of information to stand on. The main objective to achieve with constructive learning is to teach with the intention to stimulate cognitive thinking, rather than delivering knowledge in order to cultivate competence (Dolmans et al., 2005; Tiwari et al., 2006). There are various activities that can be done so as to stimulate cognitive thinking and advance competence, and one of those is *elaboration*. Elaboration can pertain to many forms, such as discussions, taking notes, questions and answers. It plays a vital part in bringing forth the knowledge one has already acquired. This can help direct the person to more linkages between concepts and aid the activation of information, leading to richer structures of knowledge (Harris and Alexander, 1998; Tiwari et al., 2006). The tree diagram illustrating the different aspects and elements of constructivism is illustrated in Figure 2.1.

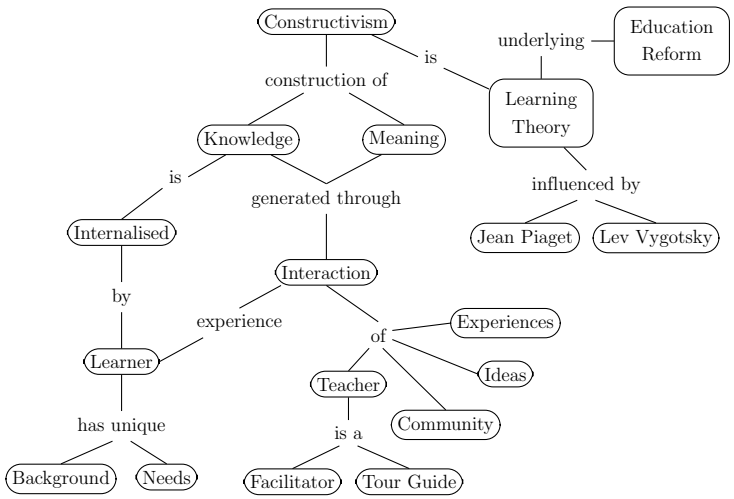


Figure 2.1: Tree diagram of constructivism (CMAP, 2019)

2. **Learning should be self-directed**

   Learning that is self-directed proves to be a crucial part in the development of a student's cognitive thinking, as they are themselves then responsible for the planning, monitoring and evaluation of the process. During the planning, the student may be directed towards examining each of the possible approaches regarding a task, creating direct goals, objectives and strategies for achieving these and identifying possible obstacles. When monitoring, the student can look back as well as ahead to be aware of what they have done and what they should do next. Evaluation is always an essential part of any task so as to assess both the process and the product of the learning that took place. Self-directed learning would be nothing without *reflection* (Dolmans et al., 2005; Ertmer and Newby, 1996; Thomas, 2009; Tiwari et al., 2006; Wood, 2012). It is from reflection that one can realise if something was worthwhile and what can be done to improve the outcome of the experience. Being a self-directed learner is a way in which someone becomes a lifelong learner, as these principles and practices of acquiring knowledge in the best possible way that suits the person becomes hardwired in them. Illustrated in Figure 2.2 is the "Kolb Learning Cycle" which is adopted when learning is successful.

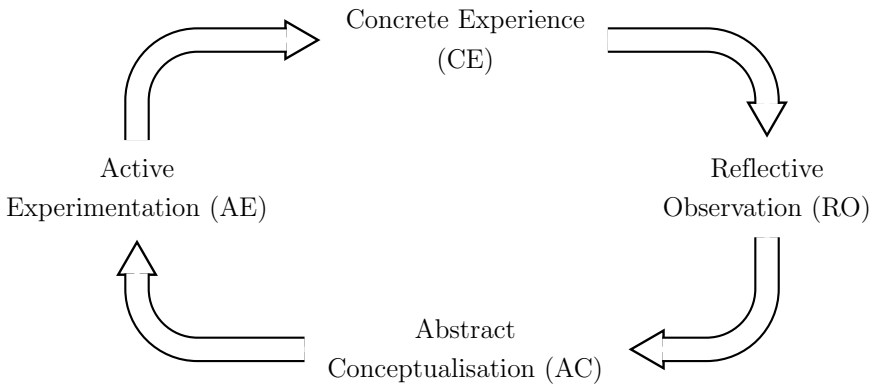


Figure 2.2: Kolb Learning Cycle, adapted from Kolb (2014)

This figure illustrates that students are initially exposed to unknown expe-

riences (CE). After exposure they need to create the time and opportunity to reflect on the activities experienced from various viewpoints (RO). Then the students should be able to integrate and create new ideas from the ones they had just been exposed to (AC). The second and third elements in this cycle can be strongly affected by **feedback** from others. The fourth step in this cycle involves using the acquired and integrated knowledge to further one's understanding by experimenting with the knowledge in different situations, linking it with previous information gathered will result in improved problem solving skills (AE).

3. **Learning should be collaborative**
   Collaboration occurs when two or more people engage with one another in certain situations. Collaboration includes more of working in unison to gain a shared understanding of the work rather than splitting the duties. The following are prerequisites for collaborative learning to take place: everyone involved shares a common goal, responsibilities are equally distributed, participants are dependant on each other and in need of agreement through free interaction. Students who experience interactions with a positive influence usually enhance their learning with the following factors: elaboration, enunciation, co-creation, support, reproof and being cognitively and socially invested (Dolmans et al., 2005; Thomas, 2009; van der Linden et al., 2000).

   Peer interaction is considered as an integral element in learning where cognitive gains are achieved and knowledge is produced. Learning environments produce the possibility for participants to acquire knowledge and create prowess, via research and experiments, offering a more diverse field of learning (Dolmans et al., 2005; Ertmer and Newby, 1996; Oliveira et al., 2011). Collaborative learning is not considered to be merely one mechanism, to regard "learning from collaboration", one must also regard it "individually". When studying individually, learning occurs when some tasks are carried out, triggering certain learning methods, not simply because the person is doing so individually. Similarly, when peers study together, learning occurs from some tasks triggering learning mechanisms and not simply due to their

joint studying. The difference collaborative learning brings to the table is the interaction amongst peers, which creates additional tasks, triggering further cognitive stimuli and aiding the process of learning new information (Dillenbourg, 2007; Wood, 2012).

4. **Learning should be contextual**
   Learning without context is useless. The use of knowledge is dependent on the context in which it was acquired and transferring knowledge across situations is difficult to accomplish. It is however possible to ease the process of knowledge transfer when viewing problem environments from various perspectives, helping students to cope with flexibility when approaching new sets of events to prepare them for future learning (Billett, 1996; Dolmans et al., 2005; Ertmer and Newby, 1996). Solving problems is a major factor in the principle of contextual learning. With the element of problems incorporated in studying, people are able to view different situations in various ways, creating the opportunity to expand on one's ingenuity and problem solving skills, something otherwise difficult to improve.

   Issues may arise when problems are too well structured (too close-ended and simple), resulting in a study session that does not challenge the students well enough to improve their cognitive thinking abilities. Creating effective problems is often difficult to accomplish and construct, where problems are often constructed in such a way that they are not realistic. Therefore, the true goal of this discipline in learning should be to construct problems cognitively challenging to the student and relevant to real world situations, so the student can apply the knowledge gained elsewhere, besides in the classroom (Baxter et al., 2000; Dammers et al., 2001; Dolmans et al., 2005).

2.2.2.2 Team-Based Learning (TBL)

In the context of post-secondary education, no other approach relies on group interaction quite as much as team-based learning. Three specific elements define

this, such as: TBL uses group work as a central to create exposure to course content and to increase the ability to apply it, most of a module's class time is spent on group work, where TBL typically involves numerous group projects intended to improve the development of self-managed learning groups (Michaelsen and Sweet, 2007). The four practical elements of TBL are: **strategically formed permanent teams**, **readiness assurance**, **team development and critical thinking activities** and **peer evaluation**. Paired with TBL is a teaching approach called Evidence Based Teaching (EBT), focussing on collaborative learning, feedback and whole-class interactive teaching, among others (Michaelsen and Sweet, 2011).

Instead of cramming as much theory into a course as possible, TBL focusses on providing students with the tools necessary to apply the knowledge gained in courses to solve complex problems; in essence to provide them with conceptual as well as procedural knowledge and skills. A certain amount of classroom time is spent on learning course content and mastering it to a degree, however, the surplus time goes into creating adequate groups with the sole purpose of mastering course content to solve future problems they may face. Unique and indefinite teams are created strategically in a TBL environment, with the contents covered during the course split up into major sections (Michaelsen and Sweet, 2007, 2011).

Figure 2.3 displays an outline of the time spent on the different sections TBL is comprised of, modified from Michaelsen and Sweet (2011).

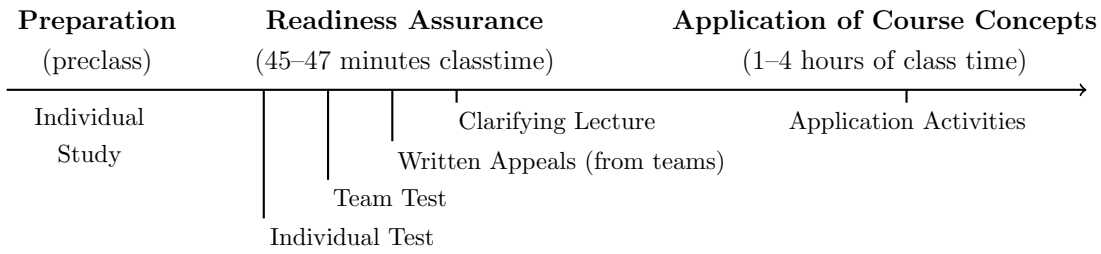


Figure 2.3: TBL Learning Sequence (Michaelsen and Sweet, 2011)

TBL makes profound use of a system called the Readiness Assurance Process

(RAP), which requires students to self-study the assigned course material before attending class. RAP includes a short trial test (individual readiness assurance test (iRAT)) focussing on key ideas from the content studied by the class as individuals, followed by the exact test in group format (team readiness assurance test (tRAT)), which leads to an agreement among the team members. Immediate feedback is given on the group tests, where students have an opportunity to present an argument with evidence for a re-examination to the questions they believe were marked incorrectly. Finally, the teacher presents a lecture on any topics the test made clear the students may have a misunderstanding of, as the final part of RAP. Directly following the RAP, the remaining as well as the majority of the class time is spent working in group format on tasks and assignments to exercise the use of course material (Michaelsen and Sweet, 2007).

In order for students to be able to apply the concepts they learn throughout a course instead of only being familiar with them, major changes need to occur to the parts that both the student as well as the teacher play in the process of learning. Shifting of roles include the teacher becoming a designer and manager of the overall process instead of simply dispensing information, where students become responsible for exposing themselves to content initially to prepare for lectures instead of only passively accepting information given. TBL is able to exploit this by being comprised of four essential elements, all focussed excessively on collaboration: properly formed and managed **groups**, students are themselves **accountable** for work quality (in both individual and group format), frequent **feedback** given to the students on their performance, **assignments** that promote both learning and team development (Michaelsen and Sweet, 2007; Michaelsen et al., 2008).

The design of TBL is meant to create the opportunity for students to easily experience the continuous repetition of information, which has been proven to be effective in mastering knowledge retention. In this format of education, students are shifted from a position of receiving information, to actively aiding one another in learning how to apply the knowledge acquired. From experience, TBL has proved to provide equal to better coverage of content, while utilising most of

class time with students actively engaged and furthering their depth of knowledge in how certain problems relate to real world situations (Michaelsen and Sweet, 2007, 2011).

A breakdown of the comprised elements concerning TBL follows:

1. **Properly formed and managed groups**

   (a) Distributing Resources of Members
   For groups to be effectively functional, they need to be as diverse as possible. Thus it is necessary for groups to consist of members each having the potential to vastly contribute to the dynamic of the team. Essentially, a mix of student characteristics need to be included in the team with regards to the course content, including demographic characteristics such as gender and ethnicity. The responsibility of creating the teams should however rest on the instructor, since the students neither have the know-how nor the expertise to create adequate teams. Due to the tasks in TBL being of an intellectual challenging nature it is vital for the teams to be of adequate size and diversity. Too small teams may cause insufficient resources, thus team sizes of between five and seven members strong are suggested (Michaelsen and Sweet, 2007, 2011; Michaelsen et al., 2008).

   (b) Time – Team Development Key Factor
   It is possible for a team to learn a great deal of skills and expertise when they are cycled regularly. However, it is much more effective for students to work together over a fair amount of time by building cohesion amongst each other, which is why it is recommended that the teams are permanent. Team development takes time, initially the members of newly formed groups are inclined to depend more on the assertive members until they have learned through a series of interactions to trust each other and tap into the vast resources at their disposal. This growth in team chemistry can only occur under the

right conditions in which they have the opportunity to function productively. Where the diversity can at first cause a setback, in the long run it can be the greatest asset of the team (Michaelsen and Sweet, 2007, 2011; Michaelsen et al., 2008).

(c) Avoid coalitions and group cohesiveness barriers
For teams to be effective in functionality, it is important to eliminate any possibility of coalitions among the groups in the form of subgroups. This usually occurs when students are allowed to form their own groups, leaving them to team up with people whom they already have a specific relationship with (friends, girl/boyfriend, residence mates) or people with whom they share background factors (ethnicity, native language, cultural beliefs). These subgroups can be disruptive and cause insider/outsider tension among the peers. This is why it is best for teachers to form the groups, mixing the students according to their diversity in character and skill traits, forcing them to build teamwork from scratch (Michaelsen and Sweet, 2007, 2011; Michaelsen et al., 2008).

2. **Accountability of the students**

(a) Individual pre-class preparation accountability
Since the responsibility of learning the course material falls in the hands of the students by studying it themselves before attending class, clear limitations are placed on the capabilities and development of a team when there is a lack of self preparation. When students neglect this part of the learning objective, it places a large handicap on the team as the learning experience depends on the preparedness of each member, hence the rest of the task will be a struggle. Thus, the importance of the students' investment need to be made clear to them, otherwise a lack of cohesion among the members will disrupt the progress

they could make. The investment of students can be ensured by following the RAP (Michaelsen and Sweet, 2007; Michaelsen et al., 2008).

(b) Team contribution responsibility
Time and effort should be contributed by each member if they wish for the team to be successful in cooperating with each other. The best way to evaluate the involvement of each member in the completion of a specific task is to have them complete peer evaluations. The traits in need of evaluation by the members regarding the contribution of their peers are: preparations as individuals, frequent attendance of class and team meetings, input on group discussions, regarding and affirming the contribution of their peers (Michaelsen and Sweet, 2007; Michaelsen et al., 2008).

(c) High-Quality Team Performance Responsibility
Teams need to be assessed effectively and in a timely manner to determine the quality of the work they produce. There are two key factors that can ensure this: a task requiring an end product which can be produced and evaluated across the board and compared to competing products and a process which has the students face frequent recurring feedback (which will be discussed below) (Michaelsen and Sweet, 2007; Michaelsen et al., 2008).

3. **Frequent and Timely Feedback**

(a) Feedback from readiness assurance tests (RAT's)
The RAT's are the principle factors of feedback needed for team development and learning improvement. Students will be able to perform more complex tasks due to the fact that the RAT's are given at the start of each key educative unit, ensuring students acquire the needed conceptual skills and knowledge to do so. The credibility of RAT can be attributed to two important traits they focus on: firstly, the scores of the various teams are presented to everyone, encouraging

team members to out perform the other teams to maintain a positive image, secondly, the feedback occurs immediately after a written test or project evaluation, constantly motivating an improvement in team communication (Michaelsen and Sweet, 2007; Michaelsen et al., 2008).

(b) Application-Focused Team Assignments timely feedback
The RAT's are specifically designed to help students understand the fundamentals of basic principles, whereas application focused team assignments are meant to improve higher-level thinking. Thus the design and grading of these assignments are much more complicated. Providing immediate feedback on these assignments are just as essential for studying and team development (Hattie and Timperley, 2007; Michaelsen et al., 2008).

4. **Promotion of Team Development and Learning through Team Assignments**
This is the most critical step in TBL. The downfall of group learning can greatly be credited to the designing of unsuitable projects. The essence of group assignments is to do them as groups, however, the problem with team assignments is that the work is actually completed by the team as individuals. This inhibits rather than advances learning, since the time for discussion in these kinds of tasks are limited. For the TBL to be effective, the most foundational part is to create tasks requiring the teams to truly work as teams with high interaction among the members. This can be accomplished by setting the tasks up in such a way: (a) that demands students to apply course material in complex decision making and (b) empower students to report decisions simpler (Michaelsen et al., 2008).

2.2.2.3 Small-Group Discussion (SGD)

This has been identified as a rather effective form of education in the STEM environment, as these professions are considered to be highly group extensive, thus

preparing students to operate better in such conditions. Apart from promoting an understanding of how science and engineering works, it is also suggested an overemphasis on high grades misrepresent what should be the main objective of these fields: to find out new things. Competition, while good in many cases, can be destructive in the fields of engineering and science when students become despondent and end up disliking it, losing confidence in their ability to do science and engineering (Springer et al., 1999).

Small group discussion is somewhat similar to TBL in that it requires the co-operation and collaboration of students who have been divided into groups. A more common description of small group discussions is: a structured systematic instructional strategy in which small groups work together toward a common goal (Springer et al., 1999). It involves ensuring students in small groups learn the skills of interpersonal and group collaboration, promoting an attitude of sharing and respect toward each other, along with the willingness to challenge perspectives and resolve conflict. It also teaches the importance of making group decisions collectively (Battistich et al., 1993; Galton and Williamson, 1992).

In teaching environments such as this, interaction is a key element to consider when regarding its success or failure (Bennett and Dunne, 1991; Lou et al., 2001). However, others are of the opinion that the frequency of task-related interactions is of more value for productivity as it aids in working toward solving a problem, which in turn increases the learning outcomes for students who participate in group-learning (Cohen, 1994; Lou et al., 2001). In the environment of cooperating with one another, students acquire the ability to improve their understanding of one another and to contribute to the development of new understanding and knowledge (Brown and Campione, 1994; Rogoff, 1994).

Small-group teaching, as opposed to other pedagogical approaches, creates the space for higher-cognitive thinking skills to develop through the promotion of socialisation and learning by helping and teaching others (Johnson and Johnson, 1991; Slavin Robert, 1995). Various tests were conducted on numerous students at multiple schools, trying to find a correlation between the achievement levels

of certain students in different types of small-groups. The tests revealed that a heterogeneous group setting is more suited for low-achieving students, while average achievers perform well in homogeneous group environments. Students with high-achievement records showed no specific preference, performing well in both environments. Many of the schools subject to these tests have referred in their policy to the practices of cooperative learning to promote an effective learning and teaching regiment (Gillies, 2004; Lou et al., 2001; Springer et al., 1999).

Cooperative learning is comprised of 5 ground level elements: **positive interdependence**, **promotive interaction**, **individual accountability**, **teaching of interpersonal and social skills** and **quality of group processing** (Tran, 2014). Positive interdependence drives individual accountability by establishing responsibility among the peers. This ensures that everyone does their part instead of one or two students doing all the work. Promotive interaction is when students accompany each other to collectively complete the goal of the group (Johnson and Johnson, 2008). Interpersonal and social skills are required for students to listen to one another, question cooperatively and negotiate respectfully. Group processing improves the effectiveness of the group through establishment of helpful and harmful activities, then eliminating wasteful actions and continuing with positive ones (Yamarik, 2007). There are various cooperative learning techniques in circulation, however some of them will be addressed further in section 2.4 on retention, namely Learning Together (LT), Jigsaw Grouping (JG), Teams-Games-Tournaments (TGT), Group Investigation (GI), Student Teams Achievement Division (STAD) and Teams Accelerated Instruction (TAI) (Tran, 2014).

Two different small-group setups exist; structured and unstructured, with the difference being that the students in the structured groups tend to understand what they are expected to do and how they are expected to work together (Gillies, 2004; Lou et al., 2001; Springer et al., 1999). Various statistical tests were done to determine the results from learning in these group dynamics and it was found that students who worked in structured groups obtained an improvement on their learning outcomes than their peers in the unstructured setup. Other positives the

students take from this experience is the opportunity to develop certain skills, such as listening to others without interrupting, asking insightful questions, how to share ideas and opinions, helping others and form new friendships.

Certain drawbacks of course do occur when this technique of teaching is "wrongly" implemented. By wrongly, it is meant that the unstructured small-groups tend to have a destructive team dynamic with unwanted qualities, such as: many interruptions (both positive and negative), unsolicited explanations and non-specific verbalisation. Due to this, when implementing this technique it is in the best interest to do it in a structured manner.

2.2.2.4 Flipped Classroom Model (FCM)

This is a method of lecturing where the activities normally performed at home and at class, are reversed. Students are prompted to learn the course material ahead of the class time where they will do activities on the work and ask questions to the lecturer. The lecturer serves to help students instead of merely teaching them, while students are given more responsibility for their own knowledge attaining (Akçayır and Akçayır, 2018).

Since the beginning of the "Millennial era" (1980 – 2000), students become all the more technological inclined than ever before, especially with the advancement of the digital age. Educators complain about the attention span of their students and tend to blame technology for this, however, Millennial expert Prensky (2005) is of a different opinion. He believes that because the generations from the Millennials onward grew up with technology, they think and reason differently. It is thus not their attention span that has diminished compared to earlier generations, but their needs and tolerance have shifted. It is due to this reason the need for direct instruction is becoming irrelevant and the necessity of a captivating environment for the digitally inclined students become more relevant. In other words, teaching must change from a teacher-centred paradigm to a learner-centred one (Akçayır and Akçayır, 2018; Awidi and Paynter, 2019; Hao, 2016; Roehl et al., 2013). By

doing this, the ultimate goal of education which is to engender understanding can be achieved. Mindless memorisation of information and facts known as "surface learning" is replaced with a "deep learning", where understanding is developed through "active and constructive processes" (Ritchhart et al., 2013).

The flipped learning approach is another method of modern teaching which poses as a viable option for the education of digitally inclined students, because unlike traditional instruction where students are considered empty vessels in need of spoon-fed information, the attention is shifted to them where they are given more responsibility for their own instruction. This approach is a new and favoured method to teaching wherein, much like TBL and SGD, the events usually occurring in the classroom are changed to be home based activities and homework becomes what is done in class-time. The time spent in class is used to partake in student-centred learning theories such as, **active, collaborative and peer-assisted learning** (Betihavas et al., 2016).

Active learning is defined as any instructional activity where the student is engaged in the learning process. They are accountable for their own learning and have the opportunity to engage in and develop higher order thinking. These activities transform students from passive listeners to active thinkers (Davies et al., 2013). **Collaborative learning** is when collaboration among students/peers lead to profound learning and shared understanding of the model content. It also provides the space to develop social skills and the expertise necessary to function in a group dynamic (Bergmann and Sams, 2012). **Peer-assisted learning** entails the attainment of skills and knowledge via back and forth help and support with equivalent companions. Technology is something that provides a grand platform for the partaking in peer related activities both in and out of the class environment (Nederveld and Berge, 2015).

Though many advantages, such as an increased motivation for learning and course grades, have been recorded through previous research conducted, it is unclear whether they are common for all flipped classroom models or simply specific to

those applications. With that, many challenges have also been noted when using the FCM, it is thus necessary to conduct a more systematic analysis of the model to point out areas of uncertainty. Research was done on 71 articles and the effects they had upon implementation. Table 2.5 and 2.6 shows some of the most common advantages and challenges associated with the FCM respectively, along with the percentage of research articles sharing the opinion:

The frequency (number of times each sub-category is mentioned in the 71 articles) displayed in the tables clearly shows that various positive and negative outcomes can come from the implementation of a FCM. The positive outcomes are rather favourable and wanted ones, such as: improved retention and understanding. Albeit a small percentage of studies supporting these positive results from FCM, there may be a way to improve the length of the effects. It is important to note however that many of these outcomes have been found to be only temporary. Additionally, the flipped model broadened the achievement gap as it was specific to students with certain characteristics, such as high achieving students (Streten et al., 2019). It begs the question as to what can be done to make the effects permanent, or at least long lasting and affecting of all types of students.

2.3 Student Profiles

While the study of various different teaching methods is important, it would mean very little without data on the numerous student profiles in existence and their specific preference of education. As stated previously, the way students learn differ as much as their appearance. Therefore, this section is dedicated to studying the different student profiles, their attributes and characteristics. In essence, the way students best consume knowledge will be investigated.

There are numerous ways in which students consume information best. Studies have shown there are seven major ways in which someone understands new information the easiest. These are visual (spatial), aural (auditory/musical), verbal (linguistic), physical (kinesthetic), logical (mathematical), social (interpersonal)

Table 2.5: Advantage of FCM (Akçayır and Akçayır, 2018)

Inductive categories	Sub-categories	Frequency
Learner outcomes	Improvement of learning performance	52.11% (37)
	Increased satisfaction	18.31% (13)
	Increased engagement	14.08% (10)
	Increased knowledge	9.86% (7)
	Better critical thinking skills	8.45% (6)
	Improved retention	1.41% (1)
Pedagogical contributions	flexible learning	22.54% (16)
	Enables individualized learning	11.27% (8)
	Enhances enjoyment	11.27% (8)
	Better preparation for class	8.45% (6)
	Fosters autonomy	1.41% (1)
Time efficiency	More efficient class time	12.68% (9)
	More practice time	7.04% (5)
Disposition	Positive student feedback	18.31% (13)
	Positive student perceptions	14.08% (10)
	Positive attitudes	8.45% (6)
	Positive teacher perceptions	2.82% (2)
Interaction	Student-teacher	9.86% (7)
	General	5.63% (4)
	Student-student	4.23% (3)
Other	Less anxiety	4.23% (3)
	Cost effective	2.28% (2)
	Quick student adaption	1.41% (1)

and solitary (intrapersonal) (Hoerner, 2013). Each of these learning styles have their own strengths and weaknesses. For students to truly excel at their studies it is necessary for them to understand how they understand. It is also necessary for educators to know about these different styles. Once they do, they can adjust their lectures in such a way to benefit the students as much as possible. The

Table 2.6: Challenges of FCM (Akçayır and Akçayır, 2018)

Inductive categories	Sub-categories	Frequency
Pedagogical	Limited student preparation before class	12.68% (9)
	Students in need of guidelines	9.86% (7)
	No help outside of class	9.86% (7)
	Educators cannot know of student diligence	2.82% (2)
	Implementation issues	1.41% (1)
Students' perspective	Time consuming	11.27% (8)
	Increased workload	9.86% (7)
	Indifference to method	8.45% (6)
	Adoption problems	5.63% (4)
	Hostility toward method	5.63% (4)
Teachers' perspective	Time consuming preparation	14.08% (10)
	Increased workload	7.04% (5)
Technical and technological	Video quality	12.68% (9)
	Technology accessibility	8.45% (6)
	Student competence with technology	7.04% (5)
Other	Parental bias	1.41% (1)
	Lack of support	1.41% (1)

outcome for the students would be a reduction in energy that they would have to exert while studying. The lecture being of proper quality will provide a good foundation to build from when students study by themselves. In Table 2.7 the explanations of each style can be seen.

Table 2.7: Descriptions of learning styles

Learning Style	Description
1. Visual	People who understand work better when it is in the form of a diagram. Knowledge and concept maps are good tools for such learners.

Table 2.7: Descriptions of learning styles

Learning Style	Description
2. Aural	People who dislike reading, but enjoy hearing someone else say something aloud. Hearing the information is key for such students and group discussions can be of great aid.
3. Verbal	Verbal learners are people who express themselves easier through writing and speaking. Mnemonics, scripting and role playing are some great techniques to helps those learners.
4. Physical	Hands-on activities rather than lectures or demonstrations appeal to these learners. They are a small percentage of the population, but they learn better through practical experience.
5. Logical	People who are good with numbers and using logic to understand. They easily recognize patterns and often tend to group information to further their understanding.
6. Social	When communicating and socialising with others come easy, someone is a social learner. Studying in group formats and learning from others are their speciality and how they excel.
7. Solitary	People who are more comfortable studying in private and introspective. The concentration of these students are at their peak when they can focus on their own thoughts without the distractions of others around them.

These profiles can be categorised in four different dimensions. These four dimensions are **sensing/intuitive**, **visual/verbal**, **active/reflective** and **sequential/global**. The sensing/intuitive dimension refers to how students perceive the world according to their abstract managerial skills. Sensing students like learning facts and solving problems using well established methods, while the intuitive students prefer to discover possibilities and the relationships between concepts. Visual learners enjoy having information presented to them in pictures, diagrams and flow charts, where verbal learners prefer written and spoken explanations. Active learners best learn through engaging in an activity related to the subject,

such as practical projects or physical activities, where reflective learners like to work alone and think about new information quietly using introspective processes. Sequential students like to prefer to progress through content toward understanding in a logical, sequential process, while global learners tend to develop an initial broad understanding of a topic before developing a more detailed understanding (Buckley and Doyle, 2017). There are clearly many different ways students learn and understand information in an easy and comfortable way. However, aside from specialising students' self-study time and methods to accompany these styles, it would not make sense to do so in lectures as it would be impossible to acquire the needed resources to do so. For example, one would have to acquire seven different classrooms and teachers to teach the same subject at once. If one were to use only one lecture hall, it would take seven consecutive lectures of whatever time frame necessary with the seven teachers to teach the module. It simply is not feasible to teach this way. The most appropriate directive to take is to attempt to incorporate as many of the styles into a lecture as possible and accommodate the majority of the students.

2.4 Retention

Since this thesis document is focussed on two main outcomes, providing an increase in both the depth of knowledge and knowledge retention of engineering students, this section will focus on the topic of retention: what it is, how it is achieved and how it can be improved.

Knowledge retention is something much desired in a learning environment. It signifies the amount of knowledge a person can retain after exposure to certain information, with little to no repetition of said information. Ideally, students would want this skill to be at its maximum, as it would mean that they have more time to spend honing other skills due to less need of study. It is of great opinion that knowledge retention is something people need to train through extensive measures and time-consuming efforts, however, there are many studies arguing otherwise. Proving that something as simple as changing the environment information is presented in can greatly increase the knowledge retention of

those subject to it.

Such an example can be found in Tran (2014), where cooperative learning techniques were used to determine whether different teaching methods result in statistically different outcomes of knowledge retention. Cooperative learning was discussed in detail in sub-subsection 2.2.2.3 and will thus not be explained further here. However, using the principles of cooperative learning, specifically the jigsaw method, a major increase in results were achieved than the students who were taught using traditional teaching. A four week experiment was conducted by Tanel and Erol (2008) in which physics students from Turkey University were divided into two groups, where the experimental group was instructed in the jigsaw method and the control group in traditional teaching. A post-test was administered with a delay-test following four weeks after. Both test results indicated a strong significant difference in the teaching methods with the experimental group scoring much higher than the control group. The test results showed the experimental students attained better and long-term achievement than the control group. Upon inspection of the post-test and delay-test scores it was found that four weeks after the experiment, the experimental group retained nearly 98% of their knowledge as opposed to the control group whom retained nearly 80%. More experiments indicating the same results were conducted by Şahin (2010) using JG, van Wyk (2011) who examined the effect of TGT, Abu and Flowers (1997) testing the effectiveness of the STAD method.

However, from the 14 tests which specifically tested the effects of cooperative learning on knowledge retention, the 7 which indicated results in favour of cooperative learning were specific to Western subjects. It was found that in the rest of the cases where the experiments were conducted primarily in an Asian context, the results were no better than, or worse than the lecture-based teachings (Tran, 2014).

A study was done by van Wyk (2011) on elaboration theory, built on the premise that one of the most effective ways of understanding is to explain the information to someone else. It was argued that cooperative learning activities creates the

environment for more elaborative thinking in the form of frequent exchange of explanations. This has the potential to increase the depth of understanding, reasoning quality and accuracy of long term retention of knowledge. It was also found by Van Wyk (2010) that students are more motivated to learn through cooperation than competition.

2.5 Gamification

While the term gamification has no set standard as of yet, the majority of sources on the subject agree in general it is defined as the use of game elements in a non-game context, with the intent of increasing people engagement, motivate action, enhance user experience, promote learning and solve problems. However, further development is required for a deeper view of gamification, including theoretical foundations, overarching purposes and standards for practice (Fitz-Walter et al., 2011; Gulotta et al., 2016; Nevin et al., 2014; Seaborn and Fels, 2015).

2.5.1 Gamification in Education

Gamification in the education environment is defined as gaming elements used in both formal and informal scholastic developments (Seaborn and Fels, 2015). There has been numerous studies conducted on gamification with respect to education from around 2011. In these studies, various topics are addressed on their validity toward an improvement of education, such as, participation motivation, the use of challenges/achievements, e-learning systems, open-source homework applications, gamified tutorial systems and behaviour motivation.

Denny (2013) conducted a multiple-choice question (MCQ) based learning system to investigate the effects badges have on the motivation of students to participate. The results indicated that badges motivated the number of answers students submitted as well as their duration of engagement, while the response quality remained unaffected. More on the findings from this research can be found in Appendix B. Another study was done by Gåsland (2011), in which "StudyAid",

a collaborative question-and-answer e-learning platform, was created to help students learn course material. This study proved useful and easy to adopt, however, it seemed as though the elements of gamification utilized did not have much of an impact. This may be due to how it was implemented in the programme, as a result most of the students did not consider it a game. Through missions, qualitative and numerical scoring using stars, levels, pressure challenges, mini-games and rewards, Li et al. (2012) was able to assist students in learning AutoCAD using GamiCAD. Results indicated enhanced enjoyment, an increase in student engagement and performance improvement of novice students. Students showed up to a 76% increase in completion speed.

A gamification study specifically aimed at medical students was done by Nevin et al. (2014) which served as a voluntary online quiz platform, engaging time-restricted medical students using activities that are certification-related. Results indicated 80% of the students participated in the quizzes with a success rate of 70%. After reviews have been made of a post-questionnaire, it was found that over 90% admired the difficulty level, more than 60% were pleased with the frequency and 30% wanted additional questions. In addition, the knowledge retention rate of the students also increased by almost 12% when questions were reintroduced. For a two round test of reintroduction, retention was found at 10.2% for round 1 and 17.4% for round 2. The conclusion conducted from this study is gamification software can engage a large number of people within a certain field in a knowledge competitive manner, facilitating acquisition of new knowledge, often outside of regular hours. The combination of the software and a metric-driven approach can reinforce critical concepts, while handing new tools to educators which augments traditional education techniques (Nevin et al., 2014).

In engineering education, it has been found by Gulotta et al. (2016) that immediate feedback along with clear cut goals and interactive learning techniques, once again is a tremendous motivator for participation. This study was specifically conducted with regards to engineering first years, where traditional homework is changed into some completely new entity. In this case study badges were also used to signify the completion of tasks and accomplishments of interest. All of this of

course is accomplished via gamification platforms and techniques. As in a normal gamified environment as well as some of the other studies mentioned in this research document, activities start at an easy level and progressively improves as the knowledge of the participant increases. Of course, the option to repeat tasks in order to become a master of a certain topic is available for those who wish to do so. Over the years, the number of engineering first year students who finish their degree in engineering tend to vary. Two separate studies conducted by Chen and Weko (2009) and Honken and Ralston (2013), showed that 60% and 76% of engineering first years respectively finished the degree they started in. The relatively low number of retention of students is due to a number of reasons, both academic and non-academic. While the non-academic reasons may be trivial, the academic ones include more pressing matters, such as curriculum difficulty, terrible teaching and poor advising (Gulotta et al., 2016).

2.5.2 Gamification in Engineering

The use of gamification in contexts other than in games stretch far and wide, including health and wellness, sustainability, orientation, marketing and computer supported cooperative work, to name a few. The one of most relevance would be engineering and science, specifically the education in these domains.

In various instances, gamification has been implemented in the engineering industry environment with rather impressive success and noteworthy results. Passos et al. (2011) conducted a test in which he aimed to improve the way software engineering skills can be taught and learned, an often challenging and solemn task to do. However, gamification has become somewhat of a trend in recent years wherein game mechanics are incorporated in various ways, to introduce a familiar and rather boring activity in a new and fun way. A novel approach was used where game mechanics were integrated directly in the process of software development, in which it is transformed into a live game.

Something a great deal of attention was given to in Passos et al. (2011) was the rules of gameplay. For games to be fun and remain challenging, the challenges

need to be balanced. Otherwise, if they are too easy or difficult, it runs the risk of the challenges becoming boring and non-stimulating. Another focus point is the punishment-reward system, closely related to game mechanics. Possibility space is tested when skills acquired are used in an attempt to complete an obstacle, where a punishment should be dealt if the user failed; similarly a reward should be received when they accomplish the goal. In both cases it is imperative that immediate feedback of the outcome is given, greatly increasing the probability of the person learning and improving on their mistakes. It is thus essential to make a task both fun and challenging.

It is in the possibility space that new skills are learned, honed and developed, as it is inherent for humans to like challenges and be chemically rewarded (dopamine) whenever they successfully utilise their skills or overcome challenges. For a game designed skill-set, it is desirable that it is **decomposable** – making skill learning fun by decomposing a complex skill into several simpler ones; **chain-able** – challenges should progressively rely on more complex ones, forming an increasingly difficult learning curve due to decomposition; **combinable** – challenges should further rely on mastered skills in combination to avoid a collection of loose isolated skills (Cook, 2008).

Certain traits are necessary in any game/gamified environment for it to function properly, these are **achievements** and **immediate feedback**. Achievements are necessary for the positive evaluation of a user's performance and for profound motivation. Two approaches are most often used when computing achievements, namely *repetition* and *rate*. Repetition achievements refer to the number of times a specific skill was used in attempting to overcome a challenge. Rate achievements are scope bound like a container challenge or a defined time slice. A good measure for this would be the number of successful attempts compared to the number of attempts.

Achievements can be graded by various metrics:

- Number of tasks completed

- Mean time for task completion
- Iteration duration
- Coverage of test code
- Complexity of code

While all these metrics possess specific meanings in the software engineering environment, it poses no use to simply expose them as is, since they lack reference goals and a compelling sense of competition. Which is why it is necessary to transform these into achievements. A critical part of this is to balance the levels and thresholds of these achievements by specific design. Levels should progress in difficulty, otherwise they will become unappealing and boring as stated earlier. Other measures which can be used are:

- Experience points (EXP)
- Character attributes
- Levels
- Character classes

Experience points are gathered upon completion of tasks and challenges, which can be used to improve a character's profile and skills. **Character attributes** are evolved as experience points are gathered and used to improve/alter attributes unlocking certain skills and abilities. In a learning environment it can refer to the type of tasks/problems one can attempt and the ease with which they can be completed. **Levels** are incremented once a certain amount of experience points are attained as tasks are completed and with each higher level, more EXP is needed to attain the next level. As the levels increase, more problems and tasks can be unlocked as well as available attributes can be learned. **Character classes** are similar to attributes, which can also determine the type of problems and tasks available for the character to attempt (Passos et al., 2011).

For a generation of people who grew up on interactive games, the same expectation is carried over to all other forms of information systems. However, in business

the use of games cannot be considered as an exception from the permeation of gamified approaches. In several studies, the most important advantage of these game-based tools has been found to be immediate feedback, active participation, learning from experience and the high motivation stemming from a competitive environment. The use of points and rankings are also used in the implementation of gamification within a company-internal social network. Studies have shown that the removal of such elements resulted in a decrease in participation and contribution. An important aspect associated with participation which comes with gamification, is the joy that stems from engaging in these elements. Another use of gamification in the engineering environment is in supporting collaborative requirement elicitation. From this came the concept of "Six Thinking Hats" (STH) technique, which tackles the collaboration problems usually faced with user involvement (Fernandes et al., 2012).

The "STH" is an intuitive collaboration technique developed by the iThink web-based gamified environment as a Western thinking method, influenced by Greek tradition of argument. This is typically used in scenarios of analysis, judgement and discussion. In plain terms, it proposes the idea of parallel thinking as opposed to traditional Western thinking, where two people will disagree and a discussion follows, wherein the two people only try to prove the other wrong. Using parallel thinking, both perspectives are placed parallel to one another, even if they are contradictory (De Bono, 2002). This enables the avoidance of the limitations of Western thinking, accomplished by viewing both standpoints as equals and objectively assessing the positive and negative aspects of both, in order to make an informed decision purely based on facts, not opinion. The method of parallel thinking has proved useful in various environments, including meetings, lectures, discussions and brainstorming sessions. The six hats, which comprise the different elements of this thinking method, each has its own meaning represented by colour. The colours of the hats are: red, white, black, yellow, green, blue and their meanings are displayed in Table 2.8.

Table 2.8: Hat colour meanings and relation to other coloured hats; adapted from (Fernandes et al., 2012)

Hat colour	Symbolism (Focus)	Relation to other colour
White	Facts and numbers in an objective way	–
Red	Emotions and feelings	Opposes focus of white hat
Black	Negative judgement and failure potential	–
Yellow	Positive thoughts and benefits	Opposes negativity of the black hat
Green	Creative thinking, new ideas and alternatives	–
Blue	Global vision and problem definition (conclusions)	–

The iThink STH method is explained further in Appendix B.
Two case studies conducted on the iThink collaboration method were a board game and prototype development, which will not be explained in detail. The results from these case studies showed user involvement greatly improved in requirement elicitation using this method. Feedback from surveys indicated the method was easy to use and useful, making it particularly motivating to participate. The method also illustrated an assurance of quality in the requirements elicited from using said method. However, despite the positive feedback, further work and research into this method is needed, as not all feedback was positive and some raised concerns.

Prensky (2005) reported that as the traditional sense of teaching is becoming rapidly outdated with the advancement of technology, educators are starting to look for new ways to educate students. Gamification is becoming all the more relevant as it becomes more popular. Especially in the newer generations where the students of the modern age grow up with games and technology as simply another aspect of life. Due to this, it would be safe to say that the incorporation

of gamified teaching techniques can aid in the educating of engineering students. A study was performed by Gulotta et al. (2016) which focussed on improving the retention of engineering first years. This study was performed by turning the familiarisation of the library utilisation into a gamified experience and truly positive results came from this study. Both the attributes of teamwork as well as the ability to learn course content showed great deals of improvement.

A study done by (Buckley and Doyle, 2017) focussed on the effects different student profiles have on the experience students have with a gamified environment. The types of student profiles considered in this study can be found in section 2.3. The study aimed to determine the impact different learning styles have on: 1. students' perception of a gamified learning environment; 2. students' participation in a gamified learning environment; and 3. students' performance in a gamified learning environment. At the end of the study, the results indicated three significant relationships. First, a small, negative correlation between Active/Reflective learners and perception of gamification was identified, indicating that active learners have a more positive perception of gamification. Secondly, a positive correlation between Sequential/Global learners and perception of gamification was identified, indicating global learners' perception of gamification is more positive. Thirdly, a negative correlation resulted between Sequential/Global and performance, which indicates that students with a global learning orientation performed better in a gamified learning environment.

2.5.3 Gamification Principles

In previous sections, the researcher referred to numerous examples of gamification in both education and engineering environments. However, the concept of gamifying something is more than simply adding a number of game elements to any situation and calling it gamification and hoping it will work. Not all game elements will work in every situation and not everyone responds the same to it. It is therefore important to distinguish what kind of level of gamifying will be appropriate given the dynamics of the situation, environment and potential participants. As there are a variety of examples of successful implementations of

gamification, there are also ones which ended up doing more harm than good. In these cases the gamification elements ended up demotivating and demoralising participants, rather than engage and motivate them. While this study does not focus on the shortcomings of gamification examples, it is necessary to draw information from previous instalments, both successful and unsuccessful, to learn as much as possible and not fall in the same pitfalls, specifically in terms of competition.

Bing Gordon, the former CCO of Electronic Arts (EA) and current partner of Kleiner Perkins Caufield & Byers, stated in an interview that it was found time and again how collaboration trumps competition 3:1. Numerous studies were conducted where the same tendencies were established, many of them covered in subsection 2.2.2. Additionally, Ke and Grabowski (2007) did a study on the effects of playing games to learn mathematics in a collaborative versus competitive environment and found collaboration outperformed competition, with respect to attitude toward the work and no significant difference in performance. Similarly, Tolmie et al. (2010) opted in favour of collaboration, coming to the conclusion of increased social benefits beyond the positive cognitive effects. It was found by Fu et al. (2009) that the combination of cooperative and competitive created the best learning strategy, since cooperation and competition stimulate different types of knowledge growth in students. The same conclusion was made by Green and Rechis (2006), stating that learning competition as well as collaboration can benefit the social competence of young students. In the end, while competition can definitely increase motivation and engagement in certain instances, doing only this in an attempt of motivating participants through gamification can be a flawed approach and potentially destructive.

Zichermann (2014) believes gamification will be revolutionary in the future of creativity and innovation. He refers to a concept called **intrinsic reinforcement**, meaning anytime someone challenges themselves to something of any size and they achieve it, the brain secretes dopamine which makes the activity feel good. Robertson (2012) coined this as the "winner effect", stating that the more achievements accomplished, the more dopamine and testosterone are secreted by

the brain and the more the person wants to do it. Success fuels success. However, it is also design principles of game concepts which enable people to become transformative. This can happen through what Zichermann (2014) calls "the three F's". Feedback, friends and fun. It has been stressed repeatedly that constant and immediate feedback is crucial for any personal development to take off. It was found in numerous studies that immediate and valuable feedback had a very positive effect on how people experience their work environment. Doing something with friends or colleagues are also invaluable to the development of people engagement. Most people of course love to have fun and if it can be applied to something they are already doing, then it will be all the better.

To identify a game, there are usually four distinct traits that can easily be identified: a *goal*, *rules*, a *feedback system* and *voluntary participation*. The **goal** can be seen as the specific outcome participants will work toward. It provides them with a *sense of purpose*. **Rules** create limitations on what participants are able to do in pursuit of the goal. Due to limitations, uncharted possibility spaces must be explored which creates the environment for *creativity* and *strategic thinking*. A **feedback system**, as stated numerous times, provides participants with immediate information on how they are progressing in pursuit of their goals. It gives a *promise* that the goal is attainable and the *motivation* to keep trying. **Voluntary participation** is when participants knowingly and willingly accept the goals, rules and feedback. The freedom to enter and leave at any time creates a space where stressful and challenging work can seem *safe* and *pleasurable*.

It has been stated that gamification is not the same as only gaming, nor is it simply playing either. Deterding et al. (2011) shows in Figure 2.4 a clear illustration of where gamification falls on a two-dimensional scale of playing/gaming and parts/whole. From the figure it can be seen that gamification falls into the first quadrant, essentially, **gaming in parts**. This means it can be considered as a type of gaming, but since it is merely using parts of games, or certain "game elements" and not full-fledged games, it is not considered as serious games. Mcgonigal (2000) coined a term called "gamefulness". It was introduced as a systematic complement to "playfulness", which broadly denotes the experiential

and behavioural qualities of playing. In the same way, "gamefulness" denotes the qualities of gaming. This distinction is important as gamification is not the same as *playing*, but *gameful design*, which is designing for gamefulness using game elements.

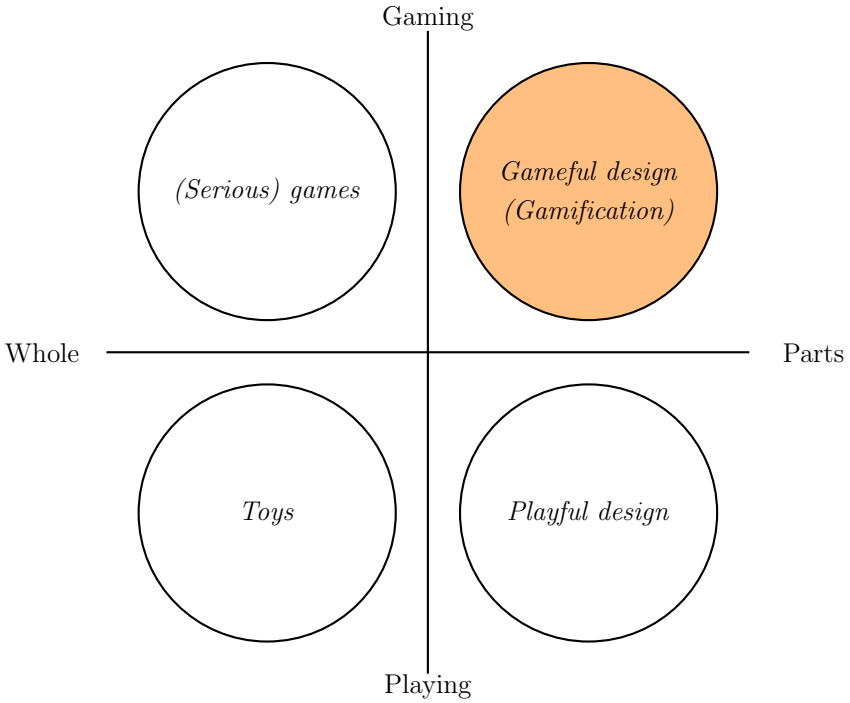


Figure 2.4: Gamification between game and play, whole and parts, modified from (Deterding et al., 2011)

Mcgonigal (2000) often said that reality is broken and the fearful way in which people see games is irrational. If people can start to see games for what they truly are, they can start to change the world for the better. Games are more than simply a way to use strategy and manipulation, to behave recklessly in terms of what is appropriate for the real world. Since games create a simulated, risk-free environment where people are constantly challenged to the limit of their abilities, games arguably present the best circumstances to explore, learn and improve.

2.5.4 Intrinsic motivation

In subsection 2.5.3, some focus was placed on the potential dangers of using only competition as a method of increasing motivation, also the probable benefits of implementing collaboration or both competition and collaboration. In most cases, it is the opinion of the researcher that collaboration holds far more benefits than competition does, with *intrinsic motivation* being the simple reason for this.

When a person is motivated simply by the act of doing something without any obvious extrinsic rewards, it is defined as intrinsic motivation. It involves people who are interested in the task they are doing and derive spontaneous satisfaction from the activity itself (Gagné and Deci, 2005). It is far more powerful than extrinsic motivation, as it is something someone inherently feels good about doing. The task itself is the reward. This causes a person to be able to do something for hours without needing to be coerced into doing it or without it draining vast amounts of energy. This is personified by something called **Self-determination theory (SDT)**, developed by Deci and Ryan (2008) which explains the logic behind intrinsic motivation and is discussed next.

2.5.4.1 Self-Determination Theory (SDT)

SDT is a macro-theory based on human motivation, development and wellness (Deci and Ryan, 2008). It focusses on the distinction between autonomous motivation and controlled motivation. It states that there are three aspects which truly drive intrinsic motivation and motivates a person to do a certain task far more than any other method could. The three aspects are **competence**, **autonomy** and **relatedness**. Their meanings in context of completing a task is explained in Table 2.9.

Each of these aspects of SDT is intrinsically motivating on their own. It is the belief of Ryan et al. (2006) that events and conditions which enhance the sense of autonomy, competence and relatedness of a person supports intrinsic motivation. As a counter, factors that diminish these perceived senses undermine intrinsic motivation. By definition, behaviour which is intrinsically motivated, stem from

Table 2.9: Three aspects of SDT (Ryan et al., 2006)

Intrinsic Value	Meaning
Competence	Feeling a sense of achievement and ability toward the task at hand. A need for challenge and feelings of effectance.
Autonomy	A sense of volition or inclination. Feeling of control in terms of choices being made and no forced coercion.
Relatedness	A connection between the person and the task or someone else (something intrinsically important).

the most unalienated and authentic place of a being, from the self. However, extrinsically motivated people can still be committed and authentic through internalisation and integration. This is visualised in Figure 2.5.

Hebert (2018) spoke in a TedTalk of a study he did with his students and how he indirectly confirmed SDT. He asked his students, the most untapped resource in school according to him, what they wanted/lacked in class. Three common trends he found in the answers provided, were:

1. "School is boring, repetitive and I do not understand why I need to know this."
2. "I do not have a choice in anything I do."
3. "Why can I not do things in ways that I like doing them?"

Each of these answers refers to one of the three aspects of SDT. The first answer received from the students refers to the lack of *relatedness* which the students experience. The second shows the students feel no *autonomy* related to their experience in their learning environment. Thirdly, they feel no sense of *competence* in doing the tasks assigned to them.

From this figure, it can be seen that there exists an entire spectrum of motivation, ranging from amotivation, to extrinsic, to intrinsic motivation. The

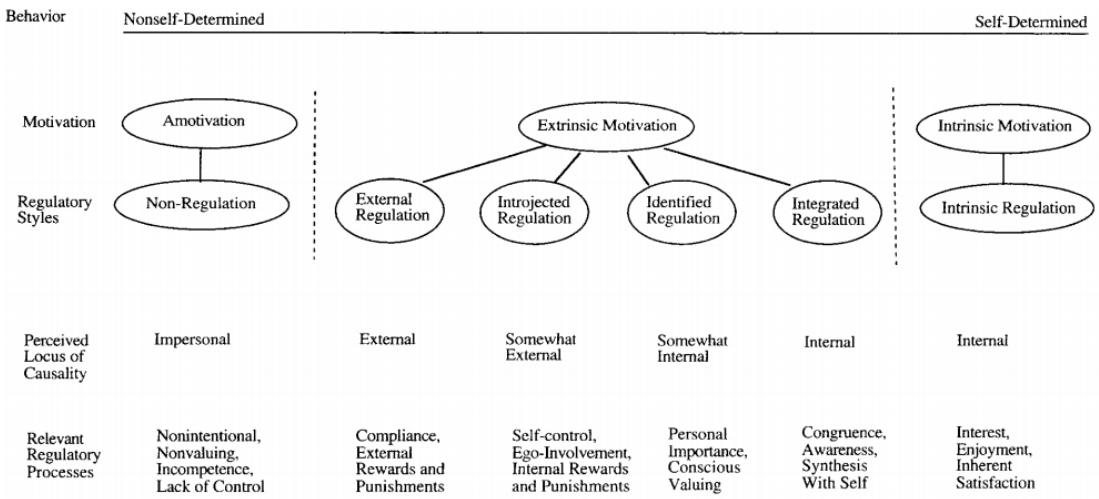


Figure 2.5: Motivational Spectrum (Deci and Ryan, 2000)

figure indicates self-determination is at its fullest once motivation is completely intrinsic. However, as stated previously, extrinsic motivation can also result in self-determination through identification and integration. Regulation through identification is a very autonomous form of extrinsic motivation, as identification reflects a conscious valuing of a behavioural goal and the action is accepted or owned as personally important. The most autonomous form of external regulation is integration. When identified regulations are fully absorbed into the self, meaning they are completely congruent with one's other values and needs (Deci and Ryan, 2000). In simple terms, external rewards can still support intrinsic motivation once it is of significant importance and in union with the person. It is important to note that this is not a guarantee to produce intrinsic motivation, it merely has the potential to do so. The safest method would still be to appeal to the three aspects related to intrinsic motivation found in most people.

2.5.4.2 Reward Structures and External Rewards

Cognitive Evaluation Theory (CET) is a sub-theory of SDT, focussing specifically on the effect of external forces on intrinsic motivation. It proposes that external events such as offering of rewards, evaluation delivery and other motivational inputs are factors which affect a person's sense of competence and self-

determination (Deci et al., 2001).

External rewards are widespread being used by teachers as an attempt to motivate their students. Rewards such as gold stars, honour roles, best-student awards as some incentive for doing good work as well as motivation for continuous improvement. However, Deci et al. (2001) found that extrinsic rewards and tangible incentives can actually undermine intrinsic motivation, which stated in subsection 2.5.4 is the more powerful form of motivation in a person. CET suggests there are two main categories of external rewards to evaluate with the second branching out into smaller categories. The two main categories are, *verbal* and *tangible* rewards. Both these are considered extrinsic rewards as they stem from a source external to the person receiving them.

Verbal rewards, more commonly referred to as "positive feedback", are typically explicit forms of affirming words given for positive performance and so they are predicted to have an enhancing effect on perceived competence. It was however determined that in an interpersonal context, such as a classroom where people's experience of self-determination is influenced, verbal rewards can have a controlling effect rather than informational. An example of this would be when a teacher uses verbal rewards to make students do what he or she wants them to do. **Tangible rewards** are usually given to people as an inducement to engage in a certain behaviour they might not otherwise do. The prediction is thus that tangible rewards would possess a controlling nature and resultantly decrease intrinsic motivation. Tangible rewards are commonly experienced as controlling when they are expected, which means one would expect a certain behaviour to lead to the reward. It is more likely that tangible rewards have less of a controlling effect when they are given unexpectedly after completion of the task. Tangible rewards of the expected nature can be branched out in terms of contingency, depending on the different aspects of task-related behaviour (Deci et al., 2001).

Three types of contingencies were identified concerning rewards: *task-non-contingent* rewards are given not for specifically engaging in the activity, but merely taking

part in the experiment; *task-contingent* rewards, requiring someone to do or complete the activity; and *performance-contingent* rewards, which requires a person to do well in activity. A further distinction can be made with task-contingent rewards into *completion-contingent* which requires the completion of the activity and *engagement-contingent* which only requires engagement in the activity and not completion. However, the tests indicated that the results for these two are remarkably similar and are thus classified together as task-contingent rewards. Table 2.10 conveys the different scenarios in which external rewards can have an informational and positive effect on competence or a controlling effect.

Table 2.10: Relationship between Intrinsic Motivation and External Rewards based on CET

External Reward	**Relationship**	
	Informational	**Controlling**
Verbal	Typical conditions	Interpersonal context
Tangible:		
1. Non-contingent	No measurable outcome	No measurable outcome
2. Contingent		
Engagement	–	Typical conditions
Completion	In cases where skill is required to complete the task	Typical conditions (more so than engagement-contingent)
Performance	When the reward level signifies excellent performance	Generally more controlling than informational

The table is a clear representation of Deci et al. (2001) on the different types of

external rewards being used and the consequent relationships these rewards have with regards to intrinsic motivation. In the study it was discovered verbal rewards tends to have an undermining effect on intrinsic motivation when it is delivered in an interpersonal context, however, in most other circumstances it would actually have an increasing effect on it. The results for tangible rewards were somewhat more interesting. It was found that tangible rewards had a more negative effect on children than it did for college students. They further tested the effects on intrinsic motivation based on unexpectedness as well as non-contingency. The results indicated unexpected rewards revealed no undermining of intrinsic motivation and non-contingent tasks showed no significant effect as the reward is not a result of doing anything. It is interesting to note that verbal rewards for the most part are unexpected, which is why they tend to be less undermining.

In terms of task-contingency, for engagement contingent, the results indicated a significant diminishing of intrinsic motivation on all fronts. The results for completion-contingent were virtually identical to the results for engagement-contingent. Performance-contingent rewards also undermined intrinsic motivation in people, especially when the tests were conducted in a way where not everyone receives the maximum reward. It is also important to note that this changes in terms of the age of the person receiving the rewards. Both the positive and negative effects these types of rewards have, were more favourable for college students than they were for children, the positive effects were more so for college students and the undermining effects more so for children.

In summary, the only type of extrinsic reward that increased intrinsic motivation was verbal rewards (positive feedback), while all others had either no effect, or an undermining one. Also, all effects tend to be more in favour of college students than children, meaning the positive effects were more so for colleges students and the undermining effects less so than for children.

2.6 Synthesis of the Literature Study

The literature study was done to determine the various types of gamification implementations which have been tried and tested. The findings and conclusions from these studies were considered with the aim of extrapolating and using some of the methods in the education environment, to motivate students to engage more with their work and as a result increase their knowledge retention. Many of the methods studied resulted in positive conclusions, while others were neutral and some were negative. The majority of research discovered that there is indeed a positive correlation between the use of game-based elements and people's level of engagement. It became clear during the study that an extremely important resource usually goes unaccounted for, namely the opinions of the participants. In most cases where the implementation of gamification principles failed, it was because the managerial party, or the implementers of the strategy, failed to consult their employees who would be directly affected by anything implemented. However, in nearly all instances where a two-way feedback loop existed, where the participants received feedback on their performance and the implementers received feedback on the implementation, the response to gamification was much more positive.

There are certain elements which are inherently received more positively than others. These elements can be considered to boost the self-image of the person affected, instead of unintentionally diminishing their intrinsic worth. These are elements such as immediate constructive feedback, collaborative assignments, achievements, points and badges to name a few. All these elements are said to introduce an environment of self-improvement, where the person does not feel they are competing against others, but rather challenging themselves to improve their own abilities and receive recognition for their efforts. By contrast, elements such as competition, leader boards and rewards are generally more risky, as it is easy to have ineffective implementation thereof, which in turn completely destroys the experience for participants. It can create the feeling that they are being coerced to do something they do not want to or do not see the value in doing.

Chapter 3

Analysis of Student Survey

This chapter revolves around the gathering and analysis of data regarding current and future learning environments from students through the use of surveys. All questions asked are addressed in this chapter referencing percentages based on the opinions of the participants of the survey.

3.1 Data Gathering and Analysis

Before any implementation or even design can take place, data is needed and in this case, data on the students evaluated for this study. To gather this data, an anonymous survey was completed by the students to collect information regarding their experiences given the current education system. The questionnaire focussed mainly on gathering data regarding the current education system, specifically their study methods, their ease of understanding new information and retaining the information for examinations and post-examinations. The rest of the questionnaire gathered data from the students regarding their opinion on the new method desired for implementation, in this case, gamification. The questionnaires sent out to the students can be seen in Appendix C. The researcher surmises that due to the timing of the surveys being mid-Covid-19 where most of the work became online based, the number of responses received was underwhelming, however, this survey expanded on the work of van Niekerk (2019) with her study doing complimentary data gathering for this one. Hers being more focussed on ground work and learning insights into the evaluations of students

of their learning environment. The responses on the gamification questions were positive given the few number of responses. With a population size of 250 invitations, a confidence level of 95%, an error margin of 9% and a sample proportion of 50% the sample size is calculated as 81. The total number of responses received from the 250 invitations were 88, which is higher than the calculated 81 and is therefore statistically significant for analysis.

3.2 Analysis of Current Education Environment

Valuable information was gathered from the students in both van Niekerk (2019)'s surveys as well as the ones sent out for this study. In her study it was suggested that 67% and 40% of the students tend to enjoy studying alone and individual work respectively. By contrast only 19% said they prefer group work with the rest being indifferent. This is rather concerning, as many of the modern teaching methods are generally more focussed on group work than the traditional methods, such as the talk-and-chalk. From the survey used in this study however, 67% said they prefer a combination of studying alone and in a group and the same percentage stated they study on campus and not in their place of residence, which increased from 48% in van Niekerk (2019)'s survey. Along with 38% preferring group work and 43% being neutral to group or individual work, this is indicative of students enjoying having people around, but not necessarily interacting with people while they study. If a certain strategy can be employed to harness their liking of having people around into interacting with them to enhance their studying, it can prove immensely beneficial.

It was stated in van Niekerk (2019) by only 22% of students that they do not prefer the "talk-and-chalk" method with 44% saying they do. These figures changed in results obtained for this study, with 52.4% opting against "talk-and-chalk" and only 14.3% in favour of it. It seems as though the demographic of the participants shifted between the final years of 2019 *vs.* 2020, which should be evaluated before implementing anything that many of the participants might not be comfortable with.

In both studies where students were asked if they believed students should teach other students with the teacher acting as a facilitator, the results indicated that they do not believe this to be a good idea. This can be seen as a contradiction to previous statements where students indicated they understand work better when they teach others and somewhat so when other students teach them. It may however be that the participants misunderstood the question, thinking the students take on a formal role with only one of them teaching the entire class.

Results for question 28 of the survey are indicated in Figure 3.1. In the question participants were prompted on how often they raise a question in class. As can be seen from the pie chart, the majority of them indicated they hardly ever raise a question with a total of 81% of responses. This is also a culture that needs to be broken, as there are more than likely other students with the same question also not opting to raise it. A way to rectify this through gamification would be to have a certain remuneration scheme for each question asked to encourage students to participate more in class.

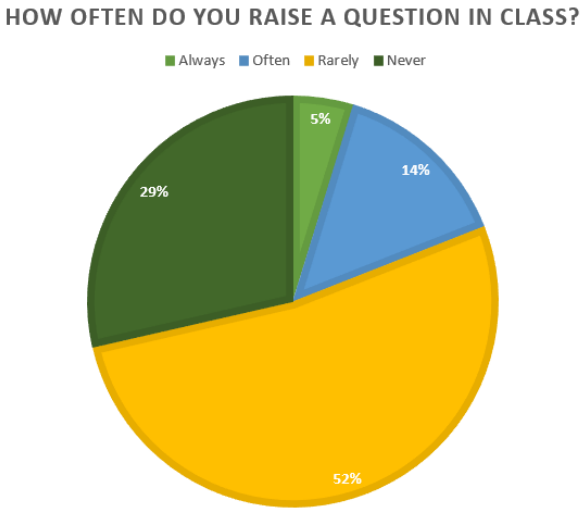


Figure 3.1: Results to the question: How often do you raise a question in a lecture, if you did not understand the content being taught?

Along with the questions on gamification which will be addressed later, other

questions were added that prompted the participants on their view of survival *vs.* retention in terms of assessments. The majority of participants stated they study for retaining knowledge after assessments with 38% of the responses and 48% being neutral on the subject. This makes sense when considering that 95% of the participants believe one should retain information after assessments. However, with the majority of them stating they study for retention, on a five-point scale, the highest retention level announced by the participants is only three. Of the responses, 71.4% of participants announced a level two on the five-point scale in terms of knowledge retained. Given that the majority of students hope to retain information after assessments, it can be stated that the system is not working at its full potential when compared to the level of retention the participants reported.

Additionally from van Niekerk (2019)'s survey, 81% of the participants said they understood work better when they have to explain it to another student, as this would mean they need to understand the work well enough to explain it. Explaining it to another student merely enforces their understanding. Relating to students teaching other students, 45% said they understand information better when another student explains it to them and 48% stated they sometimes understand it better, as they tend to explain it in much simpler terms than the lecturer. From the survey used in this study, 86% of participants stated they understand it better when they explain the work with no one saying they do not, along with 52.4% saying they do and 47.6% saying they sometimes do understand the work better when it is explained by another student.

The students were asked whether they understand work better when they are able to practically apply the knowledge compared to hearing it in a lecture and 90% of them agreed. This is an important association to make, along with the students preferring group work and the fact that they understand content better when they explain it to other students, since much of the gamification elements which were implemented in this study focussed on collaboration challenges, which means one can only perform as well as a teammate. It is thus natural to try and help ones teammates as much as possible wherever they need the help, so the

entire team can perform well.

When asked if they make use of a textbook while studying if a module has it available, 52.4% stated they often do and 38.1% said they rarely do. Compared to the data from van Niekerk (2019)'s research that resulted in 59% of participants saying they often do and 39% saying they rarely use textbooks, there is not much of a difference in results, along with 85.7% of students stating they study from both the textbook and provided lecture notes. In van Niekerk (2019)'s study, the data indicated 81% of participants do the same, thus no change in results were noticed. Students were asked whether they make their own notes during a lecture or use the lecture notes and 81% of the responses were in favour of both making their own notes and using the lecture notes, with 52.4% of participants indicating they always find the lecture notes beneficial. Linking to this information, 81% of students study with written summaries, which were probably made during the lecture, with the second most popular method being reading/speaking aloud. These results did not change from van Niekerk (2019)'s study.

Something rather concerning the researcher noticed from the data, is how long before an assessment the participants stated they start studying. The majority of participants, 57.1% to be precise, indicated they start studying only 1-2 weeks prior to an assessment. It is understandable given the work load most of the modules in an engineering degree contain. However, this information needs to be taken note of with the level of knowledge retention reported by the students. If between 1-2 weeks is the longest time before an assessment most students can begin to study, it is apparent that a method which helps students retain information easier is a crucial necessity, since they do not have a lot of time to employ repetition while studying.

81% of participants indicated they make use of previous examination papers when they are available, along with 65% stating they only look at the memorandum after completion of the paper, while in van Niekerk (2019)'s study, 94% of participants said they use past papers, but 63% of them work with the memorandum

rather than first trying to finish it by themselves.

It is the case for most people to study using more than one of their senses. This is also the case for 52.4% of participants that stated they always use various visual materials and symbols and 38.1% indicating they sometimes do. Along with this, 67% of participants stated they always use different colours while studying. These results compare significantly similar to those of van Niekerk (2019), with her results indicating 64% use different colours and 53% make use of visual material and symbols. The results for these are thus rather similar, apart from the statistics on making use of visual materials and symbols.

Another question the participants had to answer was with regards to them using a cellphone during lectures if they have it with them. 70% of the participants admitted to using their cellphone during a lecture, with 89% of them stating it causes more of a distraction than anything else. This is less than the 94% whom reported they use cellphones in van Niekerk (2019)'s study, however, 61% of them stated it distracted them from learning all the content. For people to already be using their cellphones during a time when they ideally should not be, it would be best to utilise the cellphone in some way so it does not cause a distraction, but serves a purpose towards the lecture. Perhaps gamification can prove useful in that regard. It can be noted with this that 95% of participants stated they pay more attention when they enjoy the module. Again, gamification is known mostly for its ability to improve the overall experience of anything "mundane" people do, which is something to consider before implementing any new teaching strategy.

There are a number of different teaching methods employed by various educators. The participants were asked to identify from a list the methods they have found to be used by the majority of lecturers. All of them stated lectures are presented in the form of educators using slides to present information, with 33% of participants saying lecturers read from a textbook and 57% stated they present group work and practicals. While group work and practicals is what most of the modern teaching methods focus on, the fact that 100% of responses indicated lecturers

stand in front of a class and present information from a slide is concerning. This may have been the methods used for decades, but it is simply a method that was adopted and continued with. It is not necessarily the most effective form of teaching or even how the students would want to be educated. Going forward, it is necessary to rethink the strategy for education and to adapt to the times and the changes. If humans expect everything around them to develop and improve along with the progression of time, it should certainly be expected of something as important as education, which is the building block for all knowledge.

3.3 Analysis of Potential Learning Environment

In the survey for this study, an additional question to the original survey prompted the participants on their opinion on online lectures given the recent Covid-19 situation. A total of 24% of the students indicated they do prefer online lectures, much higher than was anticipated. The reasons they gave were rather interesting, with the most common one being they can do the lectures at any time at their convenience and have control over skipping work they know or rewatching a section they find more difficult. This does indicate that the majority of participants still enjoy lectures in the traditional sense, however in an ever digitising world, it might be necessary to make more of a shift toward online platforms. Similar to van Niekerk (2019)'s study, the question of whether participants believed teaching should be more intuitive like in school, 47.6% of participants agreed it should.

Further in this study, the participants were questioned on their understanding of gamification. The results as seen in Figure 3.2, showed 14.3% of participants had a good working knowledge of gamification, while 43% have only heard of it at some point and 29% having no knowledge whatsoever. The explanations of the participants whom indicated they had some idea of gamification, were not far off of what gamification truly is, albeit somewhat in a nutshell. Most of them knew it is a platform used to implement game-elements into a non-gaming context, but most of them believe it is only used in education. A good result is 81% of the participants believe gamification can prove useful with 14.3% of them being neutral. This is a very good result since it shows the participants are open for

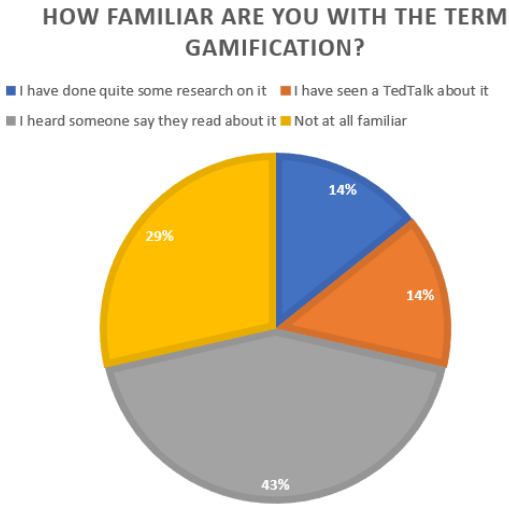


Figure 3.2: Survey question: How familiar are you with the term gamification?

new developments even though they seem to prefer traditional teaching methods.

In Figure 3.3, the elements the participants believe to be most useful in a gamification environment can be seen. Of the elements to choose from, the ones the students favoured were **challenges**, **multiplayer collaborative assignments**, **games**, **experience points** and **rewards**. The others were also given attention, but just not as much as these mentioned. A strategy that can be used in this case is to make the less mentioned ones optional, but still cater for all types of candidates.

Assessments are a natural part of any education environment. How this is applied differs depending on the policies and preferences of those implementing them. However, when the participants were asked on their opinion on weekly assessments based on the work done during that week, 81% of them agreed weekly assessments are indeed necessary. In van Niekerk (2019)'s study, the responses indicated 73% of participants agreed with this statement. It is thus indicated weekly assessments are vital and beneficial in the eyes of the participants, the only important thing to discern is whether or not the current implementation of them are effective or not.

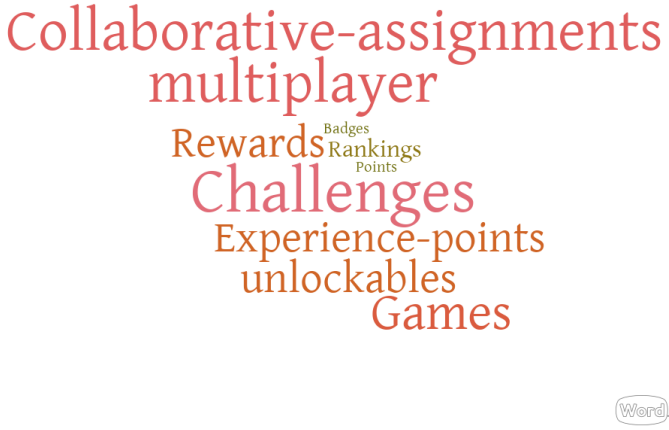


Figure 3.3: Word cloud of the elements mentioned most by participants

As stated previously, there are numerous different teaching methods educators can adopt, but the reality is that most educators stick to the *status quo* and adopt a traditional and easy method. Not many of them go through the trouble to ask their students how they believe a class should be presented, or how they understand work better. In this study however, the participants were asked what their ideal idea of a teaching/lecturing environment would be as well as how they would present a module from their degree. Some of the answers are listed below with a word cloud of the most common responses displayed in Figure 3.4.

1. "An environment where theory is handled and afterwards practically applied. The lecturer is clear about what content is important for assessments while providing experience with work that cannot be assessed through examinations, like projects and practical assignments. Sufficient teaching assistants are also available to help in any way necessary."
2. "Pre-recorded lectures with enough time to work through them before an interactive face-to-face discussion session. More lectures in which relevant practical examples are explained."
3. "As is currently done at Stellenbosch University, but with more practical examples worked through with the lecturer. Also, full-year modules where students have enough time to learn the information in-depth and make

the knowledge their own, instead of semester-modules where the work is crammed into a short period of time."

4. "Lecturers going through practical examples step-by-step in class, followed by groups of two/three students working through a tutorial with similar but slightly more complex problems."
5. "The current (amidst Covid-19) online model, but with in person tutorials/practicals where the theory discussed is applied."
6. "Having shorter lectures, or normal length lectures with more frequent breather periods, since 50 minute non-stop lectures are tiring. Having lecturers interested in the module and themselves being interesting and not robotic in presentation makes taking the module much easier and more enjoyable."
7. "Interactive learning where work is applied practically to real life situations regularly. Less tests, more assignments. More online learning for theoretical lessons, with face-to-face practical sessions for the content that require more in-depth knowledge and understanding."
8. "One subject per day. Theory in the morning and practicals/group work in the afternoon with quizzes to be completed before 12pm the same day."

These were only a few of the responses the students gave, however, even in these few examples, many students indicated that they are exposed to too little practical experience. It is clear that some of them can be linked to the teaching methods mentioned in section 2.2 where many of the students mentioned the need for practical examples and activities, this correlates to the PBL method from subsection 2.2.2.1. Another view of teaching that can be seen in the students' responses is SGD from subsection 2.2.2.3, where a liking for group work and discussions is shown. It is clear from these responses and Figure 3.4 that the students are indeed an untapped resource when it comes to designing the ideal educational environment. These responses show students are not fiercely determined to be lazy and spoon-fed, but instead are eager for more of a hands-on experience and not being force-fed a lot of information. The majority of the students who responded were of the opinion that education should have more interactive and practical

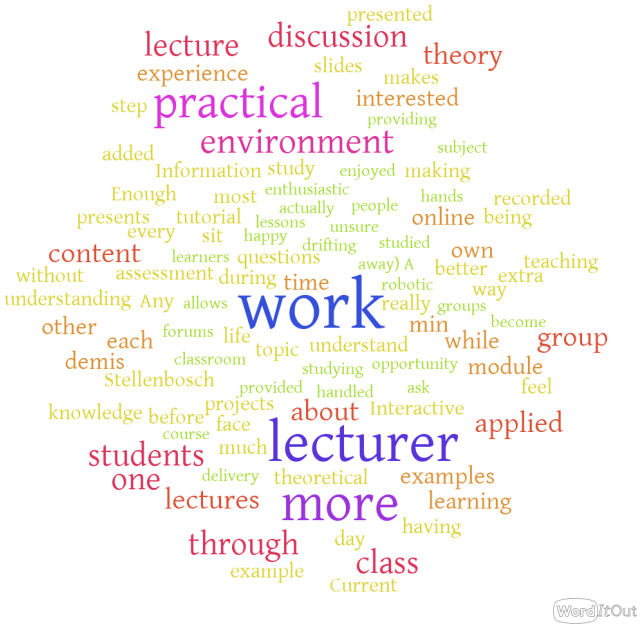


Figure 3.4: Word cloud of the most common responses on ideal classroom question

application dimensions to it, where they are able to reinforce the knowledge they gained and make it their own.

The results from the survey proved useful in the design for gamification implementation. It is known that modern teaching methods focus highly on group work, however, it is still important for students to be able to work individually. From the responses it was learned that the students have a thirst for a form of group work as well as practical experience. Given that the only way to become proficient in anything game-like is to play, the students should adjust well to the setup of gamification, where hands-on experience will be vital in the pursuit of mastery.

Chapter 4

Gamification Implementation

In this chapter, the process of choosing and setting up and implementation model for modules to allow for gamification will be discussed and how it can be implemented. The design will focus on the use of gamification and its features through various game elements in a non-gaming environment to improve the output of the user experience and satisfaction.

4.1 Choosing the Platform

After the collection of data from the students containing their views on education via the surveys on both their current education environment as well as potential future one, the data was interpreted and a decision was made on what to implement using gamification. From the data it was learned students believe there are certain gamification elements well suited for an engineering class environment. All these elements can be implemented in a class environment using the online-based platform **Classcraft**. From a vast line-up of platforms considered, Classcraft was identified as the most suitable for this study. Some of the other platforms considered are, *Kahoot!*, *Zurmo*, *Influitive* and *User Infuser*. Classcraft was chosen as it is a free, educational role-playing game-like platform, students and teachers can play in the classroom. Acting as a gamification layer around any existing curriculum, the platform transforms the way a class is experienced by the students. Using the platform at its most basic level is completely free to the public, but there is a premium version available which can be purchased for

access to additional features, which will briefly be expanded on later. In Table 4.1, information can be found on the differenet gamification platforms considered and how they cater for the different elements desired for this implementation.

Table 4.1: How each gamification platform ranked in catering for the desired elements

Platform Name	**Classcraft**	**Kahoot!**	**Influitive**	**User Infuser**	**Zurmo**
Education Specific	Yes	Yes	No	No	No
Free, Open source	Yes	Yes	No	Yes	Yes
Customisable Modules	Yes	No	No	Yes	Yes
Customisable Characters	Yes	No	No	-	No
Experience Points	Yes	Yes	Yes	-	Yes
Collaboration	Yes	No	No	-	No
Competition	Somewhat	Yes	No	-	No

Classcraft presents a multitude of different features which make the concept of class and learning fun and exciting *without taking away from the main goal, which is to learn.* It creates a space where students can immerse themselves in a game-like experience while learning relevant and valuable information. A great benefit of Classcraft is that participation can be formulated in such a way students do not feel coerced into doing something. Groups can be created among the students to form guilds who participate against each other should that be an interest for them. The students have customisable avatars for which they can unlock certain

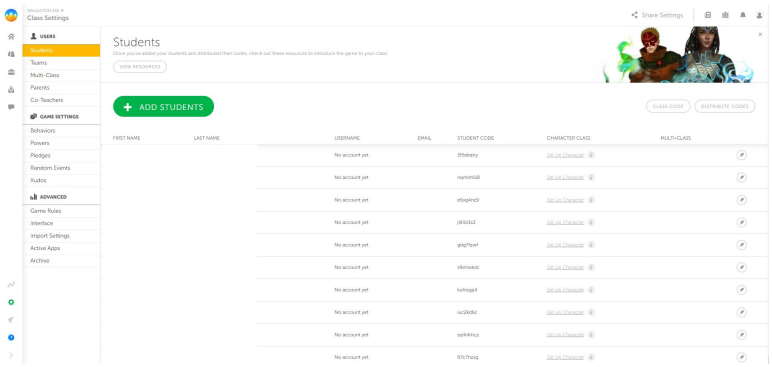


Figure 4.1: Add players to Classcraft

features of equipment as they progress in their skill level. Main tasks can be created the same way they would be for a usual platform and side tasks can be created with the description that they are not required to pass the module, but for those fiercely determined to perform well. Another good aspect of the platform is that many of the tasks can be set up as short pop quizzes or multiple choice questions. This ensures students still have to work out the questions in their own time and familiarise themselves with the work before attempting the assignment.

4.2 Setup on Classcraft

Before starting with Classcraft, the platform gives short tutorial videos of each feature before they can be implemented, in order for the user to be familiarised with everything instead of being thrown into the deep end. One of the first things the user is taught, is setting up players and teams.

Figures 4.1 and 4.2 display the user interface for these features in Classcraft respectively. As can be seen in this figure, students' characters can be set up before they are introduced to the system. This can be done either by the educator or the players themselves. Figure 4.3 shows where the characters can be created and customised for each student. This task was left for the students who were not yet introduced to the platform, which is why the characters are still silhouettes in

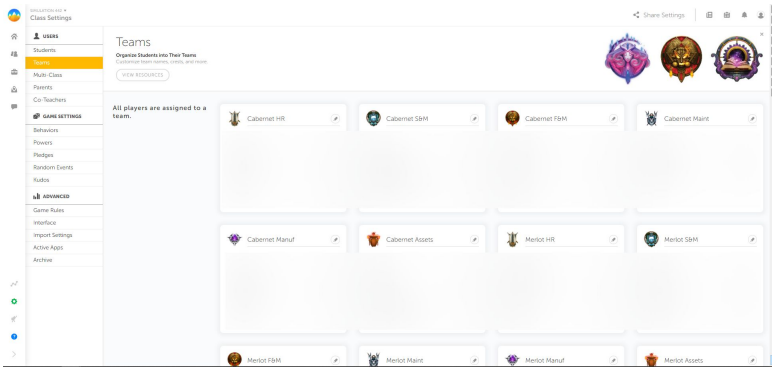


Figure 4.2: Creating teams from the added players

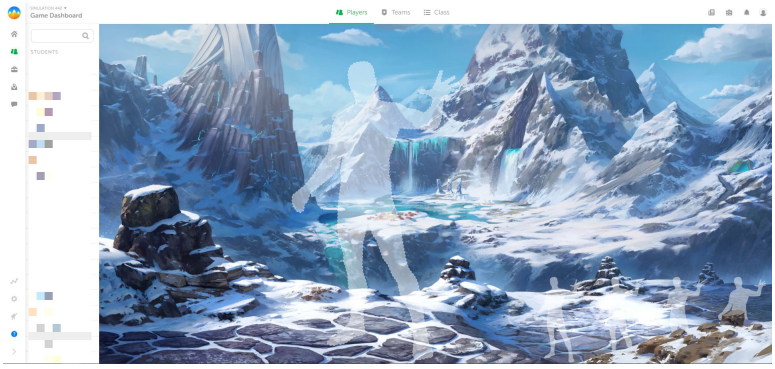


Figure 4.3: Setting up player characters

Figure 4.4: Classcraft quests and tasks

the image. The teams setup displayed in Figure 4.2 illustrates the different teams comprised of all the players added by the lecturer. The teams were created by the students by forming groups of four and creating a unique nickname as well. Embedded in Classcraft, is a tab that navigates the user to *Quests* as can be seen in Figure 4.4. The lecturer has the opportunity to choose a visually aesthetic map, which can be edited and customised in a way which transforms it into an interactive map for the students to use. Figure 4.5 illustrates a close-up image of the quests created for the participants to partake in, specifically tutorials and extra challenges. The tutorials item transfers the students to another map, illustrated in Figure 4.6 and the extra challenges icon transports them to a different one illustrated in Figure 4.7.

Each item in the tutorial map represents one of the six mandatory tutorial assignments the student have to complete in order to pass the module. The added element to this setup is before each tutorial, an interesting story is added to the assignment, making it feel as if the person is completing it for a reason other than because they have to. In the extra challenges section of the quests are numerous problems created by the lecturer that are somewhat more difficult than the regu-

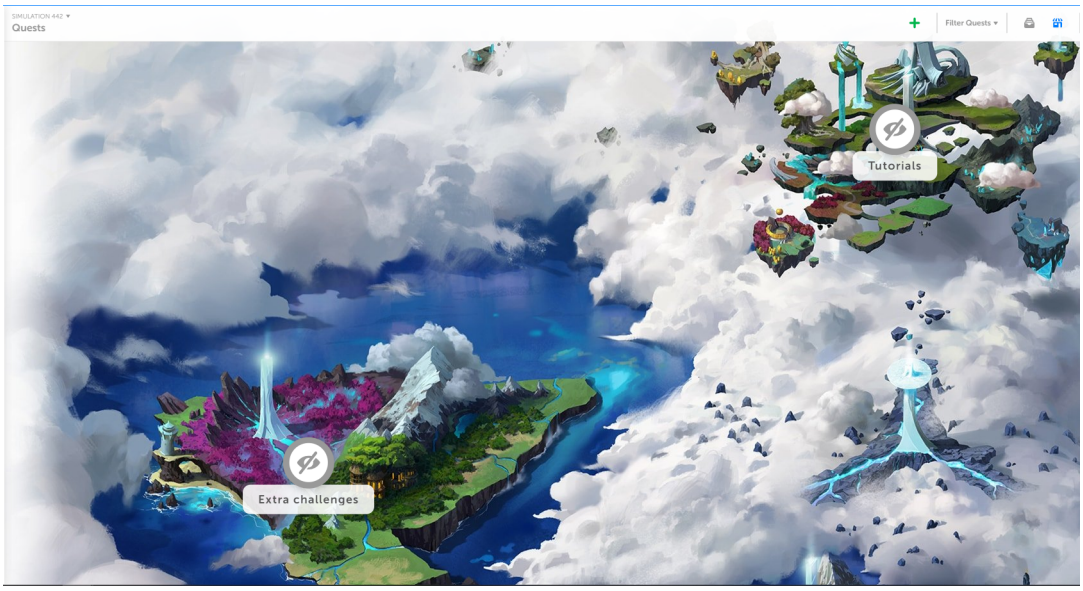


Figure 4.5: Map of created quests

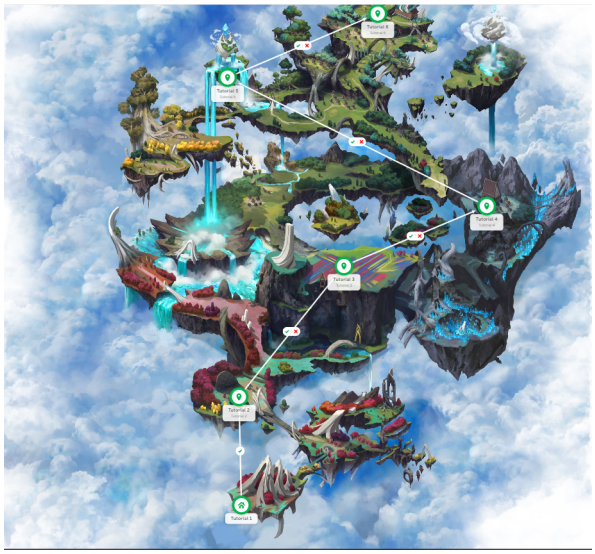


Figure 4.6: Map of tutorials for students to navigate

Figure 4.7: Map of extra challenges posed as bonus questions

lar problems the students would be exposed to. In gaming terms, these would be the tasks a player can choose to complete to gain more experience points as well as skills in the game. They are not necessary to complete the game or progress through the story, but can help the player improve in the game as well as level up in the process in order to make the game easier for them. The same principle is applied here. The extra challenges are not mandatory for the students to complete the module, however, it is for their own benefit if they choose to do them as they will gain experience and skills they otherwise would not have. However, the "extra challenges" map remains unused at the time, as the lecturer and researcher believed it would be too complex for the time of implementation, thus the extra challenges are presented as bonus questions at the end of each tutorial for the time being.

The platform creates certain class settings that can be adjusted by the lecturer to fit the needs of their class. One such a setting is *behaviours*. Figure 4.8 illustrates positive behaviours that have already been added to the system and Figure 4.9 shows some of the behaviours considered as negative. As can be seen, positive behaviours reward players with experience points, where behaving negatively can cost a player health points. However, the nature and consequences of the negative

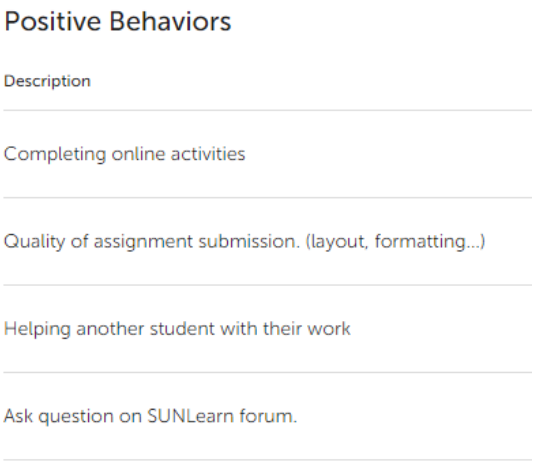


Figure 4.8: Positive class behaviours

behaviour setting is evident of negative reinforcement, which if done wrong can be very destructive in a class environment and was henceforth not included in this study. A study done by Sethi (2014) found that negative reinforcement is more effective in sparking an initial habit change, but in the long term, negative reinforcement does not get the job done, which is why positive reinforcement is what more people turn to.

There are three different types of points embedded in Classcraft, namely **Experience Points (XP)**, **Health Points (HP)** and **Action Points (AP)**. XP is gathered by characters whenever they complete an assignment or perform well in class through positive reinforcement. XP is also what is needed for characters to level up and learn new powers, which in turn will make it easier to complete certain assignments. HP is what keeps a team alive. When students do poor in certain assignments the lecturer creates, they will lose HP and will fall once their HP runs out, which will hurt their entire team. Each participant daily gathers AP with which they have the opportunity to use powers that can benefit themselves or their team, provided they are at a high enough level to use them. These powers differ depending on the character type chosen, however the Mage character has the ability to replenish AP.

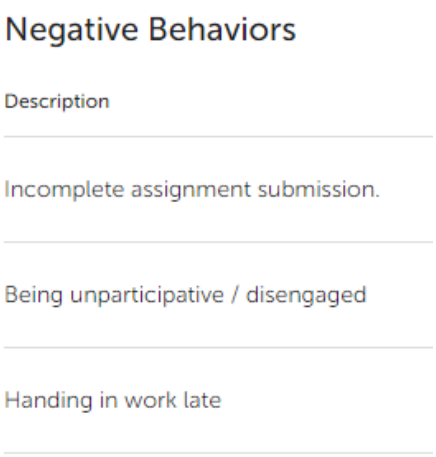


Figure 4.9: Negative class behaviours

Figures 4.10, 4.11 and 4.12 illustrates some of the different powers available to the guardian character, the healer character and the mage character respectively. It is recommended to the students that they have at least one of each character present in their team, to cover all the bases. Character descriptions can be seen in Table 4.2.

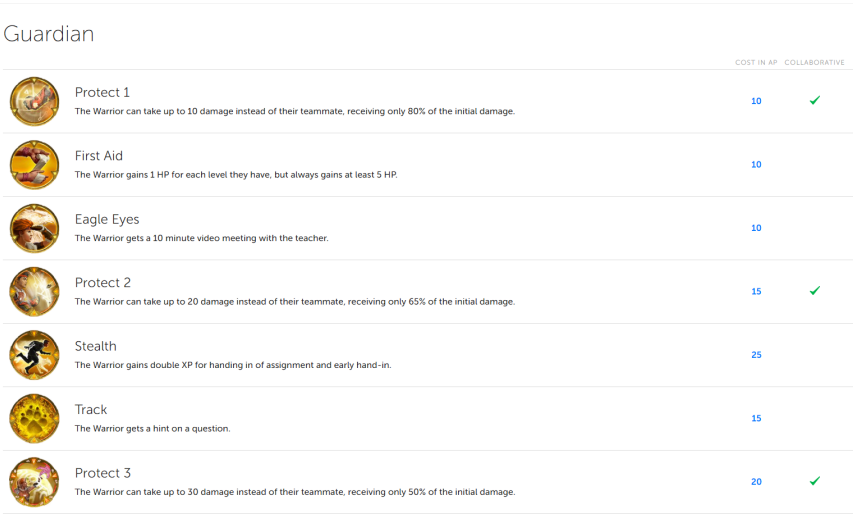


Figure 4.10: Guardian powers

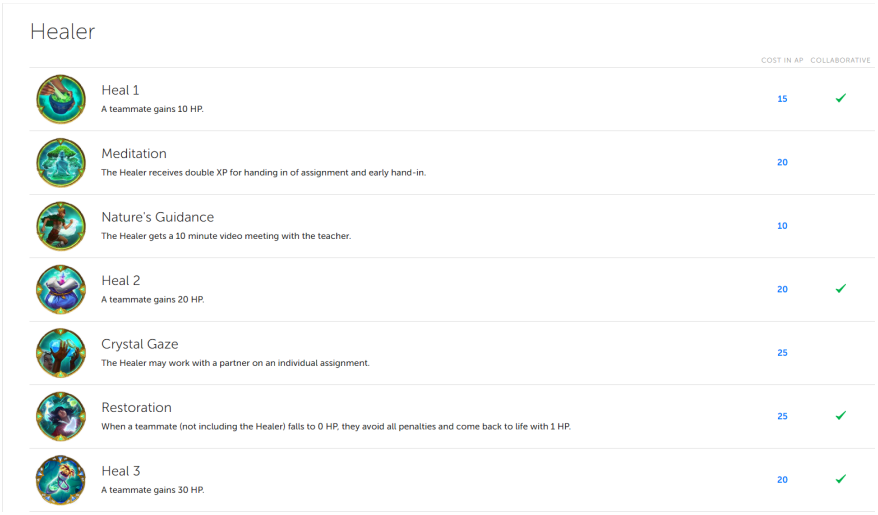


Figure 4.11: Healer powers

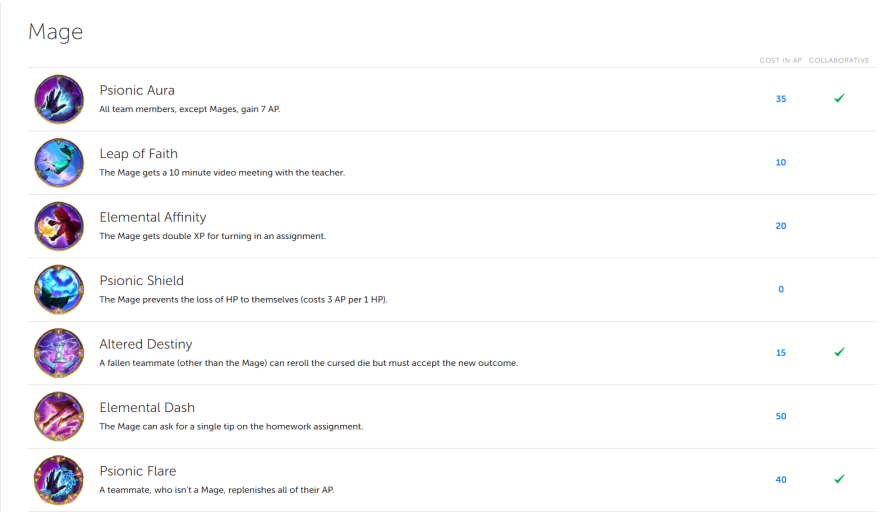


Figure 4.12: Mage powers

Table 4.2: Character descriptions of the available avatar selections on Classcraft

Name	Description
Guardian	The team defender, protecting their teammates from damage (losing HP). They are super strong, but cannot use their powers as often as the other characters.
Mage	The powerhouse of the team. They can use their powers the most often, but they have fewer HP. Mages can replenish AP so their entire team can use powers as often as possible.
Healer	The most balanced of the three characters in terms of HP and AP. It is the responsibility of the Healer to heal their teammates when their HP becomes low to prevent them from falling (which would cause everyone on the team to lose HP).

In terms of workload created for the students and lecturer, Classcraft is not at all demanding. The students simply have a platform that presents their usual work in a more fun environment, with the added aspect of being able to customise a personal avatar, gain experience points for doing assignments and displaying positive behaviour, as well as enjoying class in a different way. In terms of the educators, a class can be completely setup before a module begins, with only the student names, tutorials and extra challenges needing to be cycled if and when necessary. There is a messaging space on Classcraft where the lecturer can leave class announcements which broadcasts a message to the entire class without them being able to reply to them, as well as individual chat boxes between the lecturer and each student. This is a feature which can be used if the lecturer

and students find it convenient, otherwise all communications can continue via established platforms, such as email and SUNLearn.

4.3 Implementation for Student Participation

The gamification setup created on Classcraft was done for implementation to use by the final year industrial engineering class of 2020 in the module Simulation 442. This module was chosen for the implementation as this part of the study only started in the second semester and it was the only module at the disposal of the researcher. Introduced as a new teaching strategy, the lecturer of the module invited the entire class to voluntarily participate in Classcraft. Students were given an explanation through documents and a video telling them how to sign up and participate on the platform if they wanted to. In the video students were informed of the additional workload expected of them along with some of the technical aspects regarding the platform, such as the characters and their powers as well as how they can gain XP and level up their characters. The documents they received gave them specifics on the characters available as well as some incentives for them to participate. Listed in the documents were also the steps they needed to take to sign up to Classcraft for the specific module using their unique student codes and a class code specific to Simulation 442.

The students very rapidly responded to the invitation with roughly half of them signing up within a few days. Compared to the number of people that responded to the survey, the jump was indeed considerable. The assumption to be made is that people are less likely to consider something worth their time unless they receive something tangible from it. Of course, in participating in this system the belief is that they will improve their knowledge retention and overall experience of education, but in terms of getting people on board, they need some incentive other than intrinsic motivation. The incentive given to the students for participating on the platform is additional marks added to their Semester Marks at the end of the term. The top five teams who ended up with the most overall XP received 10%, 9%, 8%, 7% and 6% for ending up from first to fifth respectively, as well as every player received 0.5% for each assignment submitted

on the Classcraft platform. Through the responses the lecturer and researcher received at the beginning of the process, it appears as though the students were extremely excited to interact with the platform for reasons other than the obvious incentive. It can be attributed to the generation being more likely to have grown up with video games, making them inclined to try and participate in anything game-like. The students also showed appreciation for the effort created by the lecturer for trying to create new and inventive ways to engage the students that appeals to them and they marvelled at the idea of honing their skills in problems that pose more of a challenge than the regular tasks. To enhance students' skills in Simulation 442, bonus questions were added to the tutorials which were more challenging, but also repeated certain techniques practised in the tutorial. By doing these questions correctly, students were offered large amounts of XP.

On first glance it seems as though the start-up of the platform was successful as the responses received from the students were vastly positive. Since one of the main objectives of the platform is to enhance the overall experience of completing a module for students, the overwhelmingly positive feedback is indicative of successfully implementing something that approaches the students in a way that is more appealing to them. Classcraft gives the lecturer the opportunity to create certain "game rules" which regulate specific aspects on the platform. The rules created by the lecturer and the researcher can be seen in Figure 4.13.

Some of the more profound rules are the ones at the bottom specific relating to students gaining XP for doing well in tutorials. Above the XP students receive for simply participating, which is an example of *task-contingent* rewards, they also receive XP for doing well, which are *performance-contingent* rewards, explained in sub-subsection 2.5.4.2. These are employed in an attempt to keep the platform intriguing without it becoming too complex and labour intensive. As mentioned earlier, the students also have the opportunity to complete bonus questions with every tutorial which will grant them additional XP, which is also a form of *expected task-contingent* rewards. The lecturer also decided to give the students unannounced rewards at the end of the trial for behaving and performing a certain way, which is an example of *unexpected* rewards based on CET also

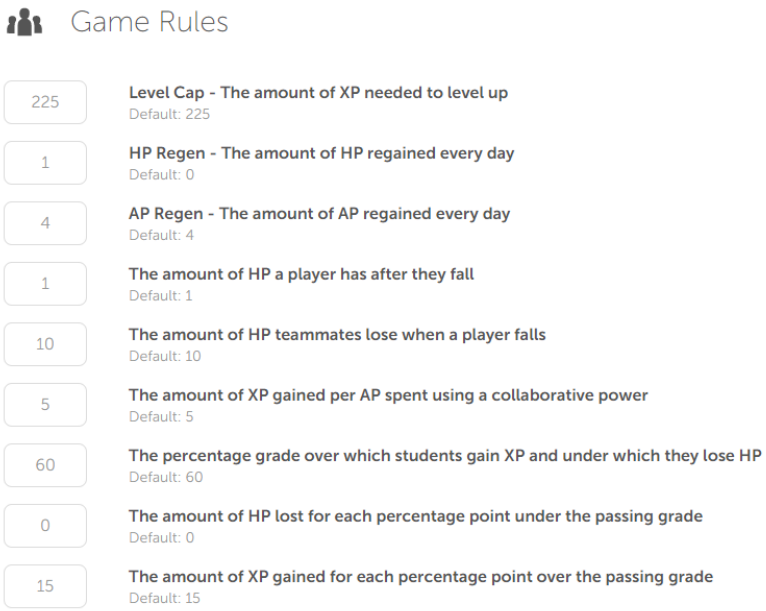


Figure 4.13: Classcraft game rules

explained in in sub-subsection 2.5.4.2.

With many of the available elements in Classcraft still unexplored, the system has a lot of potential to be of more use than proved in this study. There is a Premium version of Classcraft available with extra features that makes the system more enticing and appealing. It is up to the lecturer to decide whether or not to obtain this added package, however for this study, the most basic package was used for implementation to determine whether it holds value or not.

4.4 Summary of Gamification Implementation

Gamification is a powerful tool which can be implemented on numerous different existing platforms. From the line-up of platforms considered, Classcraft was chosen as the most suitable for this study with most of the elements desired for implementation already embedded on the dashboard. It acts as a layer of gamification around any curriculum, transforming the way students and teachers experience the classroom without taking away from the main goal of learning new

information. Classcraft presents a dashboard that can be created specific to the needs of the classroom, where student profiles are created on the system, they have the opportunity to create one of three customisable characters, complete assignments in the form of quests created by the lecturer, interact with their peers through kudos and participate in one-time events the lecturers present.

Also embedded in the platform are behaviours the lecturer can edit specific to their liking, which can function as guidelines for positive and negative behaviour which will either be rewarded or punished. The students receive a list of the behaviours the lecturer decided to keep on the system, to be informed of what is expected of them in terms of their behaviour. The students are also able to see the powers their respective characters are able to use to increase their odds of performing well in assignments as well as come to the aid of their teammates. Students must aim to create proper strategies where they use their Actions Points (AP) effectively in order to obtain as much Experience Points (XP) as possible while losing as little Health Points (HP) as possible.

Above the assignment-tasks and one-time events the students are able to complete in pursuit of XP, there are certain rules embedded in Classcraft which the lecturer can modify to their liking, which can also be used to specifically aid the students to gain more XP. These rules dictate the percentage above which students will receive rewards and how big of a reward they will receive for performing above said percentage. This mechanism available on the system is a way to ensure the students still pursue the main goal of attaining knowledge and applying it effectively. It ensures that the focus of the students is not shifted from the module content to the explorable aspects of the game.

With any new idea presented to someone, the onboarding process may need some incentive to start off. However, external rewards are not the answer to all questions, especially not in a gamified environment, where the focus can easily be shifted toward an unfavourable aspect. It is important for participants to realise that their participation will lead to the improving of themselves, thus any attempt necessary needs to be taken to ensure the students do not chase rewards

above improvement. Intrinsic motivation needs to remain the primary focus of participants and they should be informed on how the platform will aid in it, rather than replace it.

Chapter 5

Results of the Study

This chapter focusses on the results obtained from the gaming with Classcraft implementation during the Simulation 442 module. The results will revolve around the overall experience reported by the students along with their opinion on the increase in knowledge retention, as well as their feedback on possible shortcomings and improvements for the system.

5.1 Overall Experience of Gamification System

When observing the activity of the students on Classcraft, the researcher discovered that the students found the system intriguing and worth of participation. From the moment of implementation, students started to explore the system beyond the requested participation level. Students asked questions regarding the system and its workings, what they could do to earn more experience points and anything else they could do to interact more with the system. Embedded in Classcraft is a kudos system with which students can give praise to each other and earn bonus XP. When the students started to realise that some of their peers were receiving XP from kudos, they immediately contacted the researcher to determine how they also could earn these XP. At the start of implementation the curiosity overshadowed the cautiousness of the students with many of them signing up on the first day.

The curiosity decreased briefly as the weeks went by and the activity of the students started to slowly lessen, given that the platform as of yet is very basic with not much to do. However, since this is the first instalment of the system, there are bound to be some shortcomings which can be improved on by the lecturer and teaching assistants. The next iterations of the platform are sure to have expanded and improved on what exists, which in turn will spark more interest in the platform. Should this study prove successful as a trial and the idea of gamification can be branched out to other modules, the researcher believes that the activity on the platform from the students will increase immensely as engagement with the system will become more natural.

The researcher noticed through the students' use of Classcraft, the frequent engagement with Zichermann (2014)'s "three F's" as mentioned in Chapter 2 subsection 2.5.3. The lecturer and teaching assistants gave frequent feedback (first "F") to the students on their efforts and persona involving Classcraft. Kudos were mentioned earlier as part of the Classcraft platform where students can give praise to one another, either to their own teammates or members from another team for exemplary performance. This appeals to the second of Zichermann's F's in "friends" where the students enjoy interacting in a visually stimulating and entertaining platform with their friends from class. The third F, "fun", can be witnessed in the students' customisation of their Classcraft characters, which becomes possible with higher levels of their characters after earning sufficient XP.

Displayed in Figures 5.1, 5.2 and 5.3 are examples of customised guardian, healer and mage characters. In order for students to customise their characters, they need to spend Gold Points (GP) which will give them access to different items to equip their characters. This is purely for entertainment purposes and does not affect the statistics of the characters in any way. The students appeared to have a lot of fun with their character customisation as there were many different models created by the students whenever they received their allotted XP for completing and performing well in tutorials.

(a) Guardian at game start

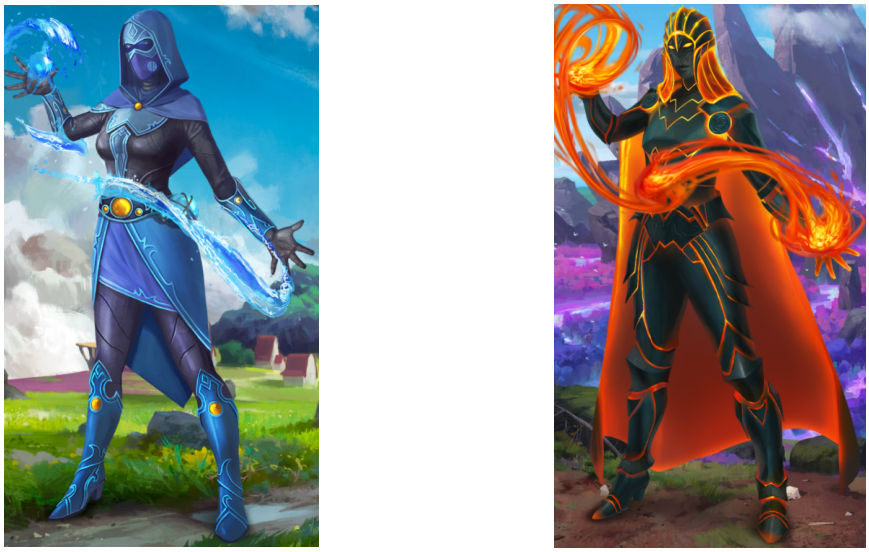
(b) Guardian after customisation

Figure 5.1: Guardian character customisation illustration

(a) Healer at game start

(b) Healer after customisation

Figure 5.2: Healer character customisation illustration



(a) Mage at game start

(b) Mage after customisation

Figure 5.3: Mage character customisation illustration

It seemed in the later stages of the semester the students started to participate less on the platform with regards to the minimum required participation, however, that can be equated to the increase in overall workload for the students in their other modules as well as their final year project all coming to an end. Although many of the students started to fade away in their participation, there were numerous extremely committed players who utilised the platform to its fullest and aimed to obtain as much XP as they possibly could. Many of them were also the ones who asked frequent questions on what more they could do on the platform, which is a big positive to take from this study, as the students experienced this as a new and fun way to engage with mundane and compulsory tasks.

5.2 Student Feedback on Classcraft

The students were extremely excited to start using the platform and try out something new, as this type of teaching method has never been attempted with this class before. The students noted that the platform looked impressive and

intriguing and were eager to start participation to begin accumulating XP. The students were prompted by their lecturer to provide feedback on their experience of gamification through the Classcraft system. Specific comments were asked regarding the positive and negative aspects of the platform, whether they believe the lecturer and future teaching assistants should continue with the system and whether or not gamification should be branched out to another subject in the subsequent year. Students were asked whether the platform created more work for them and if it was considered to be tedious. Any and all comments were welcomed, as the lecturer and researcher want to learn from their mistakes and improve on the system wherever they could. Again the feedback was given anonymously and the results from it is majority based, meaning the comments that were mentioned predominantly by the participants were added in this study.

The students gave extremely valuable positive feedback on the system, with many of them praising the lecturer and teaching assistants for the effort they exerted into attempting a new approach to something usually considered mundane. Some of the more common answers the students provided, were:

1. "It brings a fun motivation to compulsory activities which is quite refreshing."
2. "I really like this game idea! It looks fun and cool."
3. "Thank you for running Classcraft for us, I am really enjoying it!"
4. "I enjoyed the competition involved, it motivated me to start my work earlier and work hard to get the tutorial done by early hand-in."

The participants for the most part thoroughly enjoyed participating in Classcraft, specifically having something a bit more fun to do while having to complete their work. Many of them believed the bonus questions were challenging enough to motivate them to work harder which helped them to have a more in-depth understanding and build their knowledge on the module content. Another feature the students enjoyed was the ability to send kudos to one another, as it made them feel closer to each other due to their absence from the faculty as a result of

Covid-19. Some of the participants however, were mostly stagnant on the platform, did not participate as much or attempt to win at the game, they never asked questions or attempted to improve on the platform. They simply showed up and completed the bare minimum that was required of them. One of the shortcomings the students emphasised, is how the platform was introduced. They believe a more in-depth description of how the platform works, as well as ways to earn XP other than in the game itself, could have helped them in the long run by knowing the most efficient way to gain XP. Some of them suggested that due to the timing of implementation being when they were extremely busy with their final year projects, many of them were less inclined to properly participate. Of course due to circumstances, this was the only available time to implement the system as a trial run, with the aim of extending it to other modules which would run through the semester. If students are able to start the year with the system already in place, they would be more accustomed to it by the time the rest of their work becomes more intense and it would not cause a decline in motivation to participate.

Some of the students showed interest in features available in Classcraft that the researcher was not even aware of, such as pets for an extra element to the character customisation. The version of the platform used was however only the standard version, which meant the participants did not have access to this feature. Most of the students who gave feedback suggested that it would be a good idea to expand gamification to other modules, provided the semester is started with it already in place, so the students do not have to get used to a new system halfway through. As mentioned in earlier sections, certain elements such as leader boards amongst others can have an extremely negative effect on the outcome of gamification and hence was omitted from this study. However, through the feedback, the researcher learned that leader boards were one of the elements the students felt was missing in this iteration of the system. If leader boards are to be incorporated into the platform, it is suggested to do it in small scale by perhaps only displaying the top five players on the system instead of everyone, or a localised search mechanism where each participant can privately look at their own ranking. Another method of leader board incorporation to consider would be to display the top teams

instead of players. It would prevent individual students to feel diminished based on their ranking and motivate teams to come up with strategies which could put them in the lead.

5.3 Gamification Effect on Knowledge Retention

Unfortunately, due to unforeseen circumstances during Covid-19, the lecturer was unable to make an analysis on the effect gamification had on knowledge retention of the Classcraft participants, as the examination first considered for analysis only occurred after the deadline for the researcher's project. Since 41 students did not participate in Classcraft, the researcher exploited this and took them as a control group for the analysis. As a result, the analysis was made on two difference outcomes, one test focussed on the performance of the students prior to gamification and another on their performance after gamification. The first statistical analysis tests the difference in averages between the participants and non-participants of Classcraft based on their first formative assessment (A1), the second analysis tests the difference in averages of the two groups over the last five tutorial assignments. For the sake of anonymity, all statistical evaluations were done by the lecturer who provided the researcher with the results.

Figures 5.4 and 5.5 illustrate the histograms from the analysis done on the A1 averages of the two control groups. The purpose of performing a statistical analysis on the students' performance before gamification was to determine how close the two groups were in terms of ability before the implementation of gamification, so as to not skew the results after being subject to a new teaching method. In these figures it is clear that the two groups performed remarkably similar in their first assessment, with both graphs peaking at the (60,65] interval.

The lecturer also performed a two-tailed statistical t-test in Excel with unequal, unknown variances on the outcomes of the assessment with the null hypothesis stated as:

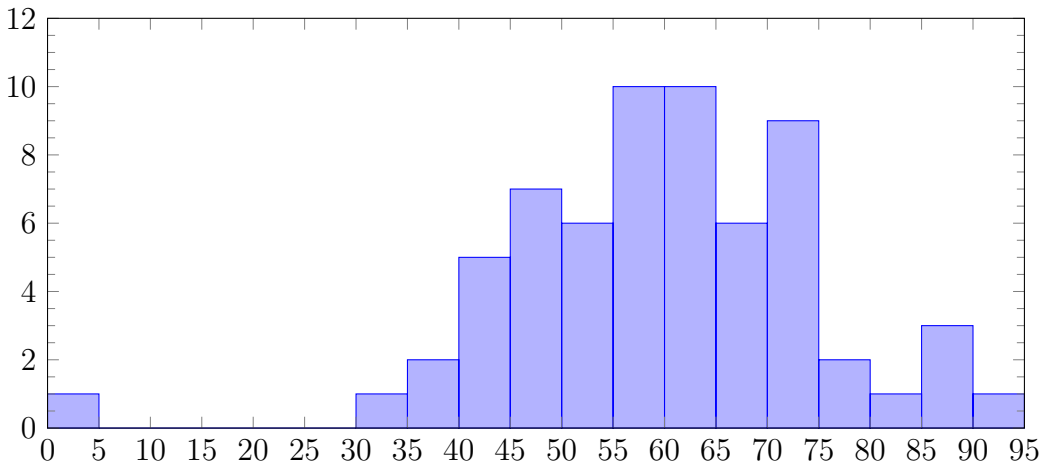


Figure 5.4: A1 Average of Classcraft Participants

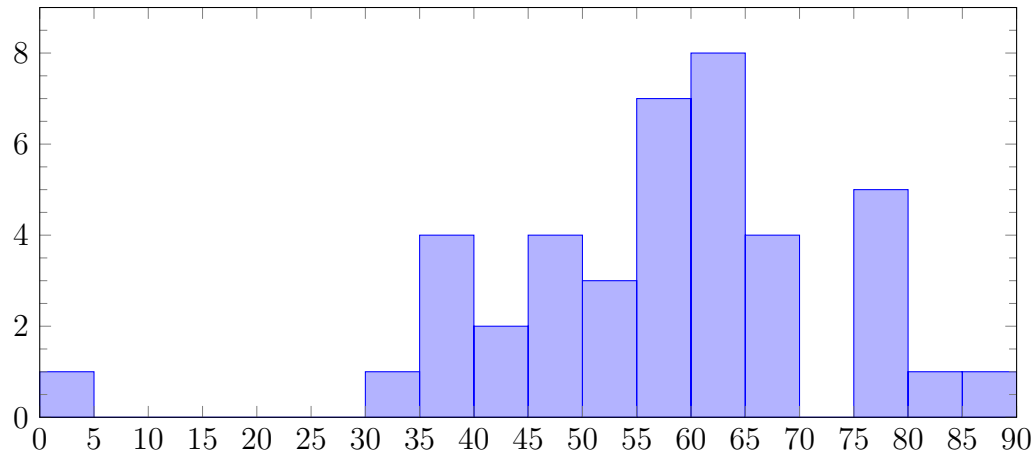


Figure 5.5: A1 Average of Non-Participants

H_0: There is no difference between the averages of the Classcraft participants and non-participants before participating in gamification.
H_1: There is a difference between the averages of the Classcraft participants and non-participants before participating in gamification.

The parameters of the test were as follows: $\mu_1 = 59.48\%, \mu_2 = 57.10\%, n_1 = 64, n_2 = 41, V_1 = 220.16, V_2 = 260.19, df = 80$. The results can be seen in Table 5.1.

Table 5.1: t-test results on the difference in group averages for A1

t-Test: Two-Sample test Assuming Unequal Variances at $\alpha = 0.05$

	Variable 1	*Variable 2*
Mean	59.48	57.10
Variance	220.16	260.19
Observations	64	41
Hypothesized Mean Difference	0	
df	80	
t Stat	0.76	
P(T<=t) two-tail	0.45	
t Critical two-tail	1.99	

The results obtained from the analysis show a p-value of 0.45 for a test conducted on two samples while assuming unequal variances with the critical t-value indicated as 1.99. The t-statistic = 0.76, falls in the interval (-1.99, +1.99) which is the non-critical region for a two-tailed t-test, indicating there is no difference in averages between the two groups. The p-value exceeds α, which means the null hypothesis is not rejected.

Figures 5.6 and 5.7 display the average distribution of the Classcraft participants and the non-participants respectively. The figures show the difference in distribution between the two groups based on their performance during the final set of tutorial assignments. In Figure 5.6 the average of the Classcraft participants is

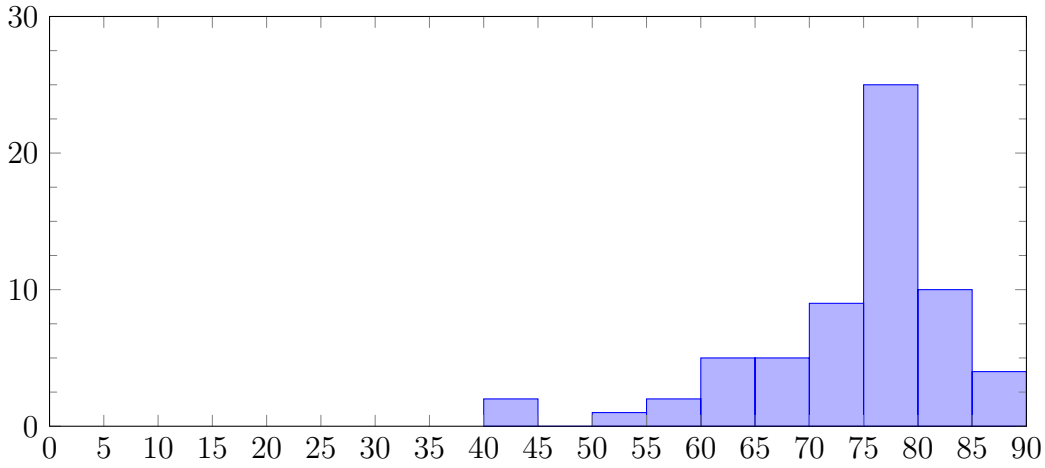


Figure 5.6: Tutorial Average of Classcraft Participants

shown to peak in the (75,80] interval, with more than 25 of the participants achieving an average of over 75%. By contrast, the average for the non-participants seen in Figure 5.7, shows a peak in the (70,75] interval with the data showing only seven of the students achieving an average above 75%. The difference in means between the two groups was almost 14 percentage points, with the Classcraft group achieving an average of 74.01% and the control group an average of 60.4%.

A second two-tailed t-test with unequal, unknown variances was performed on the difference in means with the null hypothesis stating:
H_0: The participants in gamification achieved the same mark as the control group, *i.e.* $\mu_1 = \mu_2$
H_1: The participants in gamification achieved higher marks than the control group, *i.e.* $\mu_1 > \mu_2$ with μ_1 as the average of the Classcraft participants.

The parameters for the test were as follows: $\mu_1 = 74\%, \mu_2 = 60\%, n_1 = 64, n_2 = 41, V_1 = 94.11, V_2 = 392.26, df = 52$. The results of the t-test can be seen in Table 5.2.

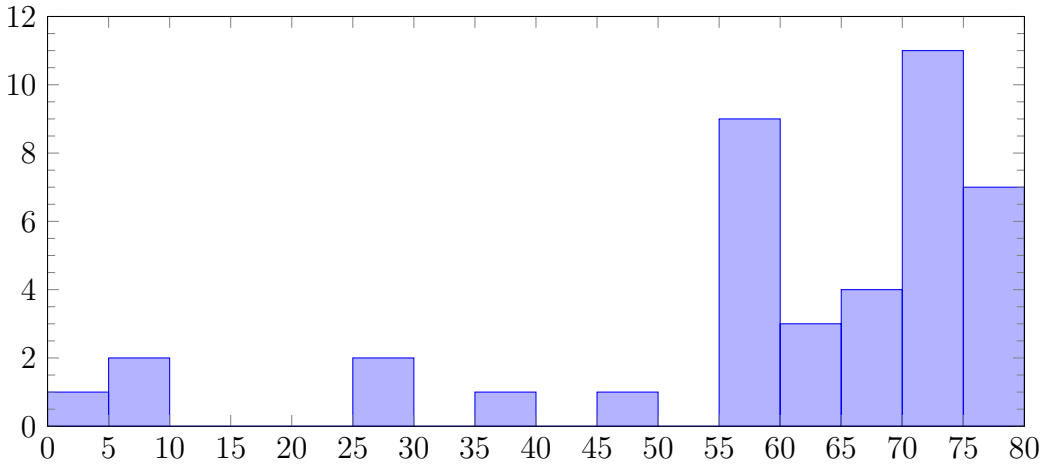


Figure 5.7: Tutorial Average of Non-participants

Table 5.2: t-test results on the difference in group averages for tutorials

t-Test: Two-Sample test Assuming Unequal Variances at $\alpha = 0.05$		
	Variable 1	*Variable 2*
Mean	74.0	60.4
Variance	94.1	392.3
Observations	64	41
Hypothesized Mean Difference	0	
df	52	
t Stat	4.1	
P(T<=t) two-tail	0.00014	
t Critical two-tail	2.0067	

Since the p-value is less than 0.05, the null hypothesis is rejected in favour of the alternative hypothesis. The t-statistic is much larger than the test statistic ($4.1 > 1.67$), so there is statistically significant evidence that $\mu_1 > \mu_2$. The conclusion is therefore that the Classcraft participants outperformed the control group.

Two more tests were conducted based on the results of the two groups' perfor-

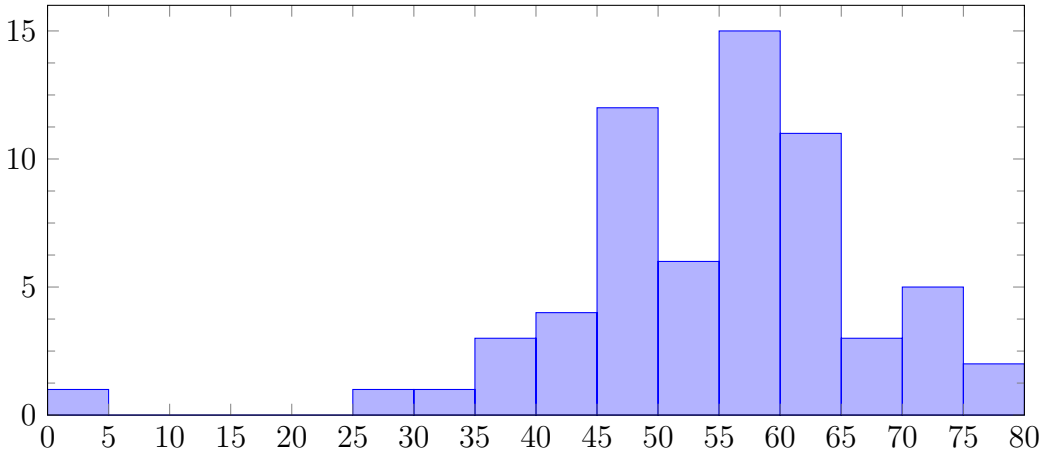


Figure 5.8: A2 Average of Participants

mance in the second assessment (A2) as well as their final marks. Figures 5.8 and 5.9 illustrate the average distribution of the A2 assessment for the Classcraft group and the control group respectively.
The results of the two-sample t-test while assuming unequal, unknown variances for the results of the A2 assessment can be found in Table 5.3. The hypotheses for this test are stated as follows:

H_0: There is no difference between the averages of the Classcraft participants and non-participants after participating in gamification.
H_1: There is a difference between the averages of the Classcraft participants and non-participants after participating in gamification.

The parameters for this test are as follows: $\mu_1 = 54.66\%, \mu_2 = 50.61\%, n_1 = 64, n_2 = 41, V_1 = 161.56, V_2 = 160.86, df = 86$.

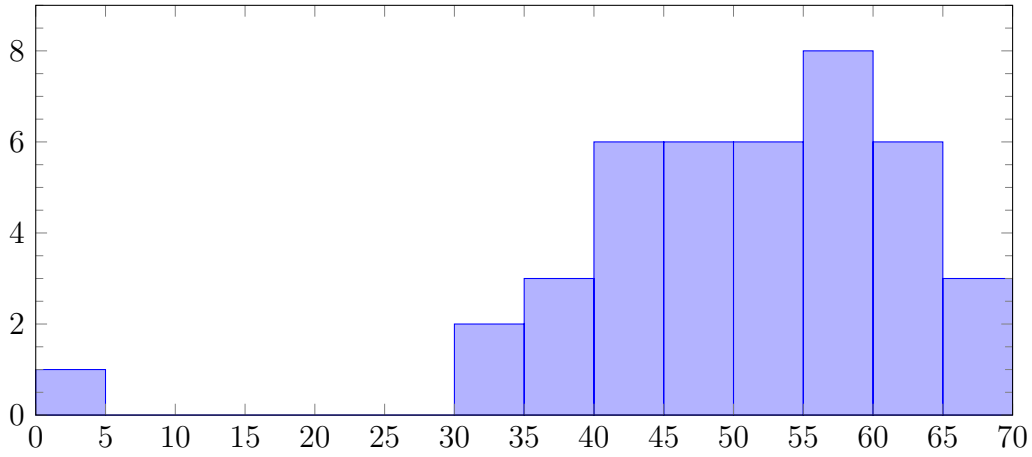


Figure 5.9: A2 Average of Non-participants

Table 5.3: t-test results on the difference in group averages for A2

t-Test: Two-Sample test Assuming Unequal Variances at $\alpha = 0.05$

	Variable 1	*Variable 2*
Mean	54.66	50.61
Variance	161.56	160.86
Observations	64	41
Hypothesized Mean Difference	0	
df	86	
t Stat	1.6	
P(T<=t) two-tail	0.11	
t Critical two-tail	1.99	

From the table, the t-statistic is 1.6 with the critical interval being (-1.99, +1.99). The p-value of 0.11 is greater than the α-value of 0.05, which means the null-hypothesis is not rejected. There is thus statistically significant evidence that the performance of the two teams some time after gamification is the same.

The fourth test was conducted between the two groups based on their final mark after the semester has ended. Figure 5.10 displays the average distribution of the Classcraft participants and Figure 5.11 displays that of the non-participants.

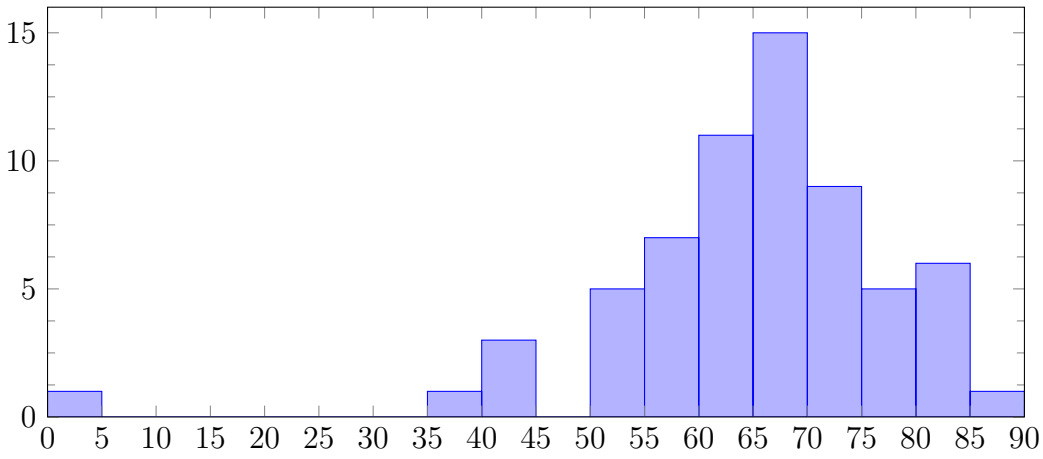


Figure 5.10: Final Mark Average of Participants

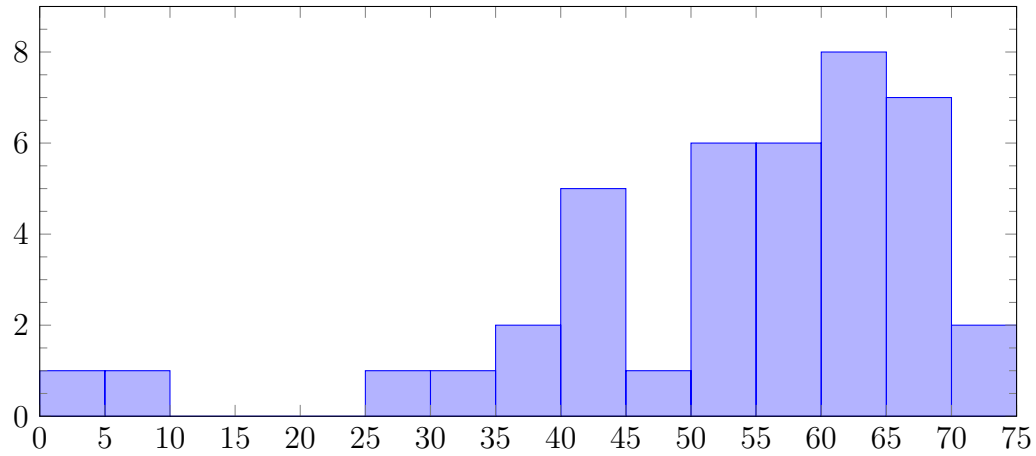


Figure 5.11: Final Mark Average of Non-participants

The results of the two-tailed t-test for the final marks analysis can be found in Table 5.4. The hypotheses for the final test are formulated as follows:

H_0: There is no difference between the averages of the Classcraft participants and non-participants after participating in gamification.
H_1: There is a difference between the averages of the Classcraft participants and non-participants after participating in gamification.

The parameters for the test are as follows: $\mu_1 = 65.55\%, \mu_2 = 53.76\%, n_1 = 64, n_2 = 41, V_1 = 169.24, V_2 = 246.59, df = 74$.

Table 5.4: t-test results on the difference in group averages for A2

t-Test: Two-Sample test Assuming Unequal Variances at $\alpha = 0.05$

	Variable 1	*Variable 2*
Mean	65.55	53.76
Variance	169.24	246.59
Observations	64	41
Hypothesized Mean Difference	0	
df	74	
t Stat	4.00698	
P(T<=t) two-tail	0.00015	
t Critical two-tail	1.99	

It is clear from the table that the t-statistic of 4.00698 falls outside of the non-critical interval of (-1.99, +1.99). Along with the p-value of 0.00015 being smaller than the α-value of 0.05, the null hypothesis is rejected in favour of the alternative hypothesis. This means that there is statistically significant evidence that the Classcraft group performed better by semester end than the control group.

5.4 Summary of the Results

The results of this study were determined based on the outcomes of numerous factors, such as the overall experience of the gamification system, the feedback from the students regarding Classcraft and the results of the statistical analysis on the students' performances. The launch of the gamification system to the students was successful, as more than half of those invited signed up within the first few days. Immediately the platform sparked interest in the students and many of them contacted the researcher to determine efficient ways to play the game. The students promptly started to experiment with the system and explore the possibilities to attain as much XP as possible. Due to being the first iteration of a gamification strategy as a teaching method, the platform was rather basic and as quickly as students started to experiment with the system, they also lost interest. There were a number of highly dedicated participants that retained their excitement for the platform until the end, but for many of them it became another task to simply tick off. With the rewards being presented to the top participants, it makes sense that the ones at the bottom of the leader board would lose interest and stop trying to win as it seems out of reach. The key to take from this is that more emphasis need to be placed on the intrinsic value of the system rather than the extrinsic reward which can be attained. If the participants were informed of and realised the importance of using the system to improve their ability, less focus would have been placed on the external rewards and more on the intrinsic value it adds to them.

The participants were asked to anonymously present their experience of the gamification system, both positive and negative, to inform the lecturer and researcher on aspects of the system which functioned well and which ones require attention. The students were very pleased with a new strategy that was attempted by the lecturer, as this has never been done before in the department of industrial engineering and it made them feel the lecturer wanted the students to achieve. The students believed that the strategy was a good way to approach them and appeal to their interests. They liked the aspect of having fun while doing something compulsory and mundane, where they can collaborate with their friends,

send kudos to them, help them with assignments, come to their characters' aid, customise their characters and challenge themselves with bonus questions while having no penalty for failing. The students did illuminate some shortcomings which the lecturer and teaching assistants will need to address in further iterations. They suggested a more in-depth explanation of how the system works and the most efficient ways to earn XP. They also believed there were certain ways to earn XP which they were not made aware of, which is something the lecturer and teaching assistants need to decide if they will tell the students about it or let them figure it out for themselves. A few of the students also suggested for a leader board te be implemented in future versions, which would help motivate them if they see another team not far above them in terms of XP.

The statistical analysis tests which were performed on the participants and non-participants before and after they participated in gamification, revealed some promising results in terms of academic performance. The first test was performed on the results of the two groups based on their first formative assessment (A1), which was completed before they participated in gamification, where a t-test was done to determine the similarity in average for the assessment between the two groups. The results indicated that the two groups performed remarkably similar with the conclusion made: there is no difference in average between the two groups. The second t-test was performed on the final five tutorial assignments of the two groups which were completed during gamification. The results showed a massive jump in the performance of the gamification group, scoring 14 percentage points higher in average than the non-participants. Another two post-tests were completed with the second assessment (A2) and final marks of the students, to determine whether a difference in performance existed after more time has passed since being subject to gamification. The test regarding the performance of the students after A2 were unflattering as the results indicated there to be no statistical difference in the two groups. However, when the final marks were evaluated, the results again indicated a strong statistical difference between the two teams of 12 percentage points. These results as positive and promising as they are, unfortunately do not reveal the effect on knowledge retention, as there is not yet a reliable way to measure it. This is however part of the future work

for this study to determine a more effective way to measure knowledge retention.

Chapter 6

Conclusions

The conclusions and recommendations on this study are presented in this chapter. Conclusions were made based on the results obtained from the surveys, the Classcraft system and the results of all the students, both on those that participated and those that did not. The recommendations stem from all the shortcomings that the researcher noticed in the version of Classcraft that was set-up, as well as some points the students brought to the attention of the researcher.

6.1 Project Summary

This study focussed on the education of industrial engineering students, as well as if it can be improved in terms of the depth of knowledge and knowledge retention of the students. The purpose was to look for new and innovative ways for modules to be presented which would aid the students with increasing the amount of knowledge they retained as well as how well they understood the content after exposure. In depth research was done on the history of education and traditional methods of teaching, as well as modern methods, comparing the two to determine if there is a difference in effectiveness. After the evaluation of numerous teaching methods, both old and new, gamification was identified as a possible solution that can enhance the overall experience of students, increase their motivation and improve their retention of knowledge. A gamification strategy was implemented as a teaching method and statistical tests were done before and after participation to determine its effectiveness. The analysis indicated that there is indeed an

increase in academic performance between the participants and non-participants. At the time there was unfortunately no reliable way to measure the amount of knowledge retained by participants, but the increase in academic performance was indeed considerable and worth exploring further.

6.2 Conclusions on Gamification System

From the research done in the study, the researcher concludes that gamification is indeed a viable option for the education of industrial engineers. The literature study for this project revealed how extensively the traditional methods of teaching are still being used and how little exploration of modern methods there is. While there is merit to using different modern teaching approaches, they are still limited to how effective they can be when considering the different student profiles and their learning styles. Ultimately, the most important aspect to consider is the opinions of whomever will be subject to the implementation of a new teaching/training approach. For the strategy to be successful, the target group need to have a positive experience from early in implementation, else the negative effect will have far more severe consequences than not implementing anything.

Through the gathering of research on different study methods during the literature study, the survey results and the implementation of gamification, it was discovered that gamification has the potential to create a platform which embodies everything needed for students to flourish in their educational environment. From the survey results specifically, it was learned that the concept of gamification is widely unknown, which caused some hesitation when imploring students to sign up, as people are generally weary of the unknown. If a strategy could be employed where a combination of gamification and the talk-and-chalk method can be explored, with an attempt to gradually decrease the use of talk-and-chalk and increase the move to gamification, the students might be more susceptible to accept the new platform. Gamification provides the potential platform for collaboration, competition, practical experience and fun, all which can contribute to the outcome of a students' performance. Though certain extrinsic rewards may be necessary for the onboarding of participants, however, only once

they experience intrinsic value in something, they tend to stay on-board, as they find meaning and fulfilment from it. From various case studies it was learned how gamification has proven successful in this regard and the participants experienced immense enjoyment in tasks previously thought to be tedious and unimportant.

In terms of added workload and the time one needs to spend maintaining the Classcraft system, the requirements are not extensive. The system can be set up completely beforehand in such a way that the maintenance during use is minimal. The design of Classcraft is optimal for the focus of the lecturer to be on the content rather than the upkeep of the system. If there are quick one-time events the lecturer or teaching assistant wants to administer, it can be done with ease as Classcraft has numerous features called Class Tools embedded into it, such as "The Riders of Vay" which creates random one-time events for everyone to enjoy; "Boss Battles" which can act as a spontaneous formative class test for the students to pass; or "The Wheel of Destiny" where one team or student is selected to answer questions to earn points.

6.3 Recommendations

The recommendation for this study, if it were to be taken forward and developed further, would be to expand the platform. There are many untapped resources not yet explored in terms of gamification as well as simply the Classcraft platform. Since the basic version of the dashboard was used during this study, there are other elements on Classcraft that were left unused, but could have proved to give more enjoyment and motivation to the students using it. Gamification is indeed a powerful tool that the researcher believes should be explored in more education areas, even if only in small steps. It is due to this reason that gamification is so useful, as it can be modified to the needs and comfort specific to each classroom. There is no one size fits all when it comes to gamification, but rather certain basic principles that need to be adhered to. If that can be done, it does not matter what form the gamification systems take, as long as it functions in its role to increase motivation and improve overall user experience as well as knowledge

retention in the case for this study.

The researcher suggests that gamification be expanded to other engineering disciplines, as well as at least considered for other teaching domains. Gamification has proved to be successful numerous times before in the short time that it has been explored since the early 21^{st} century, even outside of education. Gamification is not merely for education, but for any work environment, where people need to be motivated to do something considered tedious in other ways than extrinsic motivation or external rewards. It is also suggested that a move toward gamification should be administered gradually in small scale, with the participants receiving enough time to become acquainted with the new system, instead of being overwhelmed with a complex implementation of something unfamiliar. As participants become more used to gamification and its aspects, the question can be raised to them as to what they believe the system lacks and what they would like to see implemented. Probably the most important aspect of any gamification system is an immediate feedback loop. Participants need to receive instant feedback on their performance, what they are doing well and what they can improve on. They should also be able to respond and give comments on what they believe to be functioning well and what the implementers of the strategy can improve on. It is important to realise that no first iteration of a gamification system will be flawless, but that the system can always stand to become better and more effective in its task to motivate people.

6.4 Future Work

The future of this project is expansive considering the capabilities of gamification as a teaching strategy and the possibilities it holds. In terms of certain shortcomings that can be expanded on from this study, the future work involves determining methods to measure knowledge retention more accurately. The retention measured in this study was done on the principles of other studies with a strong focus on statistical analysis based on the academic results of the participants and non-participants. However, the possibility exist that there is a more effective and efficient method of measuring the knowledge retention of individuals. Another

consideration would be to use formal surveys before and after gamification to determine its impact on the students. Finally to share the experience and knowledge gained from the study with other lecturers to determine their willingness to adopt gamification as a teaching strategy.

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Appendix A

Problem Background

Included in this appendix is Figure A.1 illustrating the timeline that was followed in completion of this thesis document.

Ethical clearance was obtained for the data collection part of this study. To ensure the safety of participants, they will partake anonymously and no private information will be required of them. The ethical clearance reference is ING-2020-14790 and a figure of the clearance can also be seen in Figures A.2 and A.3.

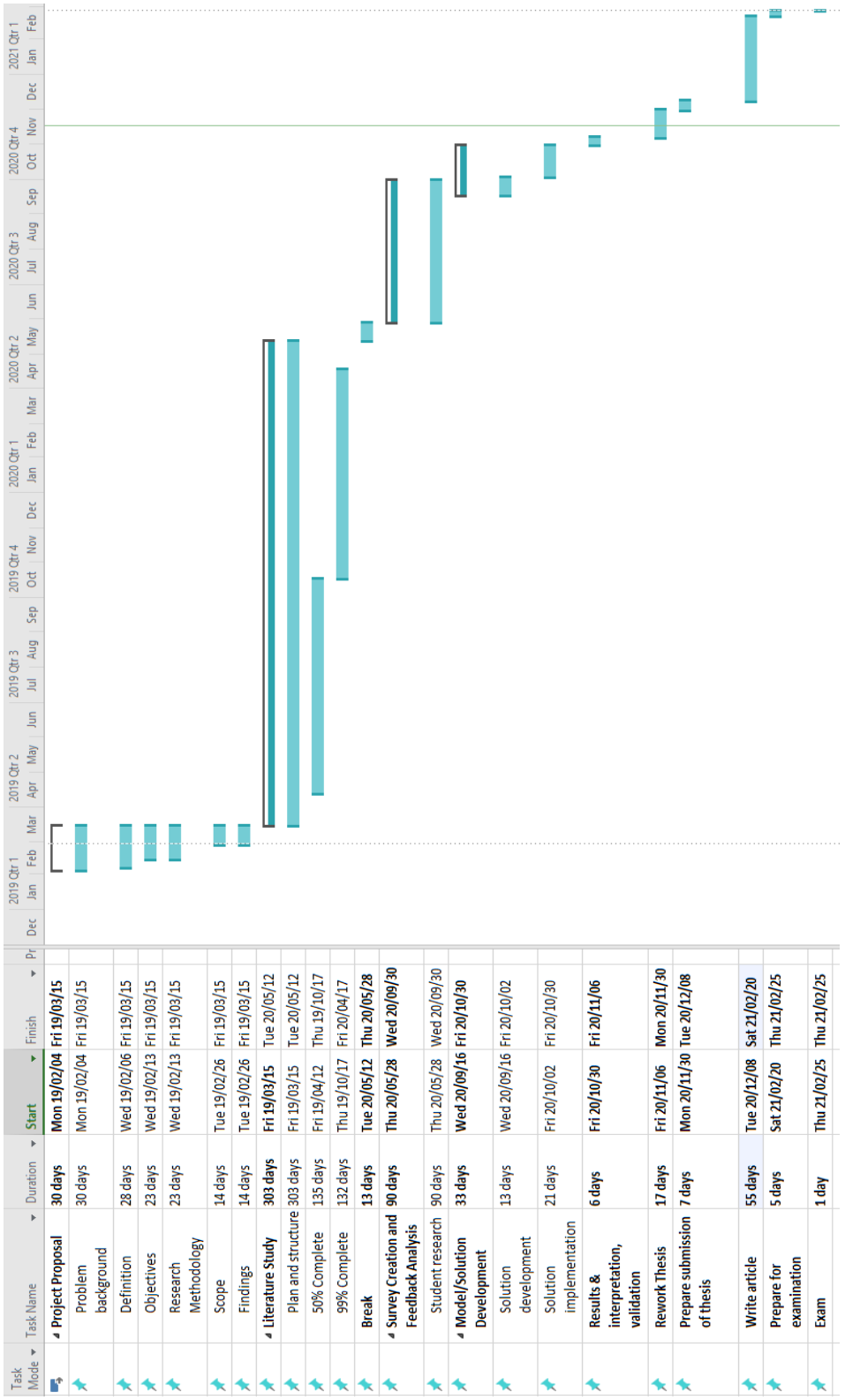

Figure A.1: Thesis Timeline and Gantt Chart

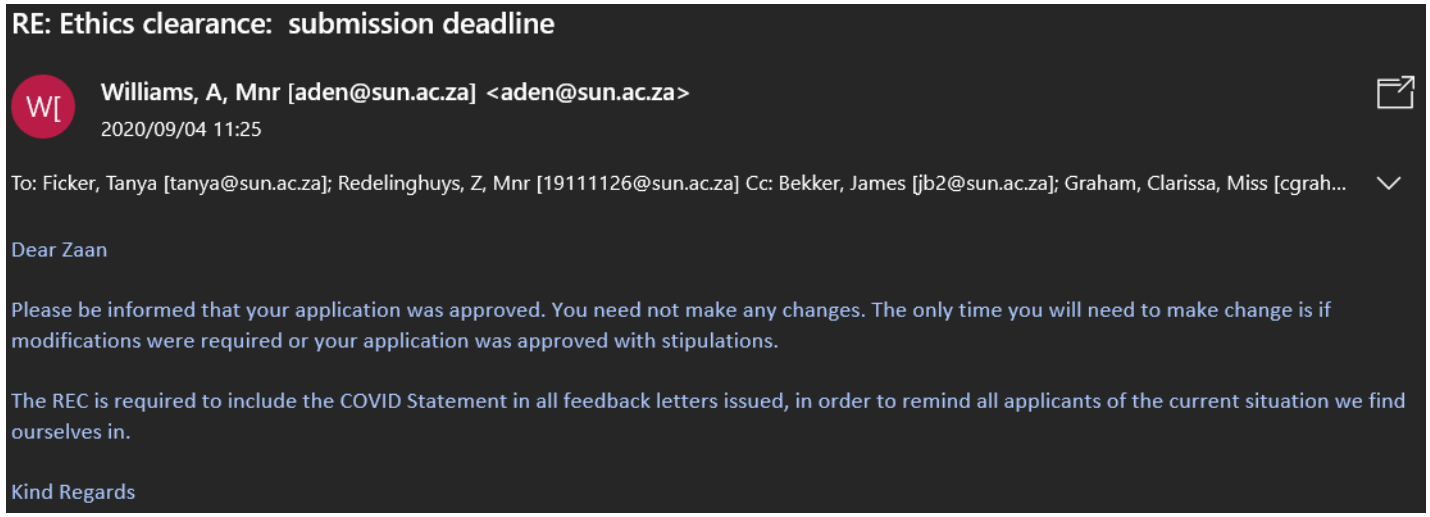

Figure A.2: Message confirming ethical clearance was obtained

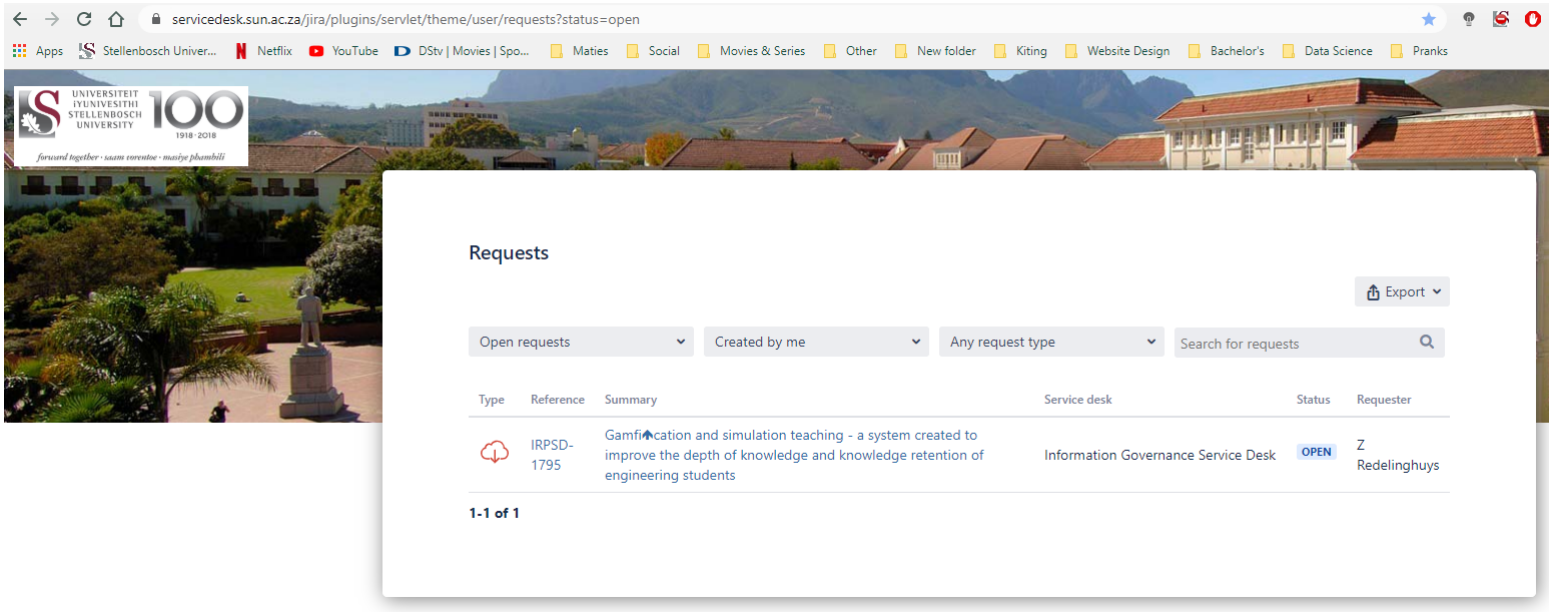

Figure A.3: Annotation of institutional permission application

Appendix B

Literature

This appendix contains additional information on some of the topics covered in Chapter 2. This is merely to satisfy any further interest in the associated topics that were not mentioned in the thesis document.

B.1 Gamification

B.1.1 Gamification in education

The work of Denny (2013) was mentioned in Chapter 2 in which a study was done to determine the effect that the gamified element known as "badges" have on the motivation and engagement of students. His work was expanded on in 2018 in which he also considered different learning measures. In this study a total of 2101 students were given the opportunity to voluntarily partake in the online tool PeerWise that makes use of collaborative learning to help students study for exams. Of the 2101 possible students, 701 of them registered to PeerWise and started using it. The students were divided into two major groups, **control** and **"game"**, where the "game" group was subjected to gamified elements, namely **"points'**, and **"badges"**. The "game" group was further divided into three subgroups, **"points"**, **"badges"**, and **"both"**, meaning that some were only exposed to points, others only to badges, and the rest were exposed to both. The groups were assessed on their engagement in the online tool with regards to their

level of activity in authoring and answering questions. The data collected from these assessments were used to formulate and test the following four hypotheses:

1. Gamified elements will cause an increase in student activity
2. Student activity will be impacted more when game elements are used in combination rather than individually
3. Student activity will positively impact exam outcomes
4. A casual relationship between gamification and exam outcomes will be mediated by student activity (Denny et al., 2018)

Of these three hypotheses, only the second one was rejected, as the combination of points and badges indicated no measurable effect on authoring and answering questions above that of only implementing badges. The conclusions drawn from this research using the PeerWise tool, firstly is that gamification elements increases the activity level of students specifically with regards to answering questions. Secondly, that there exists a strong, causal relationship between the number of questions answered and their resulting exam performance. Thirdly, that this acts as a mediator between gamification and exam scores (Denny et al., 2018).

B.1.2 Six Thinking Hats (STH)

The iThink STH method game mechanic design that was developed by Fernandes et al. (2012) is for the use of requirements elicitation. This was adjusted over the traditional method. Each hat resembles an activity in an elicitation process, and executing them will contribute to generating new requirements and discussions. The blue and green hats contains the majority of the main adjustments that are proposed. The project manager uses the blue hat in the iThink setup, to define the categories of group requirements. In the gaming context of receiving points, wearing this hat doesn't grant points as the project manager is not considered a player. When players are creating and proposing new requirements, they use the green hat and when this is done, points are generated. The points system specific to STH will be explained later, but can be seen in Table B.1.

Table B.1: Scoring scheme of STH

Tasks	**Points**
New requirements	500
Rating requirement	50
Positive comment	100
Negative comment	100
Statistical comment	50
Bonus	100

The rest of the hats are related to opinions and facts generated toward existing requirements. There are four colours related to this category, starting with red dealing with emotions and feelings regarding an existing requirement. These have no need for factual justification, as these are opinions regarding a requirements from the person wearing the hat. The person wearing the white hat cares about giving statistical facts in a neutral and objective way. Positive comments on a requirement is given by the yellow hat and gives reasons why the topic might be good.

As for the scoring scheme, points are awarded for various activities while wearing the different hats. Creating a new requirement generates the most points since this is the most important task. Other tasks include things such as rating a requirement, giving concrete statistical comments, positive comments, negative comments, and bonus points for completing a discussion in full, each with their own importance rating and awarded points.

The point allocation for the various tasks can be seen in Table B.1. As mentioned earlier, creating a new requirement scores the most points of 500 as this is the main objective. Further, rating a comment scores 50 points as this is a rather simple task, as does giving a statistical comment, which may be more difficult, but is not as vital for elicitation as other tasks. While positive and negative comments may be easy to express, they are more important to the process of elicitation and are thus awarded 100 points each. Finally, 100 bonus points are awarded, whenever

a discussion on requirements are completed in all four available ways.

Appendix C

Questionnaire

In this appendix the questionnaires used in the surveys sent out to the students can be found. As stated in Chapter 3, the first questionnaire was created to gather data on students' experiences with the current education and teaching systems. Whereas the second questionnaire focussed on acquiring data on the new method desired for implementation and the students' perception thereof.

C.1 Questions

Learning Methods

The following questions are specific to the learning methods students use.

1 How often do you attend class? (All modules as a whole)
Always
Often
Rarely
Never

2 Do you study alone or in a group?
Alone
In a group
A combination of both

3 If a module has a textbook, do you study from it?
Always
Often
Rarely
Never

4 How do you learn content for examinations? (choose more than one if applicable)
Written out summaries
Typed out summaries
Read information only
Speak/Read aloud
Other:

5 How long, in weeks, do you start studying before an examination?
Less than 1 week
1-2 weeks
2-3 weeks
3-4 weeks
More than 4 weeks

6 If the lecturer provides notes on SunLearn, do you:
Study only from notes
Study only from textbook
Study from the notes and the textbook

7 During a lecture, do you:
Make your own notes
Make your own notes and use the lecture notes
Use only the lecture slides

8 If the lecturer does provide notes, do you find it beneficial?
Never
Sometimes
Always

9 Where do you study for examination?
On campus
Place of residence
Other:

10 Do you use previous examinations papers to learn from, if there are available?
Yes
No
Sometimes

11 Do you work with a memorandum or only look at memorandum after completion of question paper?
With the memorandum
Look at memorandum after completion of paper

12 If you explain information to someone else, do you understand it better and learn more?
Yes
No
Sometimes

13 If another student explains work to you, do you understand it better?
Yes
No
Sometimes

14 Do you use visual materials or symbols to remember content of work?
Yes
No
Sometimes

15 Do you use different colours when you study for an examination?
Yes
No
Sometimes

The Teaching Environment

The following questions are focussed on the learning experience of the student.

16 What type of teaching method do you think is used by the majority of lecturers? (choose more than one if applicable)
Read out of the textbook
Use slides to present information
Write down information for students to copy down
Interactive methods where students discuss topics
Discussion and questions of topic
Group work and practical experience

17 By the use of what method do you remember content taught to you the best?
Work explained by a lecturer
Information learnt by yourself (Self study)
Group work completed
Practically applying knowledge learnt
Information explained to you by another student
Other:

18 Do you think that teaching should be more intuitive and not based on specific methodologies, such as in school?
Yes
No
Neutral

19 Do you think that each module should have weekly assessments based on the work taught in that week?
Yes
No
Neutral

20 Do you prefer individual work or group work?
Individual work
Group work
Neutral

21 Do you retain information applied practically better than hearing it in a lecture?
Yes
No
Neutral

22 On the scale below, how well do you remember content taught in first or second year? (1 being not at all, 5 being very well)
1 2 3 4 5

23 Do you pay more attention in a lecture when you enjoy the module?
Yes
No
Neutral

24 Do you prefer the "talk-and-chalk" teaching method where the lecturer stands in front of the students and presents information only?
Yes
No
Neutral

25 If you have a cellphone on you during a lecture, do you make use of it?
Yes
No

26 If yes, do you see it as a distraction to not gaining all information taught?
Yes
No
Sometimes

27 Do you think that students should be able to teach one another and that a lecturer acts as a facilitator in the process?
Yes
No
Neutral

28 How often do you raise a question in a lecture, if you do not understand the content being taught?
Always
Often
Rarely
Never

29 Given the recent Covid-19 situation, do you enjoy online lectures more than traditional lectures? If yes, why?
Yes

No
Explanation:

30 Do you think the number of students in your class is too high?
Yes
No
Neutral

31 What would be your idea of an ideal teaching/lecturing environment?
Explain:

Gamification

The following questions will focus on the concept of gamification in a learning environment.

32 How familiar are you with the term gamification?
I have done quite some research on it
I have seen a TedTalk about it
I heard someone say they read about it
Not at all familiar

33 If anything other than "Not at all familiar" at the previous question, what is your understanding on gamification? (in three sentences or less)
Explain:

Please read the following piece giving a short description of what gamification is before answering the next two questions.

Gamification is the application of typical game playing elements (such as point scoring, competitions, challenges, rules of play) within a non-gaming environment, with the intent of increasing people engagement, motivate action, enhance user experience, promote learning, and solve problems. The

aim is to engage people through a more entertaining medium than traditional lectures to improve understanding and study outcomes.

34 Do you think it could prove useful in engineering education?
Yes
No
Neutral

35 If yes, which of the following gamification elements would work in engineering education? (select multiple if applicable)
Points
Badges
Rewards
Challenges
Rankings
Games
Experience points (unlockables)
Collaborative assignments (multiplayer)

General questions

The following question are for additional information with regards to studying goals.

36 Do you learn to survive assessments or do you hope to retain the knowledge for use when working?
Surviving
Retention
Neutral

37 Describe the ideal assessment method you think would test the knowledge acquired following your learning method(s).
Explain:

38 Which resources do you use when studying? (Mark all that are applicable)
Text books
Lecture slides
Google
YouTube
Old memos
Consultations with lecturer(s)
Consultation with friends
Other:

39 Do you think it is necessary to retain knowledge after assessments?
Yes
No
Neutral

40 Consider any of your modules (first year to now) and explain how you would have taught it.
Explain: