Enriching engineering student experience of final year projects through gamification and authentic learning

Submitted in partial fulfilment of the requirements of the degree Doctor of Philosophy

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Affidavit

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Abstract

Final year projects or capstone projects form a last line of assessment in engineering education programmes in South Africa and are seen as the first major work students do on their path to becoming engineers in the future. In 2015 a review of a capstone project module in electronic and electrical engineering at the University of Johannesburg (UJ) was undertaken to explore what problems were experienced by students and faculty. Based on the results of the review this project was undertaken to solve the identified problems while also attempting to enrich the experience for students.

Literature relating to engineering education, gamification, authentic learning and self-determination theory was explored and used to inform the creation of an artefact using a Design Science Research approach. The approach was two-fold in its purpose of first solving the specific problems identified in the module while also documenting the artefact's creation in such a way that it may be of use to other DSR practitioners in engineering education. The main philosophy was that the student experience could be enriched by supporting student motivation through gamified and authentic learning experiences.

The main contributions are the artefact in the form of a gamified web portal with a number of subsystems, the evaluation of the artefact and its impact, as well as recommendations for DSR practice. The artefact was created between 2016 and 2018 over 4 iterations and was used by students and faculty at the Kingsway campus of UJ. The findings are presented for each of the full system prototypes, as well as for the sub-systems individually. Over the three years of implementation, the interventions were presented to N = (65, 89, 105) students in 2016, 2017 and 2018 respectively with approximately 20 study leaders in all years. Some parts of the artefact have also been implemented in other contexts in order to test generalizability.

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Chapter 1 - Introduction

1.1 Introduction

> "I take the vision which comes from dreams and apply the magic of science and mathematics, adding the heritage of my profession and my knowledge of nature's materials to create a design.
>
> I organise the efforts and skills of my fellow workers employing the capital of the thrifty and the products of many industries, and together we work toward our goal undaunted by hazards and obstacles.
>
> And when we have completed our task all can see that the dreams and plans have materialised for the comfort and welfare of all.
>
> I am an Engineer, I serve mankind, by making dreams come true."
>
> — Anonymous

The need for skilled engineering workers is a problem that is faced worldwide. In the South African context it is summarised perfectly by the Scarce Skills list published in 2014 that highlight the top 100 occupations that are in highest demand [20]. This list was compiled with a methodology that takes into account the local and global context and uses a number of sources as can be seen in Table 1.1. Using this methodology, the following occupations appear in the list at these positions from most to least needed:

#1: Electrical Engineer (CFO Code 215101)

#6: Physical and Engineering Science Technicians (CFO Code 311)

#14: Energy Engineer (CFO Code 215103)

#16: Electronics Engineer (CFO Code 215201)

#18: Telecommunications Engineer (CFO Code 2153)

#20: Energy Engineering Technologist (CFO Code 215104)

#48: Electrical Engineering Technologist (CFO Code 215102)

#66: Electronics Engineering Technologist (CFO Code 215202)

Table 1.1: Ranking Scorecard for National Scarce Skills List (2014)

No	POINTS ALLOCATION		MAXIMUM SCORE
1	**SSP Scarce Skills List (2013):** 1 point is allocated to an occupation if it is identified in a specific SETA Scarce Skills List (21 SETAs).		10
2	**Pivotal Skills List (2013):** 2 points are allocated to an occupation if it is identified in a specific SETA Scarce Skills List (21 SETAs). The breakdown is as follows:		20
	Identified 5 times by SETAs	**20**	
	Identified 4 times by SETAs	**16**	
	Identified 3 times by SETAs	**12**	
	Identified 2 times by SETAs	**8**	
	Identified 1 times by SETAs	**4**	
3	**Joint Initiative on Priority Skills Acquisition:** 10 points each are allocated to an occupation if it is identified in JIPSA.		10
4	**National Development Plan:** 5 points are allocated to an occupation if it is identified in the NDP.		5
5	**Industrial Policy Action Plan:** 5 points are allocated to an occupation if it is identified in the IPAP2.		5
6	**Job Opportunities and Unemployment Report:** Points are allocated to an occupation if it is identified in the index. The breakdown is as follows:		10
	+1000 vacancies	**10**	
	900-999 vacancies	**9**	
	800-899 vacancies	**8**	
	700-799 vacancies	**7**	
	600-699 vacancies	**6**	
	500-599 vacancies	**5**	
	400-499 vacancies	**4**	
	300-399 vacancies	**3**	
	200-299 vacancies	**2**	
	100-199 vacancies	**1**	
7	**Profession:** 20 points are allocated to a profession if it is identified as scarce.		20
8	**Strategic Integrated Projects:** 10 points are allocated to an occupation if it is identified as scarce in the SIPs List.		10
9	**Study Duration:** 10 points are allocated if an occupation requires a minimum of 3 years of formal study		10
TOTAL			100

Given this clearly articulated need, this work attempts to focus on one specific element of the training of electrical and electronic engineers - the capstone project. Although also common in training for Technicians and Technologists, the focus in this work is on capstone projects as they relate to training for engineers through a four year engineering degree from a South African university. The belief is that by using gamification and authentic learning while focussing on student motivation that the experience of students in such a module may be enriched. The literature drawn from will focus on both the South African and international context, but empirical work will be done in collaboration with the Department of Electrical and Electronic Engineering at the University of Johannesburg (UJ).

1.1.1 South African Engineering Qualifications

In the South African context there are three main streams of education that lead to employment opportunities in the engineering sector. The qualifications offered match closely with the professional designations that can be registered with the Engineering Council of South Africa (ECSA). This work is concerned largely with engineering education as it relates to electrical and electronic engineering, but the designations below are general to electrical, mechanical, civil and chemical engineering. These designations are:

- **Professional Technician:** Registration as a candidate / Trainee technician requires at least a recognised National Diploma (NDip) in the relevant field obtained from an accredited University of Technology or Further education and Training (FET) college.
- **Professional Technologist:** Registration as a candidate Technologist requires at least a recognised Bachelor of Technology (BTech) or Engineering (BEng) or Engineering Science (BScEng) degree in the relevant field obtained from an accredited University of Technology.
- **Professional Engineer:** Registration as a candidate Engineer requires at least a recognised degree or Bachelor of Engineering (BEng) or Bachelor of Engineering Science (BScEng) degree obtained from an accredited University.
- **Professional Certificated Engineer:** Registration as a candidate Certificated Engineer requires a theoretical component that includes all of the subjects required for an NDip in either mechanical or electrical engineering as well as additional subjects specified by ECSA which offer entrance to the Government Certificate of Competency examination. Successfully passing this examination allows one to register as a candidate Certificated Engineer.

For each of the designations above, to move from the candidate to the professional level, candidates are required to perform a period of training under the guidance of a preferably registered mentor. In this work special focus is given to the third designation

above relating to the Professional Engineer. Chapter 2 will go into a larger level of detail regarding the structure, registration and educational components of these qualifications.

The educational requirements for each of the qualifications above are defined not only by the educational institutions in question, but are also evaluated by ECSA [16], as well as being benchmarked against internationally defined graduate attributes and qualities [21]. It is the goal of this work to focus less on the legislative requirements, which are a necessity in the training of engineers, but rather to focus on one of the largest challenges for students in completing these qualifications, the capstone project.

The capstone project is not explicitly defined in the accreditation standards, but is almost universally part of the content of all South African engineering programs. For example, the capstone project is represented by the following module in each of the following recognised degrees:

- **Project Investigation (Electrical) (PJEEEA4/B4):** Design project as part of the BEng Electrical, Electronic and Computer Engineering at the University of Johannesburg (UJ).
- **Research Project (EEE4022S/EEE4022F):** Research project as part of the BScEng (Electrical) at the University of Cape Town.
- **Electronic Design Project (ENEL4EDH2):** Design project as part of the BScEng (Electrical) at the University of Kwazulu-Natal.
- **Project (EERI474):** Design project as part of the BEng Electrical, Electronic and Computer Engineering at the North-West University.
- **Project 400 (EPR400):** Design project as part of the BIng Electrical, Electronic and Computer Engineering at the University of Pretoria.
- **Project (E) (448):** Thesis project as part of the BIng Electrical, Electronic and Computer Engineering at the University of Stellenbosch.
- **Electrical Engineering Design II / Electrical Engineering Laboratory (ELEN4000A/ELEN4002A):** Design project and engineering study project as part of the BScEng Electrical and Computer Engineering at the University of the Witwatersrand(Wits).
- **Mechatronics Project IV (EMPV400):** Design project as part of the BEng Mechatronic Engineering at Nelson Mandela University.

The above list represents all of the South African universities currently recognised by ECSA to grant degrees that will lead to registration as professional electrical/electronic engineer, and as can be seen, all of them contain a capstone project module.

1.1.2 The Capstone Project Module

Final year modules, also known as capstone modules are used to create an opportunity for students to create a project that will bring together the theoretical concepts they have been exposed to in their coursework into one cohesive whole. It will in many instances be the first time they are given the opportunity to take on a project that will be similar to the work they will be expected to do in practice after they graduate. In terms of time allocated to capstone modules, they present in a variety of ways, but are generally run over one or two semesters as half or full year modules that are presented in the final two years of a degree. In the case of the module PJEEEA4/B4 at the University of Johannesburg the module is presented as a full year module in the final year of the BEng degree in electric and electronic engineering.

Viswanathan provides guidance on the kinds of design activities that can be undertaken when focusing specifically on manufacturing and design during capstone project work in [5], and also presents the typical outcomes that would be expected of such a module. According to Viswanathan students should be able to:

- define a problem and evaluate a project's feasibility,
- present a review of the literature relevant to a project,
- be able to source, generate or gather and analyse appropriate data,
- identify, describe and apply models for drawing conclusions,
- create a project report that describes all relevant elements of a project and
- defend a project's findings during oral presentations.

Due to these requirements, the nature of the work done in capstone modules is different to normal academic modules. These modules are practical and hands on by the students and faculty and often require a lot of creativity. The specific goals of the project undertaken by students can also follow different trajectories with some presenting more like miniature versions of postgraduate research work and others being focussed more on creating a fully realised concept for a product. In the case of the PJEEEA4/B4 module both of these approaches are supported and preferred by different study leaders[1].

The goal of this study is to enrich the experience of students in the PJEEEA4/B4 capstone module at UJ. In order to achieve this the following three concepts were explored:

- Self-determination theory,
- Authentic Learning and
- Gameful design, particularly Gamification.

[1] In the module faculty members that supervise students are referred to as study leaders, but in the literature the term supervisor is more commonly found. In this work the two terms are used interchangeably

In addition to the theoretical concepts explored to try and create an intervention that encourages interaction and motivation, some of the processes involved in the module were also given special attention to. The student project allocation problem is found in the literature with a variety of options on how the problem can be approached which will be explored more fully in Chapter 2 and from there be built into the artefact. Additionally the students' presentation of their work was seen as an excellent opportunity to encourage student interaction with external stakeholders and special attention was given to encouraging interaction during this period through the design of the artefact.

1.1.3 Self-determination theory

In order to enrich the experience in the module for students, it was reasoned that it would be a more enriching experience if students experienced more motivation towards their projects in general. Self-determination theory (SDT) is a framework of theories for understanding how people are motivated and in describing SDT Ryan and Deci [22] put forward that for someone to feel intrinsically motivated towards some task they need to feel:

- that they have some autonomy ie. that their choices matter,
- that they are part of some sort of community and
- that they can show off their mastery.

These high level concepts were used as a guiding framework for the design of the artefact described in this work, as motivation was seen as critical to student success. The literature regarding SDT in general, as well as how it relates to education is explored in the literature review in Chapter 2 to appropriately ground the work and in Chapter 4 it is shown how SDT is used during the design process to inform the creation of the artefact.

1.1.4 Authentic Learning

Herrington and Herrington highlight in [23] that in order for higher education to create graduates that are ready for the working world that an effective way to achieve this is to try and create an authentic learning environment. Authentic teaching and learning is described as aligning the instructional methods used with the way in which the content being taught will be used in real-life settings. In clarifying what level of authenticity is required various authors make a claim for varying levels of fidelity, but in this work the concept of cognitive realism put forward by Herrington, Oliver and Reeves in [24] will be used where the most important concept is to ensure that students are solving problems in a real way.

Capstone modules are seen as an opportunity for students to have an authentic learning experience in that they will need to create their project in a way that is very similar to what they will one day be expected to do when they become practising engineers. As

authenticity is already part and parcel of a capstone module it seemed natural to also explore authentic learning concepts in the design of the artefact that would be deployed into the module as well. To ensure the work is appropriately grounded the literature surrounding authentic learning will be explored in the literature review in Chapter 2 and in Chapter 4 it is shown how authentic concepts are brought into the design to attempt to make the experience for students more authentic.

1.1.5 Gameful Design

McGonigal proposes that games can help to optimise the human experience, help us do amazing things together and enable lasting engagements and goes on to show how many things can be seen in a gameful wayin [6]. Although a lot of literature will be presented in the literature review considering what Games, Gamification and Serious Games are and what their impact can be, the author wishes at this point to show a specific example.

For context, Reddit is a content discussion platform that hosts largely user created content allowing users to rate and interact with content posted by other users. Reddit bills itself as *"the front page of the internet"*. Subreddits are user created interest areas that users can subscribe to, or post content to, allowing other users to interact with it. In order to register as a user on reddit only an email account is required, and as such a large emphasis is placed on anonymity with only user chosen nicknames visible in the discussion forums. Of specific interest is the Subreddit "\r\Outside" [25].

"\r\Outside" gives users the opportunity in an online discussion forum to not only attempt to envision the world as a game, but to instead merely assume that life itself IS a game. From the Subreddit description [25]:

> *"A subreddit for Outside, a free-to-play MMORPG developed by Deity Games and the most popular game, with 7 billion+ active players."*

In discussions on "\r\Outside", real life situations are framed entirely in game focussed language. For example, frequent reference is made to *"the Devs"*(God), and dates are referred to as patch numbers, for example *"I joined the player base during Patch 19.83."* indicates being born in 1983. Frequent mention is made in the forums of concepts like "leveling up"(graduating), "grinding for xp"(studying) and "loot tables"(salary expectations). This re-framing of serious subjects into game based language is what Gamification designers hope to capture.

Gamification, Game Based Learning and Serious Games are by no means a new field, and have in the past been addressed and implemented in the South African context by O'Donovan, Gain and Marais [26] in terms of Gamification, and by Leendertz, Fitchart and Booth [27] in terms of Serious Games, as well as by Behnke [28] and Pourabdollahian, Taisch and Kerga [29] internationally to name but a few.

In Chapter 2 the literature surrounding gameful design is explored more fully and in Chapter 4 it is shown how gameful design is used to encourage students to interact more by creating a more engaging learning environment.

1.1.6 Players and Motivations

In the previous subsection the concept of viewing the world around us as a game was introduced. In extending this metaphor, it becomes useful to describe the players that take part in this game and the things that influence their behaviours. A more extended literature review will be presented in Chapter 2, but for now it is worth exploring the concepts of player types and motivation. The first taxonomy of players was famously put forward by Bartle as the four suits used in standard playing cards viz. Hearts, Clubs, Diamonds and Spades [30]. Although this taxonomy has been expanded on by multiple authors, for example Diamond, Nacke, Tondello, Tscheligi and Marczheski expanded it to 30 different player types [31], It is still useful as an introduction to seeing players as different styles of player as opposed to one amorphous set of entities. The original taxonomy puts forward the following player types:

Achievers (Diamonds): Enjoy scoring points, gaining levels and badges etc.

Killers (Clubs): Enjoy imposing their will on other players.

Explorers (Spades): Focus on discovery and understanding the game itself.

Socialisers (Hearts): Interested in interactions with other players and NPCs.

It is important to note that the original work done by Bartle was in the context of a Multi User Dungeon (MUD) so the interactions found by him were more suited to games of that nature, but the approach taken to determining the interactions between player types would be applicable to any game style once the taxonomy of players has been identified. This is also applicable when attempting to understand the different kinds of users one would expect to see in a gamified application. This point of view was taken when exploring the stakeholders and users that would be expected to interact with the system. In exploring their motivation the SDT framework is used to view the user stories in such a way that they satisfy all of the requirements to foster intrinsic motivation.

In this work, the assumption is made that to enrich students' experience in doing their capstone project that both motivation and engagement are key to student success. The two terms are often used interchangeably, but as put forward in a literature review by Alsawaier in [32], the two terms are closely related but distinct. Based on the literature, Alsawaier puts forward that motivation is linked to the psychological elements driving behaviour, where engagement is related to the level of energy put towards actions and tasks. Both concepts are deemed important in this work and will be explored further in the literature in Chapter 2.

1.1.7 Gamification, Serious Games and Game Based Learning

The use of gameful design in education has received significant attention in recent years [33] in a variety of fields including technical and engineering education. This interest in

gameful interventions is not only applicable outside of South Africa, as can be seen by the work done in [27], [34], [35], [26].

At points, the terms "Gamification", "Serious Games" and "Game Based Learning" are used interchangeably and although this is not necessarily problematic on all fronts, it does become problematic when people attempt to show that the values brought about by games can be merely dragged and dropped into a different context. To show why this problem arises, let us first make a distinction between the different terms so that a common understanding is put in place. Multiple authors have put forward definitions for the above terms, but in this thesis the main distinctions used will be the ones put forward by Marczewski [13] and Deterding, Khaled, Nacke and Dixon [36] [1]. Table 1.2 shows the heirarchical way in which Marczewski puts forward the distinction between each of the different concepts.

Table 1.2: Game and Game-like Experiences Split by Design Intent [13]

	Game Thinking	**Game Elements**	**Virtual World**	**Game Play**	**Non-Purposeful**
Game Inspired Design	•				
Gamification	•	•			
Simulation	•	•	•		
Serious Game	•	•	•	•	
Game	•	•	•	•	•

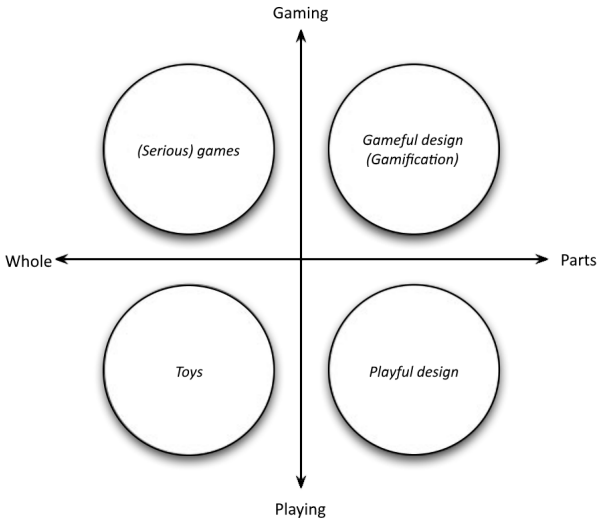
Where Marczewski made the distinction in a very heirarchical way, Deterding, Khaled, Nacke and Dixon placed a stronger focus on the the underlying elements that make up different kinds of game and game-like experiences differentiating between whether they are "whole" games or "parts" of games as can be seen in Fig.1.1. Further distinctions between different kinds of Serious Games, Gamification, Game Based Learning etc. are further explored by authors like Kapp [37] and Marczewski [31] as will be seen in the literature review in Chapter 2, but for the moment, the following definitions are the most relevant to this study as this is where the main work will be done:

> **Serious Games:** *"any form of interactive computer-based game software for one or multiple players to be used on any platform and that has been developed with the intention to be more than entertainment"* [38]

> **Gamification:** *"the use of design elements characteristic for games in non-game contexts"*[36]

> **Game Based Learning:** *"teaching-learning actions carried out in formal and/or informal educational settings by adopting games. It encompasses the use of both games designed expressly for fulfilling learning objectives (educational games) and "mainstream games" – i.e. those games that are developed for fun when used to pursue learning objectives"* [39]

Figure 1.1: Classifying Gamification, Serious Games, Playful Designs and Toys [1]



Games used in the educational space have a long history which needs to be addressed as well, and as pointed out by Chen, educational games have often been nothing more than *"chocolate covered broccoli"* [40]. In the case of Gamification authors like Bogost have gone so far as to coin phrases like *"exploitationware"* to show just how unethical the use of techniques used in gambling and other addictive behaviours can be when applied to games and Gamification [41]. For this reason and others the ethical implications will also be explored in the literature review, as well as in the reflections at the end of this work.

In this study, the theory and techniques described by SDT, authentic learning and gameful design will be used to attempt to enrich the experience of students that are moving through the educational process described in subsection 1.1.1 and have reached their capstone project module. Gameful design will be used to create an authentically inspired system that has the aim of increasing interaction between users and fostering motivation.

1.2 Background and Motivation

Using as a baseline the concepts introduced in Section 1.1 the concept of gamifying a capstone module to enrich the experience for students will be explored in the context of the PJEEEA4/B4 Project Investigation IV module offered by the University of Johannesburg. In collaboration with the course coordinator and research team, Gameful interventions will be implemented and researched to explore their effectiveness and to attempt to enrich the experience for students taking the module by increasing interaction and motivation. The reasons this specific module was chosen are as follows:

1. Access. The author and his academic supervisors are actively involved in the Project Investigation module and as such impacting the lives of students under

their purview is an important motivating factor.

2. Identified needs. Before the start of this study, feedback was received from students where they were asked whether they had any problems with the module and the ways in which projects were put forward and assigned through an anonymous feedback questionnaire. As there were problems already identified, it seemed an ideal time to attempt to address those problems at the same time as researching gameful interventions.

3. Holistic focus. As the module in question is a capstone module, it is required that students apply all of their knowledge they have gained through their studies in the creation of their capstone projects, and as such it was deemed as the most applicable to a study that would be undertaken where students would be viewed as prospective engineers.

In Chapter 3 the research methodology will be introduced, but for the moment it is sufficient to point out that an Educational Design Research (EDR) approach will be taken to attempt to understand the problems presented in the problem statement, as well as to simultaneously attempt to solve those problems through the creation and testing of one or more artifacts. In this text as well as in the literature EDR and Design Science Research (DSR) are often used interchangeably as DSR refers to the approach and EDR to the approach in the educational context.

1.2.1 Purpose of the Study

The purpose of this study is to explore the effectiveness of Gameful interventions in an electrical/electronic engineering capstone project and to attempt to enrich the experience of students taking the module. Regardless of the level of effectiveness, the creation of an artefact through a DSR process will be undertaken and implemented at the University of Johannesburg in order to empirically determine the impact of such an artefact. This is two-fold in its purpose of first and foremost solving the specific problems experienced at the University of Johannesburg and to enrich the experience of students, as well as to document the experiences of the author in such a way that it may be of use to other researchers and practitioners in the field as well as to engineering educators everywhere. It is hoped that work produced here will contribute to the greater body of knowledge in the field of engineering education.

1.2.2 Research Objectives

The overall objective that needs to be achieved is the creation of a suitable, sustainable support system for students at the University of Johannesburg undertaking their capstone project journey. Although starting initially with a goal of exploring only Gamification in the context of engineering education, the research should also uncover problems in the existing system through exploration and collaborative design with students and faculty at the university and attempt to give as much positive design support as possible.

1.2.3 Significance of the Study

In addition to the creation of an artefact for addressing the problems faced by capstone project students at the University of Johannesburg it is hoped that the system will also be sufficiently re-usable that it might be repurposed at other institutions and other contexts. Additionally it is envisioned that the work done through this project will also allow the author sufficient data and findings to meaningfully contribute to the literature in engineering education. As a DSR approach is being followed, the experience of the author will also be captured so that future researchers might also benefit from the lessons learned.

1.2.4 Motivations for the Study

As discussed in section 1.1, electrical engineering professionals are in desperately short supply in South Africa. It is hoped that meaningful effort into the field of engineering education will help to alleviate some of the economic and structural problems experienced in South Africa. Although the capstone project is only one module in a full engineering programme, it is also done by students who at that point in time have already experienced three years of engineering education. It is hoped that when a platform is in place that some of this energy can be rerouted into projects that will help to uplift communities and make meaningful differences in the world.

1.3 Problems, Delineation and Assumptions

Now that the context of the study has been introduced, at this point it becomes important to highlight what this specific work aims to achieve and what concepts fall outside of this scope.

1.3.1 Problem Statement

As the capstone project is of such pivotal importance, any issues regarding student experience or pass rates in the subject quickly raise warning flags. There have been a number of attempts to get to the heart of this problem, and in 2016 as part of a questionnaire exercise in trying to gain insight into the barriers students experience in achieving the required outcomes to show the required graduate attributes, the following findings were made:

- At the start of the module a lack of input is taken from students during project allocations,
- During this assignment, it feels as if there is a lack of transparency in the assignment mechanisms and as such some students felt unfairly chosen, or not chosen for specific projects and
- Many students felt that due to this the assignments made were not optimal.

In addition to these problems raised by students, faculty members were also consulted to understand why they felt that the problems in the module were being experienced. From this exercise the following insights were gained:

- Study leaders attested to the lack of student motivation and interest,
- Students were being assigned to study leaders with no interest in their areas, or a lack of knowledge in the areas the student wished to explore and
- Assignment was a largely manual process that relied heavily on the course coordinator to match students and study leaders.

These problems are not the only ones to be considered during this work as the nature of DSR is such that problems may only present themselves once some of the work has been done, but these problems were the initially highlighted ones that caused the project to be initiated for this specific capstone module.

1.3.2 Research Questions, Goals and Design Hypothesis

As will be seen in Section 3.2, when approaching a problem with a DSR mindset, it is important to make a distintion between the design problem(s) and the knowledge question(s) that are involved in the research work being undertaken. In conceptually splitting the research into those two categories, research goals (problems to be solved) and research questions (questions to be answered) naturally emerge. As the study being undertaken draws not only from research literature but also from best practice, both will be considered equally in this work.

The design problems speak directly to the problems that have already been highlighted that would need to be solved through the course of the study. In solving these problems, a number of design hypothesis were proposed based on the literature that underscored the way the problems would be approached. These design hypothesis are as follows:

- **Design Hypothesis 1:** Students will welcome the addition of gamification elements in the module and creating such a system would lead to higher levels of interaction between students, study leaders and external stakeholders.
- **Design Hypothesis 2:** Designing the system with SDT principles in mind will increase the levels of motivation felt by students towards their projects and enrich the student experience.
- **Design Hypothesis 3:** Designing the system intervention with authentic learning experiences in mind will enrich the student experience.
- **Design Hypothesis 4:** Drawing from the literature there would be a suitable solution found for the student project allocation problem that could be presented in a transparent, collaborative and fair way.

Along with these design hypothesis there were also two research questions that arose during the course of the project, Specifically:

- **Research Question 1:** What is the overall effect of the created intervention on student success? Does enriching the experience ultimately lead to a higher level of student success?
- **Research Question 2:** The student project allocation problem is a known problem faced in capstone modules. In using an algorithmic approach to solving the problem, how much data is actually required to reach a suitable assignment given a number of students?

The research goals that are thus put forward are the following:

- **Research Goal 1:** Solve the problems put forward by students and study leaders that are known to exist at the start of the study with regards to the fair and transparent allocation of projects, as well as to give students a voice to indicate their preferences with regards to this allocation.
- **Research Goal 2:** To create an artefact that will foster interaction and motivation in students to enrich their learning experience and lead to greater success.
- **Research Goal 3:** To document the design process used in such a way as to allow other researchers to gain value from the lessons learned.

1.3.3 Delineation

Although the literature explored will be drawn from both the South African and international context it is important to highlight that the implementation of the artefact is done at the University of Johannesburg and collaborative design sessions will only include students from that specific institution. Although for the purposes of this study, these students will be considered representative, any firm conclusions drawn can only be done so within this specific context. Integration with existing systems is explored in this work in relation to the artefact being created, but these considerations are only done with relation to the specific implementation of the artefact and may not be representative of a generic University system. For example, at the University of Johannesburg Blackboard is used as a Learning Management System. Although Blackboard does have wide market penetration in South Africa, it is not used universally. Heavy reference is made in this work as well as in the referenced literature to the concept of student engagement. As is pointed out by Ashwin and McVitty in [42] the term has a number of different meanings depending on the context. For our purposes when we refer to student engagement we will be referring to motivated interaction, be it with the artefact developed or with the student's capstone project.

1.3.4 Assumptions and Limitations

Many of the concepts and goals discussed in this work would also be applicable to the fields of mechanical, civil or chemical engineering, but as none of them are tested the discussion is limited to only electrical and electronic engineering student capstone projects. Capstone projects are a well researched topic in the area of engineering education, but it is worth highlighting that although the principle of the module is to be a summative evaluation of the students' abilities gained through the course of their degree, not all students perceive it as anything more than that - a module. The author would like to believe that all students are dedicated and with sufficient effort and dedication all students can be reached, but there is a limit to how much can be achieved through academic intervention only.

The specific technology stack chosen is the one that is most familiar to the author. Although the .Net framework enjoys a large footprint in the South African ICT sector, it is by no means the only stack that is available. The artefact created in this work is built on this platform, but it is noted that other platforms may be less, equally or more suitable to the task, it is just that the author used the one that was most accessible and effective at the time of the project's conception in his opinion based on his own experience.

Finally a DSR Approach is followed in this work, and although DSR has started achieving a certain level of respectability in academic circles, the nature of the research is such that there will always be another milestone that can be reached through just one more iteration. In this work four prototype iterations were used, but it is recognised that more iterations can still be done and the artefact can still be refined further. The work is continuing, but this thesis represents a flag in the ground, rather than a full exploration of all possible paths that could be followed in this work.

1.4 Approach

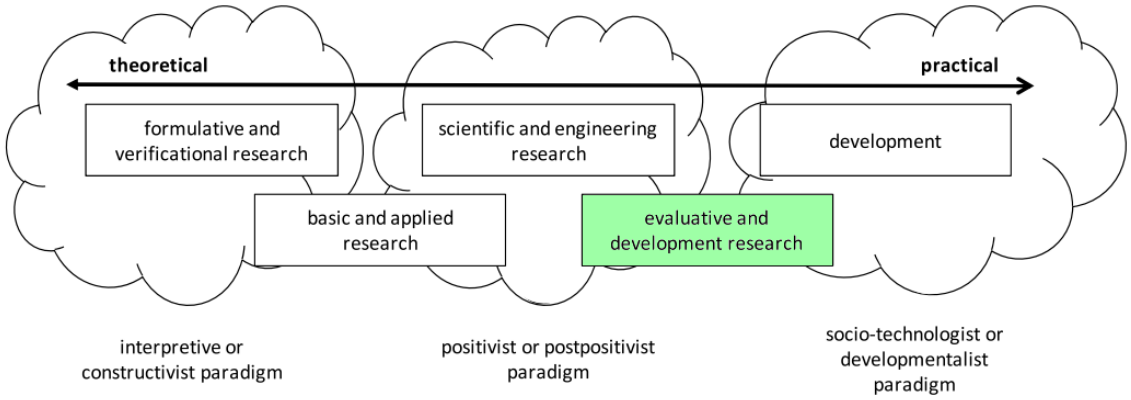
As mentioned previously in this chapter, a DSR approach will be taken in this work. This section will give a quick overview of the general approach, and will highlight some of the pertinent concepts that need to be considered with regards to the data that will be collected and analysed as well as any ethical implications that need to be considered.

1.4.1 General Approach

According to Romme there are three ways in which research may be undertaken, with a humanities approach, a social science approach and a design approach [43]. In Chapter 3, this concept will be interrogated in more detail, but for the moment it is sufficient to accept Romme's premise. With this then in mind, what is the difference then between these three research approaches? Although not universally accepted, authors like Weber do also consider the three way approach specifically in information science, and puts forward the model in Figure 1.2 as a way of distinguishing the three approaches [2]. In this model the DSR approach finds itself in the pragmatic "evaluative and development

research" position in that an artefact will be created to solve problems in the context, and it will also be scientifically evaluated.

Figure 1.2: Research Objectives and Methods - From [2]



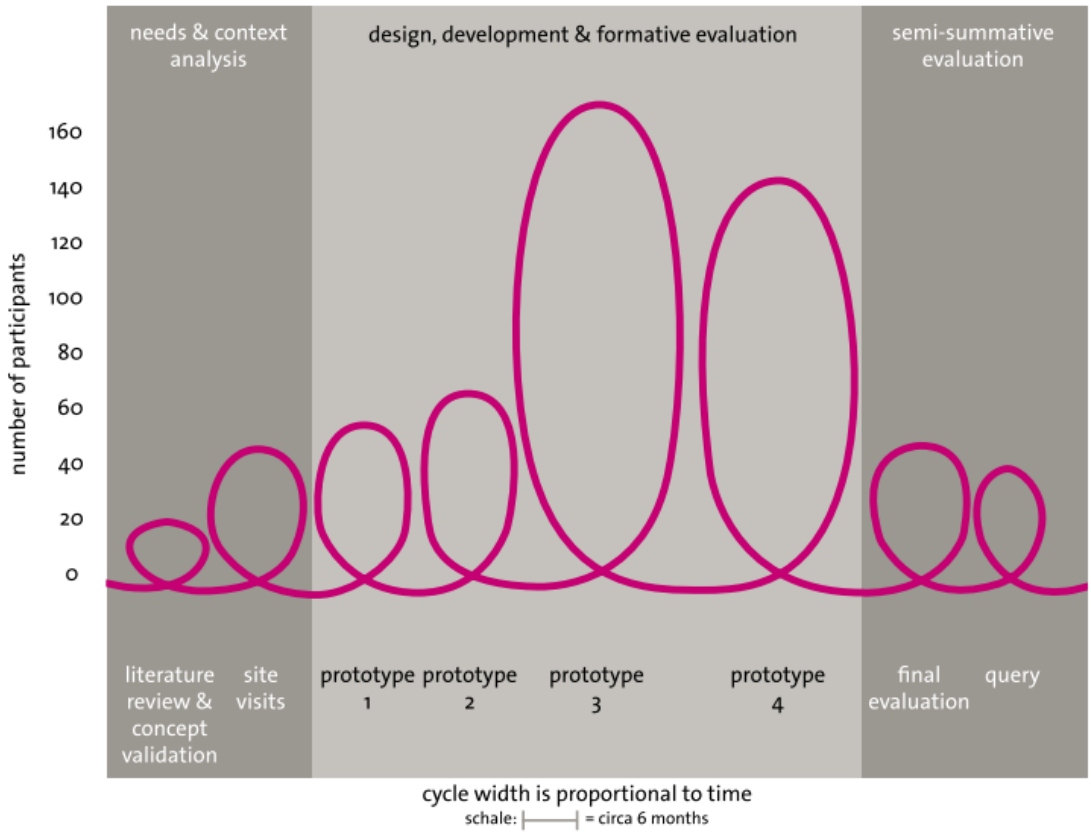
Another core characteristic of DSR is the recognition that a single research cycle in attacking a problem is not likely to bring about the ideal solution to it. DSR practitioners use an iterative approach to problem solving, and instead of creating from the ground up a final artefact, instead a number of protypes are created that are finalised after each iteration and then improved upon during each subsequent iteration. This is clearly demonstrated by the often referenced "loops" shown at first by Mckenny in the landmark CASCADE-SEA study [3] seen in Figure 1.3. The full detail of the approach will be explored in Chapter 3, but for the moment it is sufficient to consider it an iterative approach that balances the development concerns of solving the problem at hand with the research concerns of publishing results in an iterative manner. In this work, guidance is drawn from the fields of EDR and DSR, due to the fact that the study takes place both as a DSR study in the creation of the artefact, as well as taking place in the educational context.

1.4.2 Data Approach and Ethical Implications

The general approach as stated is to overcome the problems presented through a pragmatic world view using a DSR approach to develop an artefact that will address the identified problems in the module as well as to enrich the experience of students. The artefact that will be developed as a whole comprises of one main artefact that is split up into a number of sub artefacts. The overall artefect is contained in the PJE web portal that will be made available to students, and each of the sub artefacts will be presented through this portal at different times of the year as they become relevant. In order test the effectiveness of the arefact as a whole, qualitative and quantitative data will be collected and analysed.

Using the DSR approach of prototyping towards quality put forward by Nieveen in [44], artefact will be evaluated using the following techniques:

Figure 1.3: Research Cycles in the CASCADE-SEA Study - from [3]



- Self evaluation to find obvious errors,
- Expert reviews of the system obtained through interviews and discussions,
- One-to-one interaction with users, specifically during the action research period,
- Small group discussions in the form of collaborative design sessions and
- Field tests to test the system in the real context.

During each of these evaluative techniques quantitative and qualitative data will be generated that will be used to gauge the effectiveness of the artefact against the measures of validity, practicality and impact potential. The quantitative data collected will be obtained from the database to measure buy-in from students and study leaders will relate to their interactions with the system and whether they adopted it. The interactions of users with each of the three subsystems developed as well as the overall artefact will be evaluated. In addition to this data collected directly from the artefact database the following instruments will be used:

- **Intrinsic Motivation Inventory:** will be used to measure the students' level of motivation towards using the project allocation gamified system,

- **Situational Motivation Scale:** will be used to measure the levels of motivation students feel towards being part of a small group participatory design session,
- **General Questionnaire:** will be used to gauge students' views on gamification more generally as well as to give an open ended question where students' could add any general comments.

Action Research will be used after the first conceptual prototype is developed to gain insight directly from students and study leaders in addition to data being collected using group interviews and anonymous questionnaires to capture the feedback from users, and this in turn will be analysed against the measures of validity, practicality and impact potential. Although very useful from a design perspective, user feedback is not neccesarily the same as a systematic expert evaluation of the system. Expert reviewers will be sourced predominantly from the faculty at the University of Johannesburg.

The collection of qualitative data will be done through interviews and workshops, whereas the quantitative data is sourced from the questionnaires taken from users. Additional quantitative data is directly drawn from the database as each of the artefacts requires different information in order to evaluate them successfully. Quantitative analysis will be done where possible in either Python 3.x, or else Excel 2016.

Finally to gauge the impact of the artefact on student success the academic results of students that had the benefit of the use of the artefact will be compared to the students in previous years and the results interrogated using statistical tools.

As the nature of the work inherently requires ethical clearance, an application was made to the University of Johannesburg's Faculty Ethical Committee. Clearance was obtained and the clearance notice can be found in Appendix A along with the application for ethics clearance.

1.4.3 Thesis Structure

In this chapter the groundwork for the study has been laid, and the underlying concepts of engineering education, authentic learning, gamification, SDT and DSR have been introduced. The study has also been delineated, and the reader has been given the structure for the rest of the work so that it may be interrogated logically.

Chapter 2 gives an overview of existing work that relates to the different sub domains addressed in this study. This is not a complete and exhaustive overview of all literature related to these domains of knowledge but rather a representative subset of related work that attempts to address both the theoretical framework used, as well as to show how work towards solving similar problems has yielded positive results. As a DSR approach was followed the literature review was constantly updated through each of the iterations as more literature was found that guided the design of the artefacts.

Chapter 3 shows the research approach taken along with it's pragmatic paradigm, specifically the methodology of DSR/EDR, and how it is used to guide the creation of academic interventions through the developmental studies approach. The implementation specific to this study is then presented.

Chapter 4 presents the conceptual designs done and how the initial architecture was designed before the creation of the artefacts started

Chapters 5 to 8 goes into detail of the design of the artefact and how it changed over the course of the project. Results obtained are shown for each of the prototypes and indications are given as to how the design changed over the iterations.

Chapter 9 puts forward reflections on the project, DSR and the nature of games and Gamification in the hopes of adding to the greater body of literature.

Chapter 2 - Literature Review

2.1 Introduction

In this chapter relevant literature is explored and presented in such a way as to ground the study appropriately. To give a sufficient foundation to the context of the study, the following concepts in engineering education are explored:

- Engineering Education as it exists in the South African context,
- Different qualifications that are offered in engineering studies in South Africa,
- The Bachelor of Engineering / Engineering Science degrees and their content,
- Capstone project modules as part of engineering degrees,
- Capstone project stakeholders and activities undertaken in these modules.

Once engineering education and capstone projects have been explored, the educational approach that is used in this study is introduced by exploring the concepts of authentic learning as well as Self-Determination theory as it pertains to education. Finally Games, Gamification, Serious Games and Game based learning are explored to introduce the reader to these concepts as they informed the creation of the artefact.

2.2 South African Engineering Education

Engineering in South Africa as a formal discipline traces its roots back to 1893 when the South African Association of Engineers and Architects put forward a petition to the "Volksraad" calling for the recognition of individual engineers and architects. Although this initial bill ultimately failed, it paved the way for an ordinance passed in 1906 which formally recognised the "Engineers' Certificate of Competency" . In 1911 the "Mines and Works Act of 1911" recognised in law that only engineers holding such a certificate should be allowed to take on the responsibilities of an engineer [45].

The South African Association of Engineers and Architects eventually grew into the South African Institution of Mechanical Engineering (SAIMechE) [46] and during this time, various other voluntary organisations also formed to promote each of the disciplines that formed part of the larger body of engineering in the South African context. The South African Institute of Electrical Engineers (SAIEE), the South African Society

of Civil Engineers (SASoc of CE)), later the The South African Institution Of Civil Engineering (SAICE) and the Chemical, Metallurgical and Mining Society of South Africa all formed before 1910 [45] [47] [48].

In 1945 these voluntary bodies joined forces with a small group of academics at the University of the Witwatersrand to form the Engineers Association of South Africa (EASA), which took as its mandate the responsibility to consult with government on the appropriate status, requirements and standards that would be required for the graduating of engineers, as defined in South African Law [45]. The work of the voluntary associations with the EASA eventually lead to the passing of the Professional Engineers' Act (Act 81 of 1968) on 20 June 1968 [49]. This directly lead to the creation of the South African Council for Professional Engineers(SACPE) to serve the interests of professional engineers in South Africa.

One of the functions undertaken by the SACPE was the creation of an Educational Advisory Committee (EAC) under section 17 of the Act that would evaluate degree programmes to indicate their suitability in the training of new Engineers. The first accreditation of South African engineering degree qualifications by the publicly funded universities was done in 1981 [49]. It was also at this time that some friction started to appear as there were various persons acting in the capacity of engineers, but that had not gone through a traditional degree training route. Specifically problematic were the persons who had started their careers as technicians, but through many years of practice and project work with engineers had reached a sufficient level of knowledge to be considered engineers. In 1975 the EAC released Information Document E1/1 to indicate the ways in which such a person may comply with the requirements of registration.

In writing up this period of history, Gericke specifically mentions the problem between the two different kinds of training offered in the Engineering space in South Africa:

> *"During this period attempts were also made to obtain closer liaison between universities and technikons. The EAC was of the opinion that the 50% drop-out on first year level at universities was too high and that many persons were lost to the profession because they should have been referred to technikons during the first year. Courses should be so structured that referral from one to the other should be possible during the first year. Unfortunately these attempts failed by and large."* - Gericke From [49]

In 1991 the functions of the SACPE were taken over officially by the newly formed Engineering Council of South Africa (ECSA). Empowered by the Engineering Profession Act (EPA), 46 of 2000, ECSA is the only recognised body in South Africa authorised to confer the professional designations of Professional Engineer (Pr Eng), Professional Technologist (Pr Tech Eng), Professional Technician (Pr Techni Eng) or Certificated Engineer (Pr Cert Eng).

Although the powers conferred on ECSA are stated in South African law, there is international consensus that recognises that although the specific contextual knowledge may indeed be different, there are common competencies that are shared by all professionals in the fields of engineering. To promote this idea, and to ensure a common standard and

recognition of quality, ECSA is a co-signee on three international educational education recognition agreements namely [50]:

- The Washington Accord: Recognising the mutual characteristics of Engineering Education programs,
- The Sydney Accord: Recognising the mutual characteristics of Engineering Technologist and Incorporated Engineering training programs and
- The Dublin Accord: Recognising the mutual characteristics of Technician training programs.

Under these common agreements, engineering councils in different countries put forward the common graduate attributes that describe the knowledge profiles of each of the engineering professional designations. The graduate attributes are accompanied by statements of competencies that are required to be obtained before one may be considered a professional in any of the designations by the International Engineering Alliance (IEA) [21].

In this work, the greatest focus will be given specifically to engineering education as it relates to the training of professional engineering candidates in the field of electrical and electronic engineering. When taking this slightly narrower view of engineering education, the following two professional bodies of highest relevance in this context become the South African Society for Engineering Education (SASEE) and the Institute of Electrical and Electronic Engineers (IEEE) Education Society.

The principle idea of engineering education used in this text will be taken from the mission statement of SASEE and the field of interest stated for the IEEE Education Society as: *The theory and practice of education and educational technology involved in the effective delivery of domain knowledge with the goal of preparing people to practice engineering as a profession, to spread technological literacy, and to increase student interest in technical careers through science and math education and hands-on learning. [51] [52]*

2.2.1 South African Engineering Qualifications

To actually register as a Professional Engineer, a candidate is measured against the "R-02-PE: Competency Standard for Registration as a Professional Engineer" [53] which is aligned to the International Council of Engineering Councils through the Washington accord. According to this standard, the Professional should demonstrate competence and a level of skill in:

- One or more of the defined complex engineering activities,
- Engineering problem solving,
- Managing engineering activities,
- Gauging the impacts of engineering activities,

- Exercising judgement, responsibility and ethics in the execution of their duties and
- Their commitment to continuing their professional development.

In addition to showing competence in the areas described in R-02-PE, the professional should hold a degree conforming to the requirements put forth in "E-02-PE: Qualification Standard for the Bachelor of Science in Engineering (BScEng)/ Bachelors of Engineering (BEng): NQF Level 8". Graduates of BScEng/BEng/BIng degrees register as candidate engineers and practice under the guidance of a mentor for at least 3 years to gain the above mentioned competencies before submitting an application for registration membership[2].

Table 2.3: South African National Qualifications Framework (NQF) [14]

Sub-Framework/ Quality Council	**NQF Level**	**NQF Sub-Framework and qualification type**		**Sub-Framework/ Quality Council**
Higher Education Qualifications Sub-Framework (HEQSF)/ Council on Higher Education (CHE)	10	Doctoral Degree Doctoral Degree (Professional)	-	Occupational Qualifications Sub-Framework (OQSF) Quality Council for Trades and Occupations (QCTO)
	9	Master's Degree Master's Degree (Professional)	-	
	8	Honours Degree Postgraduate Dip. Bachelor's Degree (Professional)	Occupactional Certificate lvl 8	
	7	Bachelor's Degree Advanced Dip.	Occupactional Certificate lvl 7	
	6	National Dip. Advanced Cert.	Occupactional Certificate lvl 6	
	5	Higher Certificate	Occupactional Certificate lvl 5	
General and Further Education and Training Qualifications Sub-Framework (GFETQSF)/ Umalusi	4	National Certificate	Occupactional Certificate lvl 4	
	3	Intermediate Certificate	Occupactional Certificate lvl 3	
	2	Elementary Certificate	Occupactional Certificate lvl 2	
	1	General Certificate	Occupactional Certificate lvl 1	

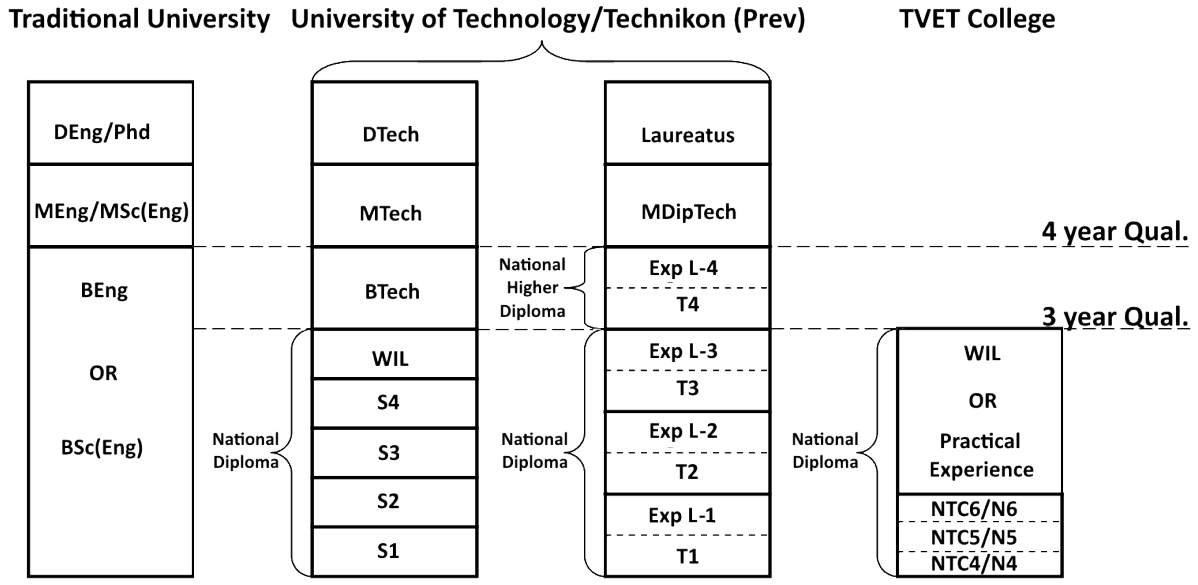
All of the qualifications offered in South Africa that are officially recognised need to be set at an appropriate level on the National Qualifications Framework (NQF). The

[2]It is a truism that many engineers prefer not to register unless required to do so by some legal impediment to work, work pressure or risk of sanctions.

structure of the NQF is shown in Table 2.3. NQF levels 1-4 are generally achieved by going to first primary and then high school, but other options are available for students who do not follow this route in the form of Technical Vocational Education and Training (TVET) colleges that offer various National Technical Certificates (NTCs) that also fulfil the requirements of NQF levels 1-4.

After the National Certificate (NQF level 4) has been achieved there are generally three options available for students wishing to move into the engineering space namely Traditional Universities, Universities of Technology and TVET colleges. McGrath and Nicola show the general level of equivalence of qualifications that can be achieved at Universities in [4] and [54] shows the process for obtaining a NDip[3] when studying through a TVET college. Extending the framework in [4] The general structure of the framework of engineering qualifications that can therefore be obtained is shown in Fig. 2.1.

Figure 2.1: Diagram of Qualification Structures (Frameworks) - Past and Current. - From [4]



The structure shown in Fig. 2.1 is current as of writing, but universities and Universities of Technology are in the process of adopting the HEQSF gazetted on Friday 2nd August, 2013. This does present an interesting situation in that the previous structure of qualifications offered by Universities of Technology (then Technikons) were published in the NATED 151 Report [55] which is not entirely compatible with the new Higher Education Qualification Sub-Framework (HEQSF). In addressing this problem the South African Technology Network (SATN) was formed from representatives of South African Universities of Technology to specifically address the needs of those institutions at na-

[3]NDip is used here to denote any of the acronyms used to name a National Diploma and is used interchangeably with NNDip, Nat Dip, ND, NTD, NED, etc.

tional level. The main gaps between NATED 151 and the HEQSF were identified by SATN and shown in Table 2.4.

Table 2.4: Comparing NATED 151 and HEQSF

Non-HEQF Aligned Qualifications NATED 151		**HEQSF Aligned Qualifications**	
Qualification and credits	**NQF Level**	**Qualification and credits**	**NQF Level**
Doctor Technologiae (DTech) Doctoral Degree (PhD) (240 Credits)	8	Doctoral Degree (360 Credits)	10
Magister Tech. (MTech) Master's Degree in Business Administration (MBA) Master's Degree (120 credits)	8	Master's Degree (180 Credits)	9
No Equivalent Exists		Postgraduate Diploma (180 Credits)	8
Professional Bachelor's Degree (480 Credits)	7	Professional Bachelor's Degree (480 Credits)	8
Bachelor Honours Degree (120 Credits)	7	Bachelor Honours Degree (120 Credits)	8
No Equivalent Exists		Advanced Diploma (120 Credits)	7
Baccalaureus Technologiae (BTech) (120 Credits)	7	**No Equivalent Exists**	
Bachelor's Degree (360 Credits)	6	Bachelor's Degree (360 Credits)	7
		Bachelor of Education (480 Credits)	7
National Diploma (360 Credits)	6	Diploma (360 Credits)	6
		Diploma (240 Credits)	6
No Equivalent Exists		Advanced Certificate (120 Credits)	6
National Higher Certificate (120 Credits)	5	Higher Certificate (120 Credits)	5

In 2013, ECSA embarked on a national engineering skills survey to determine the state of the profession within the South African context. At the time they estimated that there were approximately 120 000 practicing Engineers, Technologists and Technicians

[56]. An electronic survey was sent directly to 43 113 registered members. From this questionnaire, a total of 10 069 responses were received which showed among other things the first qualification obtained by practising members of the profession. Using the framework shown in Fig. 2.1, For respondents specifically practising as engineers (7 049 respondents), their first qualifications are reported in Table 2.5 [4] [5]. Table 2.6 [5] and Table 2.7 [5] show the first qualifications gained for technologists and technicians respectively. For Tables 2.5 to 2.7 The NQF levels indicated are in terms of HEQSF.

Table 2.5: First Qualifications Reported for Practising Engineers

NQF	First Qualification	% of respondents	# of respondents
8	/BEng/BIng	84.90%	5985
BScEng 5-7	Other	4.85%	342
6	NDip	5.36%	378
6	Nat Dip. Tech / NDT	1.35%	95
6	NTD / NED / NNDip	0.68%	48
6	NND / NHCT / ID	0.15%	11
5	T2	0.17%	12
5	T1	0.13%	9
5	N6	1.31%	92
5	N5	0.36%	26
5	NTC5 / ACT2	0.25%	18
4/5	N4	0.38%	27
4/5	NTC4 / ACT1	0.08%	6
Total Engineering respondents			**7049**

From Tables 2.5 to 2.7 it can be seen that the standard route is indeed the most common for Engineers, Technologists and Technicians but is definitely not universally accepted with 84.90% of Engineers having a BEng or equivalent, 72.78% or more of technologists having a NDip or higher, and 76.08% or more of technicians having an NDip or higher [6].

2.2.2 The Bachelor of Engineering / Engineering Science

Although the generally accepted first step on the route to professional registration is the attainment of an engineering degree, ECSA puts forward four methods for complying with the educational requirement for professional registration. These methods are [16]:

[4] Of those engineers that selected "other" as their first qualification, more than half indicated their degree as a BTech.

[5] Although part of the diploma programme offered at the TVET colleges NTC4/N4 is often used as a leg up for students that didn't achieve sufficient marks in their National Certificate to enter University as well as in previous years being used as a minimum qualifications for some non-engineering vocations. Hence being placed at both level 4 and 5 in the NQF framework.

[6] "Other" qualifications are not taken into account in these numbers as it is not indicated in the report what level they are at.

Table 2.6: First Qualifications Reported for Practising Technologists

NQF	First Qualification	% respondents	# respondents
8	BscEng/BEng/BIng	6.53%	153
5-7	Other	19.76%	463
6	NDip	55.19%	1293
6	Nat Dip. Tech/NDT	8.41%	197
6	NTD/NED/NNDip	1.92%	45
6	NND/NHCT/ID	0.73%	17
5	T2	0.94%	22
5	T1	0.94%	22
5	N6	1.66%	39
5	N5	0.94%	22
5	NTC5/ACT2	0.94%	22
4/5	N4	1.53%	36
4/5	NTC4/ACT1	0.51%	12
Total respondents			**2343**

Table 2.7: First Qualifications Reported for Practising Technicians

NQF	First Qualification	% of total respondents	# of respondents
8	BscEng/BEng/BIng	0.84%	14
5-7	Other	7.89%	132
6	NDip	64.86%	1085
6	Nat Dip. Tech / NDT	6.99%	117
6	NTD / NED / NNDip	2.87%	48
6	NND / NHCT / ID	0.54%	9
5	T2	1.73%	29
5	T1	1.14%	19
5	N6	6.45%	108
5	N5	2.09%	35
5	NTC5 / ACT2	0.36%	6
4/5	N4	3.41%	57
4/5	NTC4 / ACT1	0.84%	14
Total Technician respondents		**1673**	

1. Hold an accredited qualification from a South African university,
2. Hold an accredited qualification that is recognised under the Washington Accord,
3. Hold a combination of qualifications evaluated on a case by case basis that are considered to be substantially equivalent,
4. Present a combination of evidence relating to the individual's level of education that are considered to be substantially equivalent to the educational requirements.

This evidence can be in the form of:

- Qualifications or credits towards unrecognised qualifications,
- Completion of examinations or other forms of assesment,
- Portfolios of work done or
- Other relevant evidence relating to prior learning.

Although all four methods are recognised in this work, as this study is specifically concerned with formal engineering education, emphasis is placed specifically on the BScEng and BEng degrees which will actually put a student on the path to registration as a professional engineer as identified in the first point above. The process used to evaluate individual degrees are specified in Document E-17-P "Criteria and Processes for Recognition of Educational Qualifications for Professional Categories" [16]. Using this criteria, the list of accredited degrees and all qualifying years of granting are kept on record and publicly accessible as E-20-P "University Degrees Accredited as Meeting the Educational Requirement for Registration as a Professional Engineer" [15]. This list is continuously being updated and goes through a major revision every 5 years when ECSA visits each of the rated institutions to evaluate their programmes in detail. Revision 21 of E-20-P is current as of 31 August 2017 and contains a full listing of qualifications offered currently and in the past that are accredited. The list of current degrees related to electrical and electronic engineering that students can register for can be seen in Table 2.8.

A distinction is made between the assessment of a qualification and the evaluation of students in the program. Document E-17-P [16] presents this in Table 1 which can also be found in this document as Table 2.9. In addition to benchmarking the assessment criteria against the international benchmarks through the Washington accord, the exit level outcomes that are specified by ECSA are also benchmarked against the critical cross-field education and training outcomes specified by SAQA in [57]. The mapping between the exit level outcomes and critical cross-field education and training outcomes is shown in Table 2.10.

2.2.3 The Capstone Project in Engineering Qualifications

Ward puts forward five common elements used in the design of capstone modules by the top engineering universities in the world as ranked by the Quacquarelli Symonds Ltd.(QS) and Times Higher Education (THE) World Rankings in [58]. The common elements were:

- Problem-based learning precursor modules,
- a strong group project emphasis,
- a design-build-test program model,
- active industry stakeholder involvement and

Table 2.8: Current Accredited Electrical & Electronic Engineering Degrees - From [15]

Institution	**Degree**	**Accredited**		
		To	**From**	**Review**
University of Cape Town	BSc(Eng)(Electrical)	1985	2017	2020
	BSc(Eng)(Electro-Mechanical)	1991	2020	2020
	BSc(Eng)(Electrical and Computer)	1991	2020	2020
University of KwaZulu-Natal	BSc(Eng)(Electrical)	2004	2018	2018
	BSc(Eng)(Electronic)	2004	2018	2018
	BSc(Eng)(Computer)	2004	2018	2018
North-West University	BEng(Electrical & Electronic)	2004	2018	2021
	BEng(Computer & Electronic)	2004	2018	2021
University of Pretoria	BIng(Electrical)	1983	2017	2017
	BIng(Electronic)	1983	2017	2017
	BIng(Computer)	2001	2017	2017
University of Johannesburg	BEng(Electrical & Electronic)	1986	2018	2021
	BEng(Electrical, Electronic & IT)	2001	2018	2021
Stellenbosch University	BIng(Electrical & Electronic)	1993	2018	2018
	BIng(Electrical & Electronic & IT)	2001	2018	2018
	BIng(Mechatronics)	2005	2018	2018
University of the Witwatersrand	BSc(Eng)(Electrical)	1982	2017	2017
	BSc(Eng)(Electrical & IT)	2002	2017	2017
NMU	BEng(Mechatronics)	2007	2019	2019

- sequential assignments.

As described by Todd and Magleby, when designing capstone project modules one should also consider the needs of all different stakeholders that are present, outside of just the students and the lecturer [59]. These stakeholders can include other faculty members, administrators, industry participants, junior students, etc.

As can be seen in Table 2.9, there are a number of requirements that graduates are expected to meet, but the idea of a capstone project is not explicitly required. Although not an explicit legal requirement, as can be seen from Table 2.10, it is universally interpreted as a requirement by universities in South Africa. And why not? The capstone project, when designed correctly can allow a student to show proficiency in assessment criteria 2 - 8 presented in Table 2.9 testing the student against almost all required evaluation criteria.

But what is a capstone project? Also referred to as a final year project, capstone experience, culminating project or senior exhibition, the capstone project is the assignment given to students in their final year of study and acts as a culminating experience for the student where they get to exercise all of the skills they have learned in the formative modules in their programme [60]. There is also a close link between capstone projects and the concepts of authentic learning as they both require the student to bring forth a portfolio of work that is presented as a way of measuring the readyness of the student

Table 2.9: Individual vs. Qualification Criteria [16]

	Qualifications Evaluation Criteria	**Individual Assesment Criteria**
1.1	The programme covers fundamentals of mathematics and natural science appropriate to the discipline. The programme contains the equivalent of at least one semester of mathematical sciences and one semester of natural sciences; and	The applicant displays understanding of and the ability to apply the fundamentals of engineering in a selected discipline together with the underpinning fundamentals of mathematics and natural science.
1.2	The programme adequately covers the engineering fundamentals appropriate to the discipline;	
1.3	The programme contains engineering studies related to current practice in the selected field	The applicant displays proficiency in engineering specialist fields at the exit level
2	The level of problem solving demanded at the exit level corresponds to complex engineering problems defined in ECSA document E-02-PE.	
3	The programme contains a selection of engineering tools and IT support appropriate to the discipline	The applicant displays proficiency in the use of engineering tools and IT support appropriate to the discipline.
4	The curriculum has the requirement for a major design exercise. The design problem meets the requirements of a complex engineering problems and the design approach is properly structured.	The applicant demonstrates design proficiency is demonstrated through substantial project work. The design problem meets the requirements of a complex engineering problems and the design approach is properly structured
5	The curriculum requires experimental work and research methodology.	The applicant demonstrates proficiency in experimental and research methodology
6	The curriculum requires oral and written communication at the level expected of a graduate	The applicant communicatesin writing at the exit level of a BEng programme
7	The curriculum contains elements that give an understanding of the impact of engineering activity	The applicant explains and analyses impacts of engineering activity
8	The curriculum contains elements that give an understanding of ethics and engineering professionalism	The applicant explains ethical principles and analyses ethical issues

Table 2.10: ECSA Exit Level Outcomes vs SAQA Critical Cross-field Education and Training Outcomes [17]

SAQA Critical Cross-Field Outcomes								
1	Identify and solve problems using critical thinking skills.							
2	Work effectively with others as a member of a team or group.							
3	Organise and manage oneself and one's activities and responsibilities.							
4	Collect, analyse, organise and critically evaluate information.							
5	Communicate effectively using visual, mathematical and language skills.							
6	Use science and technology effectively, critically and responsibly.							
7	Demonstrate understanding of the interrelatedness of different contexts.							
8	Contribute to the personal development of the learner and their life long learning needs by creating awareness of the needs for it.							
ECSA Exit Level Outcomes								
1	Problem Solving							
2	Application of scientific and engineering knowledge							
3	Engineering design							
4	Investigations, experiments and data analysis							
5	Engineering methods, skills and tools, including information technology							
6	Professional and technical communication							
7	Sustainability and impact of engineering activity							
8	Individual, team and multidisciplinary working							
9	Independent learning ability							
10	Engineering professionalism							
11	Engineering management							
CCO (Critical Cross-field vs Exit Level Outcome mapping)								
	CCO 1	CCO 2	CCO 3	CCO 4	CCO 5	CCO 6	CCO 7	CCO 8
ELO1	X			X			X	
ELO2	X				X	X		
ELO3	X			X		X	X	
ELO4						X		
ELO5	X			X		X		
ELO6					X			
ELO7						X		
ELO8		X	X					
ELO9								X
ELO10								X
ELO11		X	X					

to enter the working world [61] [60]. Although in this work the capstone project referred to is specific to the work done by engineering students, according to Hauhart capstone projects have now become almost ubiquitous in the higher education space in all fields

[62].

The origination of capstone projects in their current format is not entirely clear with their first recorded use being in the 1850s [62], but they do share many characteristics that are common to apprenticeships and journeyman projects that can be traced in many trades back to at least the early middle ages. The term itself refers to the "capstone", also called a keystone which is the wedge shaped stone block placed at the apex of an archway in architecture used to lock all of the stones in the archway into place allowing the archway to bear weight [63]. This makes it an apt analogy considering when students are given the opportunity to do the capstone project.

In addition to allowing the student to demonstrate the learning they have done in their coursework up until the capstone project, various authors also point out the benefit to the student's learning that takes place during the completion of the project. In a literature review of more than 100 papers on the topic of teaching design through capstone engineering modules, Dutson, Todd, Magleby and Sorensen found that although various differences are apparent in the way modules are structured, they almost universally have as their objective an experience for the student that reflects what they will experience in a real-life engineering design context [12]. One of the highlighted problems however lies not in students, but rather the willingness of faculty members to actually take on the mantle of capstone project work due to the workload that comes with it, as well as the inability to streamline the process like other modules [12].

In differentiating the approaches to capstone projects between universities, the four characteristics that had the largest impact on the structure of the modules were [12]:

- Module duration - Durations of one, two or three quarters, as well as one or two semesters are common.
- Module format - Modules can be structured to allow students to work in a mock company that closely mimics an engineering firm, or be heavily structured or any variation in between.
- Module content - Content can be individual, team based or have a combination of both approaches.
- Evaluation strategies - Peer review, industrial panel reviews, external reviews, project sponsor reviews, educator reviews and alumni reviews are all approaches that are in use.

The same characteristics above can be seen up to this day in current work where there is a continual search for ways to make the capstone project experience more innovative and interesting to students. Examples can be found in the literature of projects that take on a more community based focus [64], a greater focus on innovation [65] or industrially focussed projects [5]. An extensive list of design tasks that can be done during the capstone project module is found in Viswanathan [5] as well as in Figure 2.2. In contrast to many other modules in the engineering degree, there is a much larger focus on creativity and problem solving in a capstone module as the expectation is that the

student will undertake work that is not already solved. The project is not expected to be as complex as one that would be undertaken at the postgraduate level, but it is expected to be more open ended to give the student the opportunity to explore the process of identifying the problems, conceptualising solutions and implementing those solutions using the knowledge and experience they have gained through their studies in previous years. With regards to identifying suitable design projects Dutson, Todd, Magleby and Sorensen reference the work of various authors to compile the following list of features that characterise a good indicate that the following characterise a good design project [12]:

- the project should be challenging, but have good chances for successful completion,
- be a common enough problem for the student to be able to find relevant literature,
- allow for extensive use of the theory the student has learned,
- involve some aspect of engineering design work,
- require the student to meet some specific safety standards and
- the project should not require any proprietary data or tools to implement.

Figure 2.2: Activities Associated with a Capstone Project - From [5]

In this study that takes place at the University of Johannesburg the capstone project module is split up into two semester modules namely "Project Investigation" PJE4A and PJE4B. Projects are allocated at the start of the year and students then have to continuously work on their allocated project throughout the course of the year and show progress by hitting predefined milestones like having an introductory chapter completed, completing the literature review, having their conceptual design completed etc.. There is however some flexibility in the milestones for different students as projects are generally unique.

2.2.4 Capstone Project Stakeholders and Activities

In the previous subsection the concept of the capstone project was introduced. As highlighted, a variety of approaches exist in how the module is presented by different universities. Although an extensive guide to developing capstone projects can be found in [62], for the purposes of this work the summary presented by Viswanathan [5] can be used as a good example of the stakeholders and processes that are needed for a successful implementation. In addition to activities shown in Figure 2.2 the instructor of the module also has the opportunity to present students with a number of lectures to convey design concepts as well as more ideas that need to be taken into account during the project process. Although, again not uniform, Dutson, Todd, Magleby and Sorensen present a representative set of typical lecture topics that can be adressed [12]:

- The Profession
  - Engineering as a profession
  - Professional engineering ethics
  - Professional societies
  - Professional registration
  - Life-long learning
- Legal Considerations
- Documentation And Presentations
- System Development
  - Needs analysis
  - Trade-off analysis
  - Requirements definition
  - Design specifications
  - Test planning
- Design Process
  - Methodology

  - Risk assessment and mitigation
  - Test and verification
  - Quality assurance

- Engineering Project Operations
  - Phased system development
  - Organization structures
  - Introduction to management theory
  - Interpersonal relations
  - Proposals
  - Work breakdown structures

Depending on the nature of the module, these lectures may be presented in any order, but are representative of the information conveyed to students. There is however generally an ordered structure to the module, as there are certain things that need to happen before others. One of these is the assignment of projects to students, and the optimal matching of projects to students is still an area of active research. The problem is generally referred to as the Student Project Allocation problem (SPAP) with a number of authors presenting ways in which this problem can be addressed depending on constraining factors.

The SPAP problem was initially described and approached by Abraham, Irving and Manlove as a variation of the Hospitals and Residents (HR) problem in [66]. When looking at approaches to this problem, the authors use the concept of a stable matching, where the allocation of projects to students is done in such a way as to be a best-possible matching for students. In other words, the preferences of students are seen as most important in defining the matched pairs. This work was extended in [67] to include a situation where both lecturers and students have preferences over projects and have capacity constraints. The algorithm put forward by these authors are however not the only approaches that are relevant and popular hybrid approaches combining heuristics, hill climbing, search and genetic algorithms are used in [68], Linear programming in [69] along with qualitative and statistical methods in [70]. An extensive review of methods and variations on the problem is presented by Faudzi, Abdul-Rahman, and Rahman in [71].

In exploring the methods put forward by the authors above the assumption is made that a transparent, algorithmic approach would be the best way to answer the problems highlighted in research goal one. In this study the specific algorithm used is the Gale-Shapley algorithm proposed by Gale and Shapley in their seminal paper "College Admissions and the Stability of Marriage" [72]. In it, they authors put forward a simple algorithm where two similarly sized sets of elements, each with a list of preferences for the elements in the other set are matched in such a way as to find a stable matching of all pairs of elements. In conceptualising the algorithm the authors used the concepts of stable marriages where the elements in one set are seen as men that propose to women in

the other set. The algorithm iteratively has the men proposing to the women they have not proposed to before in preference order and the women accepting the proposal of the man that is highest in their preference list creating an engagement. Once all men and women have been engaged the match is considered stable. There exists an inherent bias towards the men in the algorithm in that in each iteration they have the opportunity to choose from all women they have not proposed to, where the women can only choose from the men that have actually proposed to them in that iteration. This algorithm is explored more fully in Chapter six where it is shown how it is implemented in the artefact.

In extending the work of Gale and Shapley, Irving introduced the concept of Indifference in [73], which describes a situation where the elements of each set have only partial preference lists available. This concept is explored fully in Chapter six where there is also a presentation of simulation done establishing a baseline of how much data is required in terms of preference for the algorithm to work in the situation where only incomplete preference data is available for different sized sets. This work was also published in [74]. In addition to introducing the concept of indifference, Irving goes on to establish algorithms that can test for three levels of stability:

- weakly stable where no matched pairs prefer each others' partners
- super stable where no matched pairs prefer each others' partners or are indifferent to them
- strongly stable where no man prefers another woman and no woman another man

In this study, only weakly stable matches are required as the match needs to be stable, but the level of stability is not relevant. This algorithm is used and explored extensively during the allocation phase of the capstone project module to match students with study leaders through the artefact.

As shown in the previous sections, the nature of the capstone project is that it does give an opportunity for students to present their engineering skills, and as identified by ELO6, the ability to successfully communicate work is a core skills of engineers. Communication takes place generally in two ways, first with the project report created during the completion of the project, and finally verbally by a seminar, presentation or project day where students get to show of their work to their peers, study leaders, and often external members of the public. In the South African context this can be seen in events like the SAIEE National Student Project competition held annually where each of the public universities that offer engineering programmes send their best students to compete by presenting their capstone projects [75].

2.3 Educational Approach

In the previous sections Engineering Education was introduced as it exists in South Africa, and the concept of the capstone project was explored to give context to this study. The literature that will be explored will be focussed on two concepts that greatly

informed the design of the artefact that was developed namely Authentic Learning and Self-Determination Theory (SDT) as it exists in the educational space. This section does not intend to be prescriptive, in that other researchers may have different theories they rely on and still present suitable research in the areas of engineering education, but these are the theories that informed this study and the design of the artefact that was created.

2.3.1 Authentic Learning

As shown by Abbott, Authentic Learning is not a single approach, but rather a collection of instructional techniques where the underlying principle is that students are more likely to be motivated and interested in new skills and concepts when they see that their learning reflects the practical use of the concepts in a real-life context. Abbot also goes on to show that some of the different strategies that educators might use are the creation of portfolios, demonstrations of learning as well as capstone project work [61]. Rather than then defining a single definition for the term, a number of authors have rather sought to instead indicate the characteristics that specifically define an authentic learning experience for students. In answering the questions "What do you mean by authentic learning? What are its components?", Rule puts forward the essential components of authentic learning in [76] as:

- Learning involving problems rooted in the real world
- Learning through applying inquiry and thinking skills
- Learning through discourse among learners
- Learners are empowered through the learning activities.

For Authentic Learning to be effective in the higher education space, Herrington puts forward a number of characteristics of an effective authentic learning environment as well as the tasks that should be done in the environment to foster a learning experience [77]. He goes on to point out that for online spaces to be considered authentic, they should attempt to simulate the same characteristics and tasks. The ten characteristics and tasks, and how they are reflected in the context of this study are:

- **Provide an authentic context**: In this study students are given opportunities to create tenders for projects, applications to study leaders in a similar way to applying for a job, and presentations of their work that will be evaluated by industry representatives among others. Additionally, the nature of projects proposed are all done with an authentic context in mind, and not just busy work. Students are expected to propose a solution to a real life problem. The capstone module thus provides excellent opportunities for presenting an authentic context.
- **Authentic Activities**: The students will be creating a project in their capstone module where they will be expected, often for the first time, to perform as

engineers. This means that they will need to go through all of the steps of conceptualising, documenting, designing, implementing and presenting their work in order to pass the module.

- **Access to expert performance and models**: Students need to see how engineers have solved similar problems in the past so that they can see what they need to emulate and what they can learn from others' experiences. This is a large reason for the literature review that forms part of the work done in capstone projects, but it is also important for the study leader to use their knowledge and expertise to guide the student.

- **Multiple roles and perspectives for students**: In this study the students are given three distinct perspectives through which to see the work they will be doing, namely the Student Phase, Journeyman Phase and the Candidate Phase. The artefact is designed to support students through each of these phases and the detailed description of how they are mapped to the academic year can be found in Section 3.3.6.

- **Collaborative Construction**: Due to the nature of the capstone project module that this study is based on there is not a lot of opportunity for collaborative work, as each project is undertaken individually by each student. There are opportunities to get peer feedback through events like the project presentations and the final project day at the end of the year, but these are not collaborative as such. This characteristic of authentic learning spaces will be explored in future work, however it was not used in the design of the artefact in this study as it would have completely changed the nature of the work done.

- **Reflection**: As the capstone module takes the student through all the phases of an engineering project and is also documented at the end into a formal document there is provision made for a final chapter that includes reflection on the work done during the year. Additionally students are encouraged to reflect on their work during presentation days.

- **Articulation**: As the capstone module is envisioned conceptually with three phases, it is also means there is a sense of articulation that students experience by moving from one phase to the next. Additionally, as the deliverables that are expected of students in creating and documenting their projects build on each other naturally, this again reinforces the articulation that students should experience.

- **Coaching and Scaffolding**: Although, as mentioned, there is no emphasis placed on collaborative work between students, the study leader / student relationship is one with a deep emphasis on coaching where students get personal attention from their study leader which is in contrast to the learning experience in large lecture halls. Scaffolding of the knowledge is done through the generic lectures that given to all students that cover concepts like creating the conceptual design, doing the literature review, etc.

- **Authentic Assessment**: The capstone project module is again well set up for authentic assessment as, in addition to the marks obtained from external examiners, the project presentation day gives an opportunity for industry representatives and other academics to evaluate the projects put forward by students to emphasise this transition between the student experience of writing tests and assessments, to now having to sell oneself and be judged as an engineer.

It can therefor be seen that the characteristics of authentic learning environments are exceptionally well suited to capstone project modules. The design of the artefact in this study was also deeply impacted by the concepts of authentic design as can be seen from the discussion above.

One of the advantages of the modern age is that mobile phones have become ubiquitous, and as such are a valuable tool for educators to create learning journeys. Jones et al. put forward five progress and feedback indicators that they extracted from the literature as the places where learning app developers should focus. The five indicators are Social, Cognitive, Affective, Motivation and Progress, Collectively called the SCAMP framework [78]. By creating an authentic environment and ensuring to focus on these indicators, the educator has the opportunity to engage the student more fully.

2.3.2 Self-Determination Theory

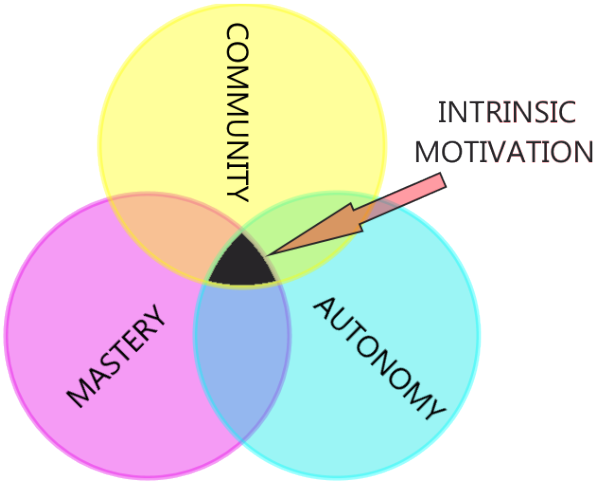
Although Bloom's taxonomy is seen as one of the cornerstones of the educational literature, it is the study done by Krathwohl, Bloom and Masia on the affective domain [79] that had a larger impact on this work. According to the authors the student internalizes the content being studied in a number of stages from least to most internalized. The stages students go through are:

- Receiving: Students become aware of the ideas and materials of the content being delivered.
- Responding: Students show some measure of commitment to the content by actually engaging with it.
- Valuing: Students are willing to show others that they value the content being received.
- Organization: Students take the content they receive and integrate it into a larger whole of their knowledge.
- Characterization: Students value the contents to the point that they have internalised the ideas and materials.

It stands to reason that, in order for the student to internalise the content being presented or the work that is being undertaken, deeper levels of internalisation require a much higher level of engagement and motivation to do so. It is from this concept that the author explored the concepts of Self-Determination Theory (SDT) to gain a deeper understanding of how this can be achieved.

SDT is not just a single set of statements but rather a larger framework of understanding issues in human behaviour relating to motivation. Work by Ryan and Deci started in the early 1970s in differentiating between intrinsic and extrinsic motivations [80], and through continued work together they eventually published at the start of the millennium a full framework for SDT on facilitating motivation, social development and wellbeing [22]. As the capstone project requires a high level of internal motivation to complete, the author decided to draw upon the rich area of SDT as it seemed to address most directly the concepts of motivation and engagement.

Figure 2.3: Self-Determination Interaction Between Needs



As described by Ryan and Deci [22], for persons to feel a sense of intrinsic motivation to complete some task, they first need to feel:

- That their choice matters
- That they are part of a community (or a greater whole)
- That they are mastering challenges

Figure 2.3 shows how the interplay between these three needs brings about intrinsic motivation in the person.

Although the three needs are the core of SDT, the meta theory actually comprises of six underlying theories that each focus on a specific kind of motivational phenomena. The six theories highlighted by Ryan and Deci are [81]:

- Cognitive Evaluation Theory is concerned with studies on intrinsic motivation and the interplay between competence and autonomy in generating a feeling of motivation to perform some task.
- Organismic Integration Theory is concerned with studies on extrinsic motivation which is the behaviour of striving for external goals and rewards in response to actions performed by the person. Of chief importance is just how internalised

the extrinsic motivation is, which indicates how autonomous the person is when working towards it. Organismic Integration Theory studies the societal constraints that impede internalization.

- Causality Orientations Theory is concerned with how people orient themselves to environments and set their focii in relation to goals and anxiety about competence.
- Basic Psychological Needs Theory looks at how barriers to achieving the three main needs can impact the well-being of people in different contexts.
- Goal Contents Theory is concerned largely with goals, and people's attitudes towards them and how their nature can impact the wellbeing of people.
- Relationships Motivation Theory looks at the nature of interpersonal relationships as one of the core needs, and how much support can be gained from them.

Other authors have also built on these core theories, notably Pink who put forward an additional need, Purpose [82]. In the Gamification space, the combination of the Pink approach and the traditional SDT approach is often shortened to the combined needs as Relatedness, Autonomy, Mastery and Purpose or the RAMP approach. This need for a purpose is twofold as put forward by McGonigal in [6], in that there is the immediate purpose that can be seen by creating a goal, but there is also a larger concept, one of "heroic purpose" that can be seen as a way for people to show their mastery and contribute to something larger than themselves. The Example that McGonigal uses is of the World of Warcraft wiki that, at the time of her writing was the second largest wiki on the internet after Wikipedia. This need to contribute to something larger than oneself is what could also spur students on in some cases to expand their project work into postgraduate research.

What is important to differentiate at this point is the concepts of motivation and engagement. According to Schaufeli et al.[83], engagement is the opposite of burnout and:

> "Engagement is defined as a positive, fulfilling, work-related state of mind that is characterized by vigor, dedication, and absorption"

This is as opposed to motivation where, according to Ryan and Deci [84]:

> "To be motivated means to be moved to do something. A person who feels no impetus or inspiration to act is thus characterized as unmotivated, whereas someone who is energized or activated toward an end is considered motivated."

From this it is the authors opinion that it is very difficult, if not impossible, to be engaged in some act if one is not motivated to do so. The two concepts are heavily dependant on one another though, and to enrich the experience of the capstone project module both would need to be considered.

2.3.3 Self-Determination Theory in Education and Games

SDT has a long history in the educational space. The Self-Determination Theory Institute maintains an index of studies that have validated the use in the educational context [85] which at the time of writing contained many hundreds of articles from all over the world. It is well established in the literature that SDT has a place in the creation of educational interventions.

In the context of capstone and project based work, Liu, Wang, Tan, Koh and Ee [86] showed by measuring pre-, during- and post-project work students in Singapore that levels of enjoyment, percieved value and perceived learned skills could all be positively influenced by being cogniscant of SDT principles and can be a great boon to educators. It is important to note that this study was employed on senior high-school students, as opposed to final year university students, but in the author's opinion the very clear positive results would be applicable to all long term capstone style projects.

As the impact of motivation on learning is a well studied area, it has even branched out in to very specific areas of science education and goal setting with relation to games and Gamification. A study by Behnke showed that there was promise in combining the the coursework elements of computer science education with a Gamification approach focusing on the SDT needs [28], and in the South African context a similar study was done at the University of Cape Town with relation to students in a game design module [26].

In the author's opinion the main reason that the two areas seem to have such a strong overlap is that when educators wish to fully engage students in some task they seek other things that have a high level of engagement and games seem to fill this need very well. As will be seen in the following section however the link between motivation, games and Gamification is not nearly as clear as people would like to think it is.

2.4 Games, Gamification and Serious Games

Although many people would consider there to be a very strong split between the concepts of *work* and *play* [7] there are those who challenge this concept through the use of Gamification. One of the most prominent figures of this movement is McGonigal who has over the course of more than 10 years attempted to spread the idea that games can change the world. Nowhere is this more prominent than in her book "Superbetter: The Power of Living Gamefully" [87]. What then is Gamification? This is a more complex question than is immediately apparent, and in this section we attempt to unpack why that is. The first question to ask however, is fundamentally:

Question: *"What is a game?"*

It may be surprising to learn that there is no one single answer to the simple question of what a game is. The study of games is called Ludology, and what a game is has

[7] It is worth pointing out that this is a very generalised statement as there are many people that love their job and their education - this is more of a truism than a fact.

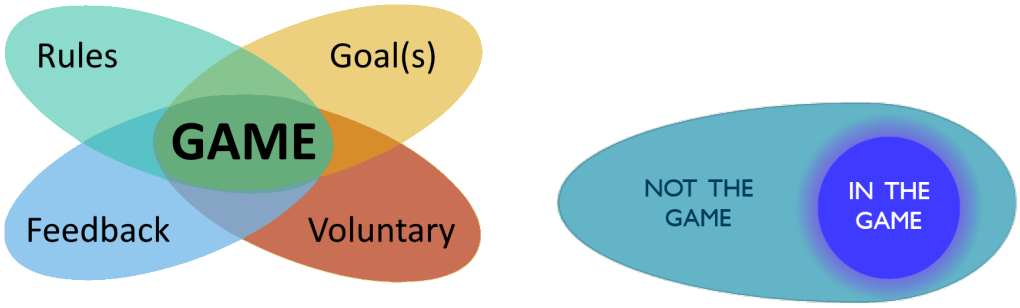
been studied through various lenses in the fields of psychology, sociology, anthropology, mathematics and philosophy to name but a few. Each of these approaches will approach the problem from a different angle, but the one that the author has found to be the most applicable is the definition put forth by Suits[88]:

"Playing a game is the voluntary attempt to overcome unnecessary obstacles."

Additionally In this work, two concepts are used as seen in Figure 2.4 to give the definition of what a game is. Mcgonigal put forward four characteristics that are required for an activity to be a game [6]:

- Rules: There needs to be a common set of rules that players buy into.
- Goals: There needs to be some sort of aim that will signify a change, or end of the game
- Feedback: Players need to be informed if the state of the game changes
- Voluntary Participation: If players are not voluntarily engaging, they cannot have fun

Tekinbas and Zimmerman [7] however went for a simpler approach and put forward the concept of the magic circle. In this theory, players know that they are in a game when they recognise it as such. Players can also clearly distinguish the barrier between things that are in and out of the game.



(a) The Four Characteristics (b) The Magic Circle

Figure 2.4: The Two Definitions of Games that will be Used [6] [7]

In section 1.1.4 the distinction was made between Gamification, Simulation, Serious Games and games. In this section however more detail will be given with regards to the concepts of the characteristics of games, players and mechanics to give a fuller understanding of how these concepts are understood and used in this work.

In this section the concepts of games, gamification an serious games are explored, but it is important to note that, as pointed out by Kafai in [89] and [90] that from a construnctionist point of view it can be very effective for students to also make games as learning experiences. In the course of this study the students that the author supervised

all created serious games and associated hardware controllers with a focus on childhood development. The results of these students work and the experiences of the authors are presented in [91] and [92].

2.4.1 Characteristics

Characteristics are those things that we can identify in a game that are fundamental to it. A good framework for understanding the characteristics of a specific game is given by Hunicke, LeBlanc and Zubek in the Mechanics, Dynamics and Aesthetics (MDA) framework [93]. In this framework:

- **Mechanics** are actions, behaviours, control mechanisms, assets, equipment that players can interact with to bring about the dynamic behaviours of the game.
- **Dynamics** are processes that bring about changes in the game state based in the current state, previous or current outputs and player input.
- **Aesthetics** are the things that make the game a desirable thing to interact with. Hunicke, LeBlanc and Zubek go on to give an example of an 8 element taxonomy that could be used to evaluate the aesthetics of a game[93]:
  - **Sensation:** The game can give tactile or sensual pleasure
  - **Fantasy:** The game can appeal to lovers of make believe
  - **Narrative:** The game can appeal to lovers of drama
  - **Challenge:** The game can appeal to those who enjoy overcoming obstacles
  - **Fellowship:** The game can encourage social interaction
  - **Discovery:** The game can be interesting to explore
  - **Expression:** The game can encourage self discovery and expression in players
  - **Submission:** The game can be a pleasurable way to pass the time.

These characteristics are also concepts that can be brought over into the gamification space as they each represent a lens through which one can make an existing process or system more gameful by changing or implementing specific MDA characteristics. According to Burke, games, Gamification and commercial rewards programs share the following characteristics [94]:

- Voluntary engagement of players,
- The use of common mechanics like points, badges and leaderboards,
- A general level of interactivity and
- They incorporate a way for players to progress between levels.

But she does also go on to say that although they all share these characteristics, they fundamentally differ in purpose as follows:

- **Games** attempt primarily to entertain players,
- **Gamification** attempts to engage people emotionally in order to motivate them to do something and
- **Rewards Programs** attemp to engage players in a transactional way in order to compensate them for their actions.

In the author's opinion, the main differentiator between rewards programs and Gamification is simply whether the motivation aimed for is of an extrinsic or intrinsic nature.

2.4.2 Players

Understanding the nature of different kinds of players is not a new approach as was shown in 1.1.4 with the work of Bartle, but this has been built on significantly over the years. Taking this idea further are authors like Adams which highlights the need to take into account not only player preference, but also the larger demographic split in the player base along age, gender, preference or access lines [95]. Adams goes on to extend the concepts put forward by Van den Berghe on the five domains of play [96] that entice different kinds of players by adding a sixth domain to create - novelty, challenge, stimulation, harmony, threat and narrative. The attitudes of the players to these six domains is what classifies them as different kinds of players.

- **Novelty:** Relating to openness to experience in the five factor model, players that seek novelty want games that have large amounts of discovery and unexpected elements built into them like No Man's Sky or Don't Starve as opposed to players who seek familiar and repetitive experiences like Tetris.
- **Challenge:** Relating to conscientiousness in the five factor model, players that seek challenge want difficult or punishing games, for example, dark souls or cuphead, as opposed to players that shun challenge that rather seek peaceful non confrontational games like minecraft or farmville style sandbox games.
- **Stimulation:** Relating to extraversion in the five factor model, players who seek social stimulation will be drawn more to multiplayer games like World of Warcraft or Overwatch, be they competitive or collaborative as opposed to players who seek a more solatary experience like an adventure game in the style of Monkey Island or Grim Fandango.
- **Harmony:** Relating to agreeableness in the five factor model, players seeking social harmony would seek out collaborative or peaceful games like Tearaway Unfolded as opposed to directly conflict driven games like Mortal Combat or Soul Caliber.

- **Threat:** Relating to neuroticism in the five factor model, players in this group prefer games that invoke fear or anxiety during gameplay. Examples here would be games like Until Dawn or FEAR as opposed to Bound or Journey.
- **Narrative:** Not directly related to Van den Berghe's original model, players who seek highly narrative driven games will seek ones that have deeply involved stories like Star Wars: Knights of The Old Republic, as opposed to players who seek narrative free games like Bejeweled or other puzzle games.

A concept that is often referenced in educational and game design circles is the idea of flow that was initially put forward by Csikszentmihalyi [97]. A player that experiences a flow state is fully engaged in their activity and many benifits of a flow state have been identified and are apparent. It is however the author's opinion that although it would be exceptionally useful to assume all students will achieve a flow state when using their intervention, when considering the idea that players are fundamentally different in so many ways it is naive to assume that a single game could engage ALL players into a flow state.

Table 2.11: Gamer Dedication Qualities That are Relevant to Serious Games.

	Quality	**Relevant to Serious Games**
1	Technology savvy	✓
2	Latest high-end gear	X
3	Willingness to pay	X
4	Preference for violent/action games	X
5	Preference for deep, complex games	✓
6	Play games over long sessions	X
7	Hunger for gaming information	X
8	Discuss games with friends	✓
9	Completionist attitide	✓
10	Tolerance to frustration	✓
11	Competes with themselves, the game and others	✓
12	Age they started playing games	X
13	Comparative knowledge of industry	X
14	Early adopter	✓
15	Desire to modify or extend games	✓

A more useful measure to consider is the idea of gamer dedication put forward by Adams [95]. Gamer dedication uses 15 measurable qualities of gamers to see how dedicated they would be to engage with a game. It is however still worth pointing out that the context of Gamer dedication is still in commercial games, rather than serious or educational games. When adding this filter, the following dedication qualities that would,

in the author's opinion be applicable can be found in Table 2.11. Although Serious Games attempt to capture the essence of these qualities in the same way as designers of commercial games do, this is an inherently difficult process.

Koster puts forward the idea of games as a medium, and then shows how people can interact with games on different levels depending on their goals [18]. In Table 2.12 the different interactions are mapped with the goals being:

- **Constructive**: Building or creating games or parts of games
- **Experimental**: Experiencing or playing games
- **Deconstructive**: Trying to take games apart and understand how they work

Table 2.12: Human Interactions With Games [18]

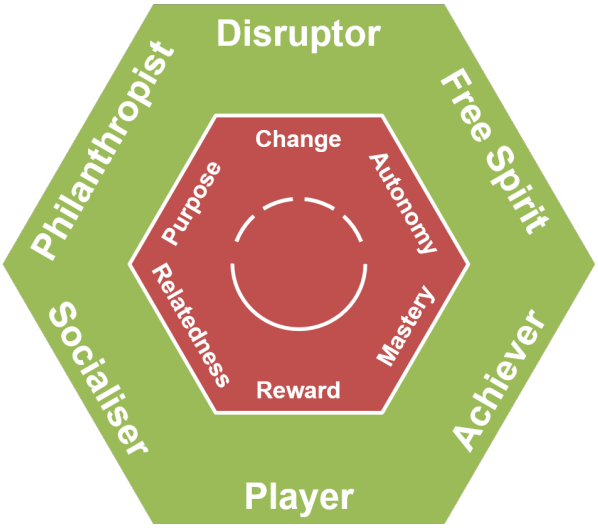
	Gaming in the human activity matrix		
User Goal	**Collaborative**	**Competitive**	**Solo**
Constructive	Team game design	Commercial game development	Modding and skinning
Experimental	Co-op player vs. the game	Player vs. player	Single player games
Deconstructive	Strategy guide writing	Hacking and cheats	Game design book writing
	Many participants		**One participant**

Although player types have been explored in games, there are also authors like Chou who go through the same process for users in Gamification systems [98]. Tools are also under development to attempt to make this classification of players simpler in the Gamification space, amoung others the HEXAD project [31] based on the taxonomy initially created by Marczewski which divides the Gamification player base into six different types [13]. The six player types in this model further expand the RAMP model proposed by Pink in [82] which had the four drivers of Relatedness, Autonomy, Mastery and Purpose to now include Reward and Change drivers as well. In SDT these two additional drivers would relate to the extrinsic motivation that players will experience. The Gamification player types as they relate to the drivers of motivation are shown in figure 2.5. The types of players are important to take into account in any gamification implementation, but in the implementation in this study the focus is more on the RAMP framework and drivers which focus on intrinsic motivation and not on the kinds of players that would be driven primarily by extrinsic motivation.

2.4.3 Mechanics

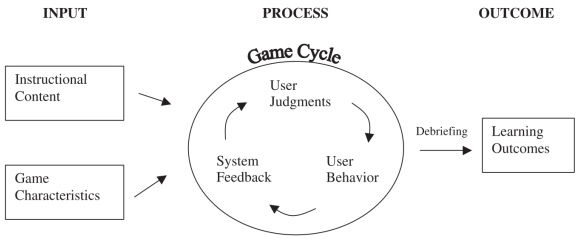
Mechanics in the game context specifically relate to the rules, procedures and elements that players will use when interacting with the game. Understanding which mechanics

Figure 2.5: The HEXAD Player Types



are most effective is a complex area of study, but some measure of clarity can be found from the literature. In seeking clarity on this mapping, Garris, Ahlers and Driskell put forward the Input-Process-Outcome model to attempt to evaluate elements of games more consistently [99] which can be seen in Figure 2.6. This model is specifically meant to be used in the educational context and highlights the interrelatedness of the characteristics of the game and it's instructional content.

Figure 2.6: Input-Process-Outcome Game Model



In addition to the model, they put forward a number of dimensions that games can be judged on namely: the level of fantasy, the rules and goals, the sensory stimuli, the challenge rating, the level of mystery and of control that players experience. As research has continued, it has become clear that the sheer scope of games make this a complex endeavor to measure directly. For example, an ongoing project by Howard is attempting to classify 300 different mechanics in order to create a more complete taxonomy of mechanics [100]. Fullerton took a different approach, instead of attempting to measure the game and it's mechanics as a whole, he instead highlighted 8 different kinds of ways in which players can interact with others and the game itself as [101]:

- Single player vs. the game
- Multiple individual players vs. the game
- Player vs. player
- Unilateral competition (multiple individual players vs. a single player)
- Multilateral competition (three or more players directly competing)
- Cooperative play
- Team competition (two or more groups competing)

Gamification mechanics and elements can be similar to game mechanics and as such there is also work under way to formally document these with Gamified UK identifying 52 elements can be used in combination with the six player types identified in the HEXAD framework [102]. For the purposes of this study, from the 52 mechanics presented the following were found to be suitable to the artefact:

- Signposting
- Progress and Feedback
- Scarcity
- Social Networking Elements
- Discovery
- Competition
- Exploration
- Challenges
- Learning new Skills
- Quests
- Sharing Knowledge
- Voting and Giving a Voice
- Anonymity (in voting)
- Points and Experience
- Physical Rewards and Prizes
- Badges and Achievements

In this work, mechanics are drawn from various places, but as it is an educational space, competitive elements will always be framed in a positive light, but significant use will be made of mechanics that have come before in order to not re-invent the wheel.

2.4.4 Games and Ethics

> *"It is indeed true that the bow, the slingshot, and the peashooter have survived as toys where they have replaced the more lethal weapons. But children play just as well with water pistols, cap pistols, or air rifles. They also play with miniature tanks, submarines, and airplanes which drop sham atomic bombs. There is no new weapon that may not momentarily be introduced as a toy."*- Roger Caillois [19]

It is interesting to note that in Caillois early work, he does not immediately give a definition of what games are but rather let's the reader explore through the lens of play only - in other words, games are things that are played [19]. From this however, he cautions that there are corruptions to games and the forms of play that can sneak in. Table 2.13 shows the forms of play, their use in life outside of games and their corruptions that Caillois identified as cautionary examples.

Table 2.13: The Corruptions of Play [19]

Type of play	**Cultural forms at the margins of the social order**	**Institutional forms integrated into social life**	**Corruption**
AGÔN (Competition)	Sports	Economic competition/ Competitive examinations	Violence Will to power Trickery
ALEA (Chance)	Lotteries Casinos hippodromes Pari-mutuels	Stock market speculation	Superstition Astrology, etc.
MIMICRY (Simulation)	Carnival Theater Cinema Hero-worship	Uniforms Ceromonial etiquette	Alienation Split personality
ILINX (Vertigo)	Mountain climbing Skiing Tightrope walking Speed	Professions requiring control of vertigo	Alcohol and Drugs

It is clear that even from early works on games that it was important to distinguish between forms of play that are more damaging than ones that are more constructive. A full discussion on ethics in games would be outside of the scope of this work, but it is important to acknowledge that it is an area that needs to be addressed when game design work is undertaken and in the author's mind doubly so when the game in question is meant for some other purpose than entertainment.

Sicart started providing a framework for an ethical exploration of games in [103], based on the work of Floridi in defining the concepts of gradients of abstraction (GOA) [104]. In his framework Sicart put forward that it is important to be able to identify the moral and ethical nature of the actions that can be taken by any agent in affecting the game environment, whether that agent be sentient or not. He put forward that there are two GOA of relevance, one which impacts merely the procedural workings of the game and a second which is related more to the semantic meaning of the actions.

In Gamification spheres however the concept of ethical behaviour becomes significantly more complex. Hughes and Lacy highlight many of the ethical problems specifically as they relate to Gamification in education in [105], but in essence Gamification is about motivating people to do things. When you are motivating people to do things they don't already want to do, you face an ethical problem. There is a fine line between encouragement and coersion. This has become a sufficient problem that authors like Nicholson have started distancing themselves from the underlying concepts of traditiona Gamification and instead put forward an idea that before designing the Gamification system itself, first the value to the user needs to be explicitly defined and focussed on [106]. The concept of ethical Gamification or user-centered Gamification has fortunately been embraced by many practitioners.

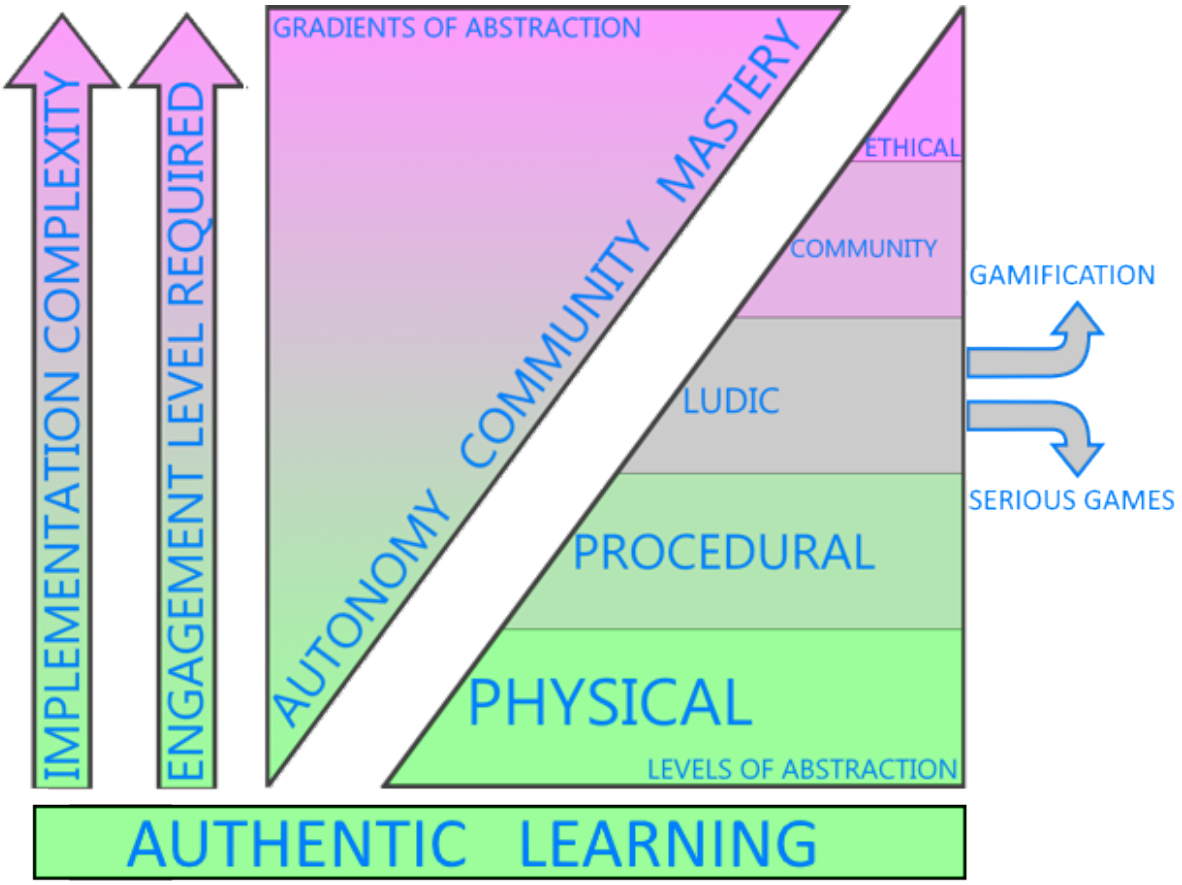
When considering the building of Game Based Learning systems it is always important to remember that the concept of the game-loop and its engaging nature is used equally in game design, Gamification and the design of gambling systems. Systemic support for the problems created through not taking this into account have reached a point now that the American psychiatric association has added "internet gaming disorder", most significantly with a specific exclusion for gambling and sexually based internet use to the diagnostic and statistical manual of mental disorders [107].

2.5 Conclusion

In this chapter an in depth look at the underlying literature that will be used in the rest of this work was given. A summary of how the different concepts fit together into a cohesive whole is presented in figure 2.7. In this diagram an attempt is made to show how each of the areas of the theoretical base are brought together and how they are analysed in order to gain the desired insight. It is naive to assume that the complexity of the system will scale linearly as described in the figure 2.7, the idea of giving students a platform to receive information, engage with it and simplify the physical act of capturing their decisions is measurably less complex than attempting to get students to internalise ethical concepts and show off their mastery in a socially connected system where they have a high level of control and autonomy. To reflect this non-linear complexity, Floridi's Gradients of Abstraction (GOA) as opposed to Levels of Abstraction (LOA) is used [104]. This technique gives the benefit of seeing the features or levels of a system more as a gradient highlighting the steps between each area in a way that is neither linear nor discreet. The theoretical components are thus:

- Authentic Learning: In this work the stance is taken that authentic learning is

Figure 2.7: Educational Approach



an effective way to teach students in a capstone module, as well as in engineering education in general. There are other techniques, but from the literature and the author's personal experience this has been taken to be an effective approach, and will be used as a guiding technique in the creation of the artefact that sits at the heart of the study. Opportunities will be made for authentic learning experiences that will hopefully lead to more engagement and motivation on the part of students.

- Self-Determination Theory: The three core feelings that we will be attempting to evoke in students relate to the level of autonomy they feel, the level of access to their community they will have and then the level of mastery they can show off. This is seen as a gradient, but not only as related to student engagement, but also with regards to the amount of work that will be needed from the researchers as well as the level of insight required. This is partially due to the fact that in this model, the three concepts build on each other quite directly - for example, in order to show off your mastery to members of your community, you need to already have the autonomy in the system in order to do so.

- Implementation Complexity: The levels of complexity of systems are not simply

split up between easy, medium and hard. Implementation complexity relates not only to the scale of a project, the number of moving parts in it or the complexity in the user base, but also on the level of skill of the practitioner implementing it. Due to this variability, the implementation complexity is also seen as a gradient, taking into account that the complexity does not scale up linearly.

- System Intervention Levels: The levels of abstraction with relation to the actual design of the system are seen not through GOA but rather through LOA simply because many of the concepts are already defined by the module and are understood quite well. For example, giving students more autonomy by allowing them the opportunity in the system to give their preferences is already measurably easier than it is to automate the procedures that are used to assign projects. By the same token, creating a game based interaction from an existing process will require the underlying process to be fully understood before it could even be attempted, which means that it is clearly measurably more complex as it is a super set of the previous two problems being solved. The five levels considered in the system intervention are:
  - Physical: The physical actions that need to happen during the module like the handing in of documents and registering with the admin office. Many of the physical aspects of managing the course need to be automated as part of the artefact development process. This is concerned largely with the simple moving around of paper and other simple actions.
  - Procedural: These are the processes that need to be automated through the implementation of the artefact, like the allocating of projects to students and the managing of the different states of the artefact based on the phases in the academic year.
  - Ludic: The ludic layer refers to the gamification and game elements that will be implemented into the system to increase engagement by students.
  - Community: This is the layer of the system that relates to the social aspects of the artefact such as the sending of messages, the posting of site messages, being able to comment on projects etc.
  - Ethical: The final layer relates to the ethical considerations that need to be taken into account in the creation of the artefact, as well as in the collecting, analysing and reporting of data.

  The design of the overall system is described in depth in Chapter 4.

- Engagement Level Required: The level of engagement required by students to address more complex sections of the work is also well recognised, but as with the level of complexity in implementing the artefact, the engagement required will also be dependent not only on the level of understanding the student already has and how much information they will take in, but also on the level of abstract thought that is required to understand the work. Understanding complex mathematical

sections of the coursework may or may not require higher levels of engagement depending on the level of interest, understanding and current situation of the student, regardless of the work being considered. As such it is seen as a gradient.

Figure 2.7 can be seen as a summary of the literature review, but the concept of the GOA will be used in future discussions as well. For example, when using the cognitive domain in Bloom's taxonomy, consider for a moment that a student may be already synthesising something without having full understanding of it, not because they are weak, but because this synthesis, which may fail, can be part of the learning experience. At that point it does not make sense to take them out of the analysis section of the domain, as they are clearly synthesising, but it also means that they are also not at the point where they have mastered synthesis as they are still analysing what is happening. They will be at the transition, but not yet fully over. In the author's opinion this is more effectively seen through the GOA approach.

In the following chapter the methodology that will be used will be laid out and the design choices will then be explored.

Chapter 3 - Research Methodology

3.1 Introduction

In this section the approach used in this study is presented. The initial sections will focus on the philosophy, approaches and methodologies that will be used, and after that the research ethics approach is given, as well as a more in depth exploration of Design Science Research (DSR) and Educational Design Research (EDR) specifically as it pertains to this study. The author will first justify why this exact position is started from.

3.2 World View

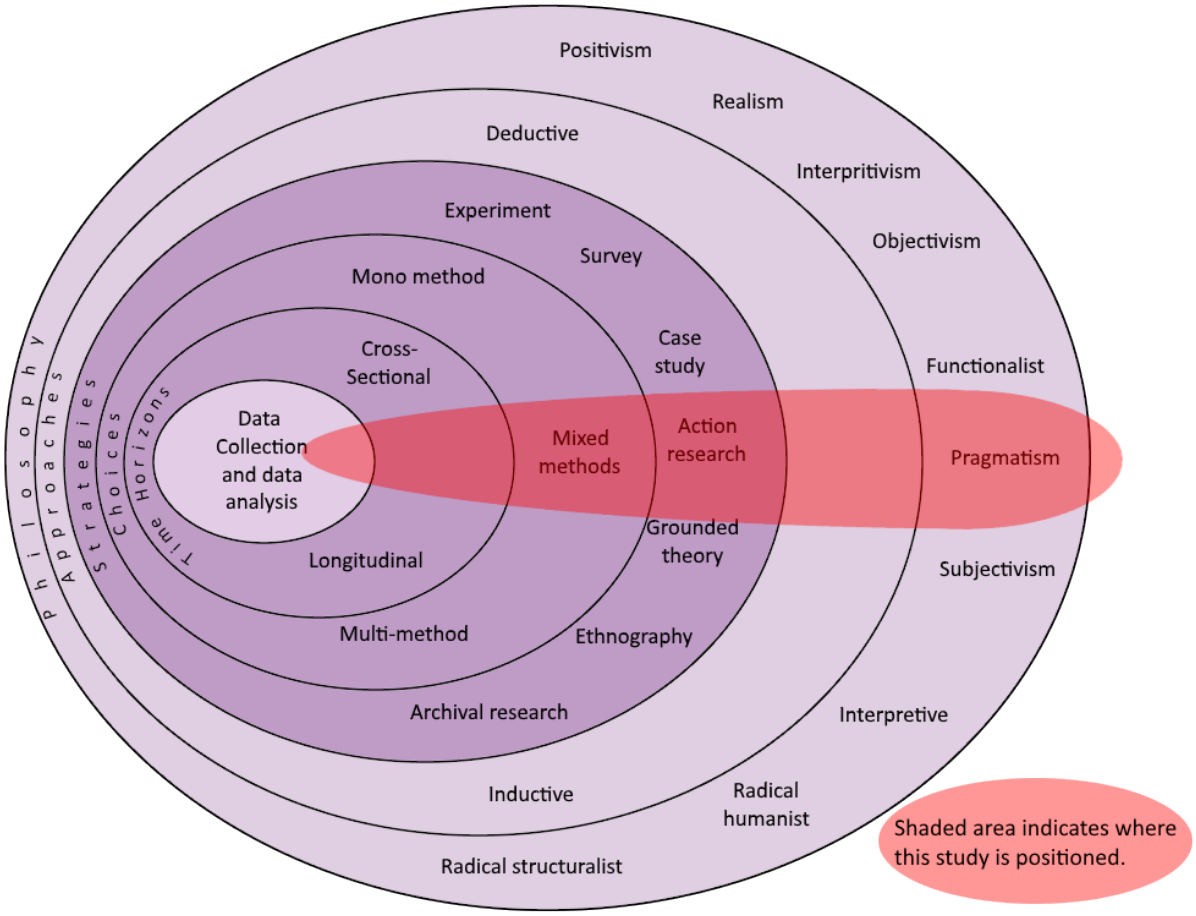
As research does not happen outside of the specific world view of the researcher, it is useful to first outline what the philosophies are that the researcher prescribes to as it gives a clearer understanding of why certain decisions were taken and how and why data would be collected and analysed. At this point, it becomes useful to look at a more holistic framework that explores how different philosophies and approaches fit into a cohesive whole. Although published in a guide for students in business administration, the research onion put forward by Saunders, Lewis and Thornhill has found use in a great many areas of research due to its simple approach [108]. The research onion has gone through a number of iterations and is at the time of writing found in the 7th edition of the book, but changes in each of the versions of the research onion merely shift the order in how different philosophies relate to each other. As such, Fig. 3.1 presents not only the research onion [108], but highlights how it will specifically be used in this study with emphasis placed by the researcher. The research onion used as the base for the image is from the 2012 version presented by Saunders, Lewis and Thornhill but the latest version of the image is available in [108].

In terms of the research onion approach, this study would fall directly in the middle as DSR/EDR and Action Research move hand in hand. It is then clear that this study finds itself in the pragmatic paradigm. At this point it is useful to first present some definitions [109]:

1. **Pragmatism**: *noun.* 1. A pragmatic attitude or procedure. 2. A philosophy that evaluates assertions based solely on their practical consequences and bearing on human interests.

2. **Functionalism**: *noun.* Belief in or stress on the practical application of a thing.

Figure 3.1: The Research Onion and Approach to This Study.



3. **Subjectivism**: *noun.* The doctrine that knowledge is merely subjective and that there is no external or subjective truth.

These simple dictionary definitions belie the fact that volumes have been written on the subjects, but a full philosophical discussion on any of the above mentioned concepts would be outside of the scope of this work. For the most part however, the reason that the author has chosen to put forward pragmatism as his world view is that it highlights the goal of the author to not be bogged down by theories that are primarily abstract and not applicable but rather to include only theories and philosophies that relate directly to the work at hand. Although chosen here as a philosophical viewpoint, it is the author's belief that all work undertaken in the Faculty of Engineering would be similarly informed. The author wishes to believe that he has a largely pragmatic and functional approach to creating artefacts that would directly achieve the research goals put forward in Chapter 1, but is also sensitive to the fact that the perceptions of the users of the artefact can only ever be viewed through individual user's subjective experiences.

With this pragmatic world view, it is worth introducing DSR. In the literature there

is some discussion as to whether DSR is in fact an approach or a paradigm all on its own as can be seen in Weber in [2]. The author would say that it is an approach that falls in the pragmatic paradigm where the creation of the artefact to solve the problem is of prime importance. Additionally:

- DSR with its close ties to Action Research takes from the interpretive domain with its focus on understanding phenomena and underlying truth to give it a solid grounding in the social sciences.
- DSR is concerned with the creation of artefacts that ultimately solve problems, and it uses basic research data, as well as quality evaluative techniques from engineering and hard sciences in order to optimise the creation process.
- DSR is cognisant that information systems artefacts that are not used by people are not useful[8]. People work within a context and a structure, and through understanding the artefact that would be required to serve people within their context, an understanding can be gained of the processes and structures that those people form part of. It is only through participation that this process can be optimised.

3.2.1 Research Approach

As stated in the previous section, DSR in this context is seen as an approach rather than a paradigm. Having said that, it does have a rich literature and very vocal proponents. The most important contributors that informed this work are [110], [9], [111], [43] and [2]. It is recognised by the author that EDR and DSR have a rich literature, but the author is choosing to mainly follow the approach put forward by Van den Akker, Bannan, Kelly, Nieveen and Plomp [111] [112].

In [111], Plomp points out that there are two main purposes under which DSR would be undertaken, namely for a developmental or a validation purpose. It is important to note that although both purposes are valid, Plomp does show that validation is the one that is most likely to contribute to human knowledge. With this in mind the author is aware that it is not sufficient to apply design techniques in creating an artefact to solve a particular problem, but it is only in evaluating the artefact and iteratively overcoming and documenting it's shortcomings that DSR research is brought about. It is worth noting that DSR is also used interchangeably with EDR in certain sections of the literature - to clarify, DSR refers to Design Science Research as the approach where EDR refers to Educational Design Research following this approach in the educational context only.

This then brings about the approach that will be taken in this work. A DSR approach will be taken where the approach to gathering the requirements will be very subjectively taken, with the view of understanding the nature of the problem from the view of the

[8]It is interesting point out that even machine to machine systems that work without any interaction from humans are still considered to be useful to humans. More complex are applications of information systems to art installations, as the discussing the purpose and usefulness of art is far out of the scope of this work.

different stakeholders involved with the system, and once understood, an artefact will be created to solve the problems presented. Once created the artefact will be evaluated rigorously to understand what systematic problems are present to ensure the best quality artefact is put forward. In the author's view, this would constitute a pragmatic approach to DSR.

In terms of the kinds of contributions that can be made to the literature through a DSR approach, Gregor and Hevner put forward in [8] a model for the different levels of knowledge that are relevant and how different levels of knowledge are on a spectrum from specific to abstract. The model can be seen in Figure 3.2.

Figure 3.2: Design Science Research Contribution Types from [8]

Table 1. Design Science Research Contribution Types

	Contribution Types	Example Artifacts
More abstract, complete, and mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
↕ ↕ ↕ ↕	Level 2. Nascent design theory—knowledge as operational principles/architecture	Constructs, methods, models, design principles, technological rules.
More specific, limited, and less mature knowledge	Level 1. Situated implementation of artifact	Instantiations (software products or implemented processes)

In terms of the synergy between Action Research and DSR, there is conflict in the literature as to whether the two approaches can be used simultaneously successfully or whether they are even substantially different. In [113] Järvinen puts forward the argument that Action Research and Design Science are in fact similar approaches when one considers the characteristics of both of these approaches side by side. The author does this by first identifying seven characteristics of Action Research and six characteristics of Design Science and then draws parallels between them. Although a compelling argument, this paper was disputed by Livaru and Venable in [114] where they argue that there are a great many differences in the two approaches from paradigmatic, ontological, epistemological, methodological and ethical perspectives. They also go on to highlight the dangers of combining the approaches. For the purposes of this study, the main approach is DSR, but in understanding the nature of the problems that needed to be solved, the author used an Action Research approach in becoming one of the study leaders to a number of capstone project students so that the issues could be understood from within the system. The difference in the authors opinion between the two approaches is that when using Action Research the researcher is an active participant in the research and makes up one of the moving parts of the system, where with DSR the focus is more on understanding the nature of the problem one finds, using any suitable technique, and then approaching that problem with a design mentality and creating a knowledge containing artefact that will solve it. DSR is therefore the main approach used in this study and will be explored fully in Section 3.3.

3.2.2 Methodologies

The study is being undertaken as a mixed method approach because information systems always have a significant human factor to them, and therefore to supplement the quantitative data that will be collected from the database during various field tests, qualitative data will be collected from participants in the study through questionnaires, interviews and participatory design sessions.

To ensure a high level of validity to the data being collected, in addition to the general questionaire that has been set up specifically to gain insight into the needs of the participants, a number of previously validated instruments will be used to collect data. Specifically, the Intrinsic Motivation Inventory (IMI) [115] and Situational Motivation Scale (SIMS) [116] questionnaires were used to both measure the impact on motivation of the participants to partake in the using of the gamified interventions, as well as to attempt to gather whether they were in fact motivated to partake in the participatory design sessions. To test concepts like the Jen Ratio [117] which is introduced in chapter 5 and stable matching from Chapter 6 quantitative data will be used that will be taken from the database of the artefact.

In designing the artefact that forms the heart of the study, the author will rely on enterprise architecture principles for the design and development implementation of the work. Specifically, heavy use will be made of the TOGAF9.1 approach[9] [10].

The SIMS, IMI and general questionnaire will now be introduced to give the reader an understanding of the kind of data that will be collected and used to feed back into the design of the artefact.

Situational Motivation Scale

The Situational Motivation Scale (SIMS) consists of 16 questions on a single questionnaire where the participant is asked to rate a question on a seven point Likert scale indicating how much they agree or disagree with the statement. Each value is assigned a specific statement of truth.

The scoring sheet is replicated here in Table 3.14. The SIMS questionnaire will be given to participants during the participatory design sessions to gauge how the participants experienced the session. The Mozilla foundation puts forward that an effective participatory design session requires three to 16 participants and one to two facilitators [118]. In the author's experience a participatory design session of more than eight members however tends to regress to the mean and the least offensive design is chosen rather than allowing participants to bring any new and innovative ideas to the table. The SIMS is used to measure the levels of motivation experienced by participants in the design sessions.

The nature of the SIMS is that it needs to be presented to participants within two hours of participation as it is situational, and as such it is made an integral part of the

[9]The Open Group Architecture Framework is both the acronym of the group as well as the official name of the approach and standard

Table 3.14: Situational Motivation Scale Scoring Sheet

Why are you currently engaged in this activity?	Disagree 1	2	3 Neutral	4	5	6	Agree 7
1. Because I think that this activity is interesting							
2. Because I am doing it for my own good							
3. Because I am supposed to do it							
4. There may be good reasons to do this activity, but personally I don't see any							
5. Because I think that this activity is pleasant							
6. Because I think that this activity is good for me							
7. Because it is something that I have to do							
8. I do this activity but I am not sure if it is worth it							
9. Because this activity is fun							
10. By personal decision							
11. Because I don't have any choice							
12. I don't know; I don't see what this activity brings me							
13. Because I feel good when doing this activity							
14. I believe that this activity is important for me							
15. Because I feel that I have to do it							
16. I do this activity, but I am not sure it is a good thing to pursue it							

participatory design sessions. Scoring of the questionnaire is done on four dimensions namely intrinsic motivation, identified regulation, external regulation and amotivation.

In scoring the SIMS, the following key is used:

- Intrinsic Motivation: question 1, 5, 9 and 13
- Identified Regulation: question 2, 6, 10 and 14
- External Regulation: question 3, 7, 11 and 15
- Amotivation: question 4, 8, 12, 16

All of the questions in each of the sections are summed together giving four values out of 28 for each of the measured constructs with higher values indicating a higher level of construct presence in the participant at the time of measurement.

Intrinsic Motivation Inventory

In addition to using the SIMS questionnaire, the IMI is also employed to determine the level of intrinsic motivation students experienced when using the artefact. The IMI consists of 22 questions on a single questionnaire where the participant is asked to rate a question on a seven point Likert scale indicating how much they agree or disagree with

Table 3.15: Intrinsic Motivation Inventory scoring sheet

	not true 1	2	3	neutral 4	5	6	very true 7
1. While I was working on the task I was thinking about how much I enjoyed it.							
2. I did not feel at all nervous about doing the task.							
3. I felt that it was my choice to do the task.							
4. I think I am pretty good at this task.							
5. I found the task very interesting.							
6. I felt tense while doing the task.							
7. I think I did pretty well at this activity, compared to other students.							
8. Doing the task was fun.							
9. I felt relaxed while doing the task.							
10. I enjoyed doing the task very much.							
11. I didn't really have a choice about doing the task.							
12. I am satisfied with my performance at this task.							
13. I was anxious while doing the task.							
14. I thought the task was very boring.							
15. I felt like I was doing what I wanted to do while I was working on the task.							
16. I felt pretty skilled at this task.							
17. I thought the task was very interesting.							
18. I felt pressured while doing the task.							
19. I felt like I had to do the task.							
20. I would describe the task as very enjoyable.							
21. I did the task because I had no choice.							
22. After working at this task for awhile, I felt pretty competent.							

a statement. In this scale one corresponds to "not true", four to "somewhat true" and seven to "very true". The scoring sheet is replicated here in Table 3.15.

IMI scoring is done by scoring across four different areas namely interest/enjoyment, perceived competence, perceived choice and pressure/tension. It also includes six reverse scored questions. To score these questions, the marked value is subtracted from eight (thus a higher mark on a negative question gives a lower value to the overall score). The reversed questions are also added to filter out spoiled scoring sheets, ie. if a student marks everything as a seven in the hope of conveying only positive values, or all one in the hope of only giving negative marks without actually considering the questions.

General Questionnaire

The General questionnaire consists of five questions measured on a five point Likert scale, a multiple select question and three open ended questions that attempt to gain insight into the participant's view on game based interventions in engineering education. The questionnaire questions are replicated in Figure 3.3.

3.2.3 Data Collection and Analysis

A full discussion of the data collection and analysis techniques to be used for the questionnaire and semi structured interview data can be found in Appendix A. As a summary however, ethical approval was sought to do the following data collection activities:

- Supply questionnaires to more than 50 students in order to get a representative sample of them to give input into the system. As approximately 100 students take the module yearly, this was considered sufficient.
- In addition to the questionnaires given, it was envisioned that at least 10 students would need to be interviewed to gain a deeper insight into their experience of using the artefact.
- In keeping with Action Research principles, the researcher would participate actively in the system by serving as an external supervisor to a number of students during the academic year. As the author is not from the hosting institution, this would be done in collaboration with one of the internal study leaders.
- As the artefact is split up into sub systems that are not all active at the same time, the functionality would be measured both as a whole and each subsystem as an individual case study.
- In addition to the subjective data collected from participants, the artefact would capture quantitative data as described in Appendix A for each of the sub sections.

Ethical clearance for analysing the data was obtained, and the certificate can be found in Appendix A.

3.3 Design Science Research

As discussed in the previous section, a DSR approach is followed in this study. We will now go a little deeper into DSR, and show the actual workings and how it will be applied in this study.

Q1. Do you think a more gameful approach to coursework will help students in their coursework?

◯ I strongly agree ◯ I agree ◯ I am neutral ◯ I disagree ◯ I strongly disagree

Q2. Do you think the projects offered in this course are of a high quality?

◯ I strongly agree ◯ I agree ◯ I am neutral ◯ I disagree ◯ I strongly disagree

Q3. Do you feel that the university of Johannesburg is offering students the opportunity to work on projects that are relevant to the south African context?

◯ I strongly agree ◯ I agree ◯ I am neutral ◯ I disagree ◯ I strongly disagree

Q4. Could university coursework also have an element of fun to it?

◯ I strongly agree ◯ I agree ◯ I am neutral ◯ I disagree ◯ I strongly disagree

Q5. Do you think that gamifying coursework content would dilute it?

◯ I strongly agree ◯ I agree ◯ I am neutral ◯ I disagree ◯ I strongly disagree

Q6. What sorts of games do you enjoy playing most?

◯ Adventure ◯ Board games ◯ Alternate Reality Games ◯ Card games

◯ Platformers ◯ Puzzlers ◯ First person shooters ◯ Sports games

◯ Strategy games ◯ Role playing games ◯ I don't play games

◯ other games:

_____

_____

_____

Q7. What sections of the course did you find most challenging?

_____

_____

_____

_____

Q8. Are there any specific areas of the course you think would benefit from a gameful approach?

_____

_____

_____

_____

Q9.Do you have any ideas or advice for the research team?

_____

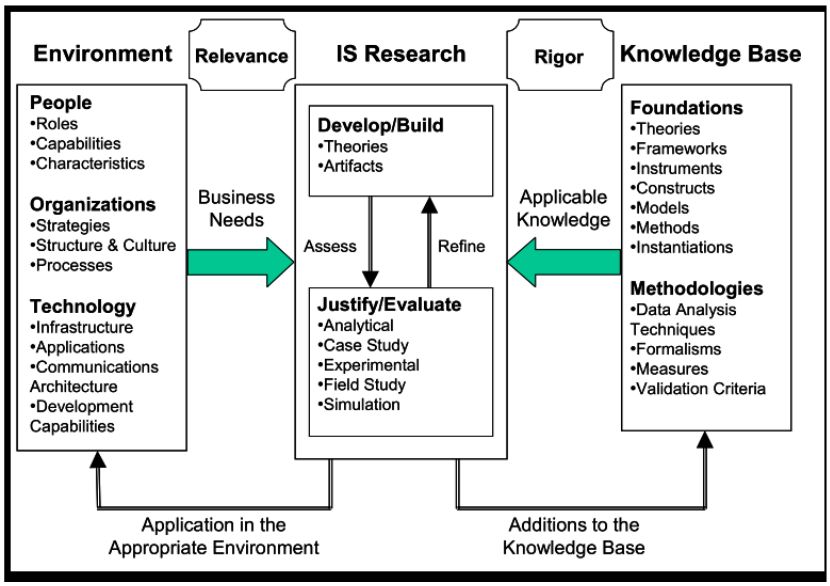
_____

_____

_____

Figure 3.3: General Questionnaire

Figure 3.4: The DSR Framework [9]



3.3.1 DSR Framework

Hevner, March and Park [9] put forward a framework which can be used to gain an overview of the DSR approach which can be seen in Figure 3.4.

It can be seen that when using the framework the following areas need to be investigated to gain an understanding of the environment in which the research is to be done:

1. The roles, capabilities and characteristics of the people involved.
2. The strategies, structure and culture of the organisation.
3. The infrastructure and architecture of the existing technologies.

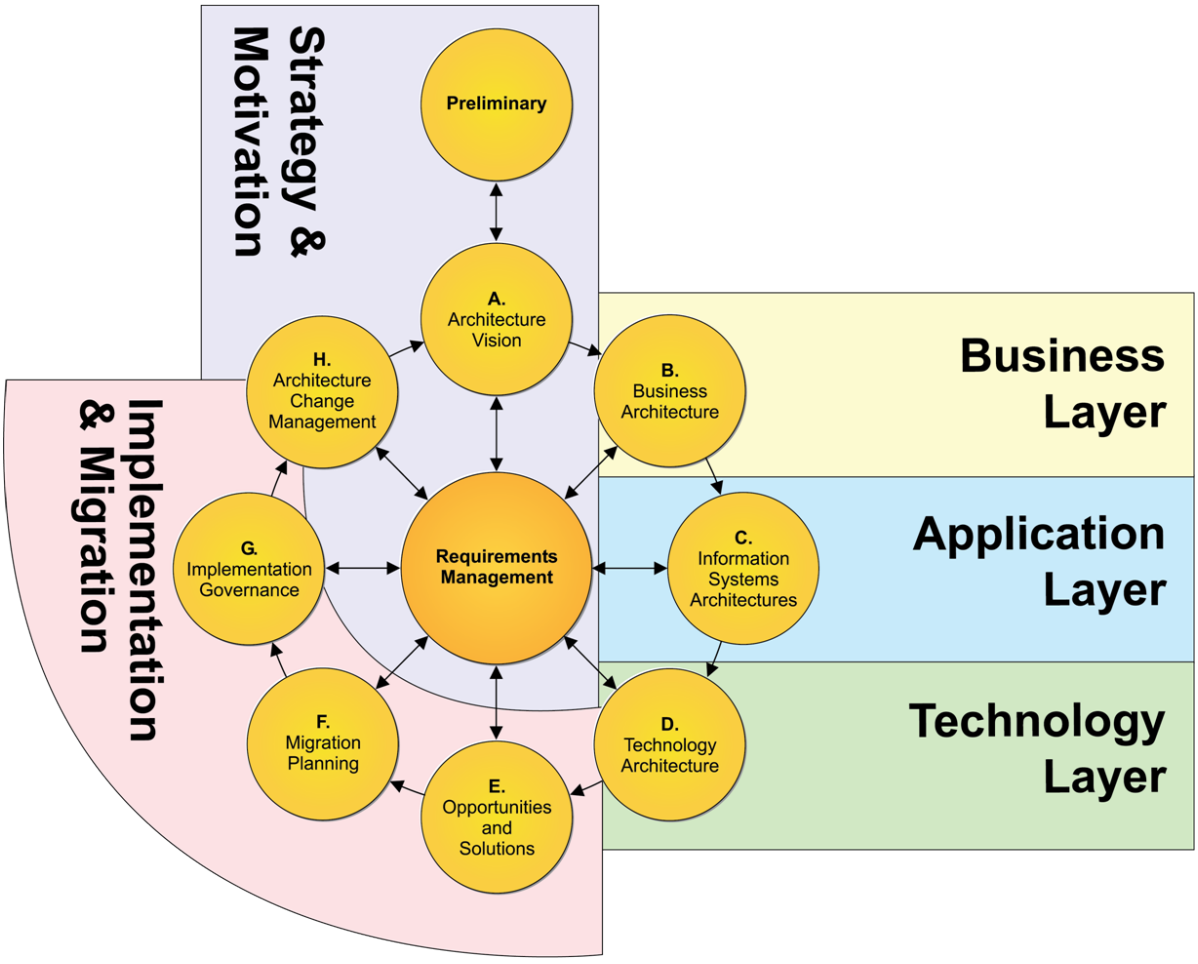
These will be used in conjunction with a knowledge base that is held by the different stakeholders that will action the project consisting of foundational models, theories and frameworks used by applying existing methodologies to give rigour and validity to the work being done.

Given an understanding of the environment and a suitable knowledge base, a DSR approach to the research is to take in this information to assess the needs and refine them into actionable tasks that can contribute to the design and development of a suitable artefact for the specific problems experienced by people in the environment. Each of the artefacts that are developed are not just taken at face value, but are instead developed and deployed as prototypes which are then evaluated for effectiveness and measured against applicable standards to ensure the work is progressing in the right direction, while simultaneously integrating what is learnt back into the knowledge base and the arena of best practice. This cycle of developing artefacts and evaluating them is done iteratively over multiple cycles.

This iterative approach is seen as one of the core characteristics of DSR work, and is often the first characteristic that is encountered by new researchers. The iconic cyclic process is shown to great effect by the loop diagram presented first by Mckenny and Van den Akker that can be seen in [3] and is presented in this work in Figure 1.3.

This approach is used partially due to it's proven applicability, but also because it ties in very well with the author's experience in using the TOGAF 9.1 methodology [10]. When looking at the framework itself, the core approach used by practitioners is the application of the Architecture Development Methodology (ADM) that can be seen in Figure 3.5.

Figure 3.5: The TOGAF Architecture Design Methodology - From [10]



The ADM is a powerful tool used to develop a full understanding of the environment, organisation and data specific requirements that are the catalysts for developing information systems artefacts. It is worth highlighting just the circular nature of the ADM, affectionately called the "wagon wheel". Projects start off with a need being identified, and then a preliminary investigation. From this point, the developer puts forward a high level vision of the theoretical system that would fill this need (marked as A). By then sequentially evaluating the business, data, applications and technologies (marked as B,

C and D) that are present in the environment, the requirements are refined to a point where an understanding of what needs to be done is obtained. Once requirements have been refined, opportunities and solutions are identified that could address the requirements (E), without looking only at development, but also looking at whether existing systems could be re-purposed to solve the problems more simply, or alternatively identifying possible solutions that could be purchased. Once an appropriate match is found between a solution and the requirements, a plan can be put in place to migrate from the current environment to a future point where the requirements are addressed (marked F, G and H).

A key principle here, is that should the requirements not all be addressed by the possible solutions, or if additional requirements come to light, then the migration plan may be to not implement anything, but rather to head around the loop one more time to ensure that the vision and requirements accurately reflect what is actually needed.

In the following subsection these two frameworks are combined to show how they can be applied effectively in the education space.

3.3.2 Framework Application

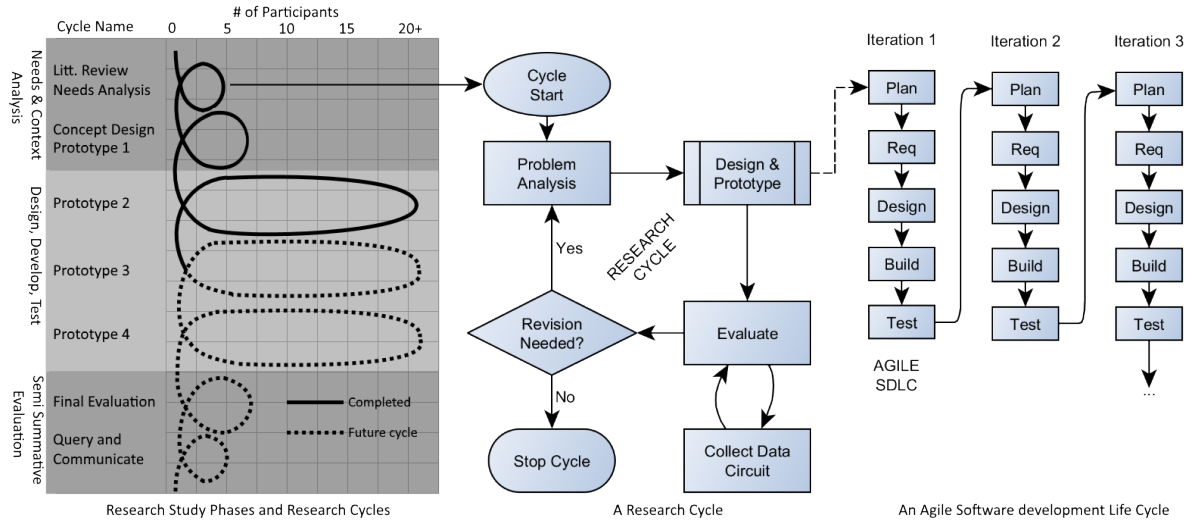
As pointed out previously from [111], DSR is an inherently iterative approach. This approach feeds in well with the current push towards more agile software development. Although there are multiple approaches that can be taken when discussing "Agile" software, it is the author's opinion that regardless of which specific approach is followed that the original agile manifesto's principles [119] remain a valuable check to see if the project is "on track". In designing the research aspect of the work, Figure 3.6 shows the approach that has been used by the author, not only in this work, but in multiple projects done at the North-West University Serious Games Institute (SGI-SA) that at the time of writing is overseen by the author. The approach combines Mckenny and Van den Akker's loops [3] with the TOGAF ADM, the research cycle from [111] and a generalised iterative software approach. This approach has been used successfully in the following projects [27], [34] and [35], in addition to this work by the author and his students and colleagues.

This technique has already proven itself to be a useful approach having been used in the stuties referenced above and has become the standard approach now at SGI-SA. Planning each of the iterations is done using the principles put down in [10] in order to ensure that all aspects are taken into account at the start of each prototype iteration.

3.3.3 Iteration and Planning

As the prototype iterations are performed according to TOGAF principles, heavy use is made of Unified Modeling Language (UML), wireframe design and Business Process Modeling Notation (BPMN), as well as architectural design and layout tools to map out what would be done in each iteration. A full description of the techiques used can be found in [10].

Figure 3.6: DSR Framework Expanded



3.3.4 Evaluating Success

As can be seen in section 3.3.2 at the end of each iteration there is also a need for an evaluation of the prototype to see if the goals were achieved. In this section the approaches of Nieveen and van den Akker are followed [44] and [3] and the following techniques are applied: workshops, developer screening, expert appraisal, micro evaluation and tryouts depending on the nature of the changes in the prototype. The main tests were then performed as field trials at the University of Johannesburg.

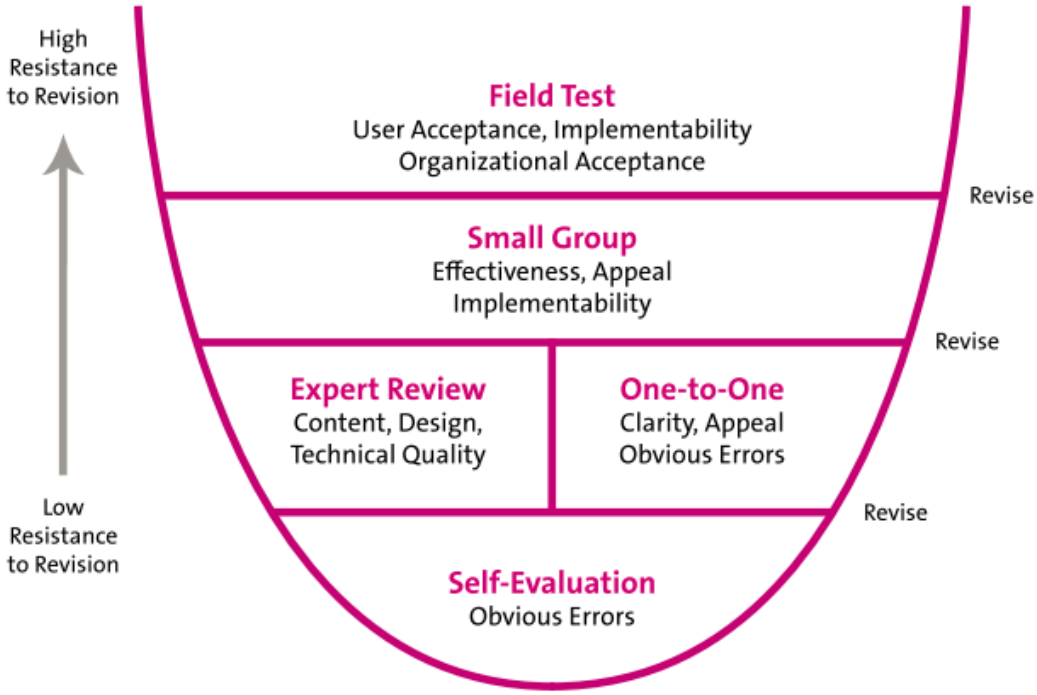
In terms of workshops, a participatory design approach is followed as put forward in [120] where students who will ultimately be the users of the final system are invited to partake in design sessions to give their input on how the system could be made better. Figure 3.7 shows the approach put forward by Tessmer and refined by Nieveen in [111] and [44] to give ways of both evaluating and reporting on the quality of the prototype as well as reporting on the size and make-up of the participants in the evaluation.

3.3.5 Design Ethics

In subsection 3.2.3 the ethical application for the study was described, with full information on the scope of the ethical application available in Appendix A.

It is worth recognising at this point however that although games and Gamification would previously have been considered a pretty innocuous area, recent studies have brought to light some of the very real ethical concerns that need to be taken into account during the design of interventions of this nature. Authors like Sicart plunge the depth of ethical questions that can be raised during game play in works like [103], where Nicholson highlights the long term negative effects that Gamification can have on people due to the inherent goal of modifying their behaviour patterns [106]. Some even go as far as Bogost to consider Gamification nothing more than exploitation of behavioural triggers

Figure 3.7: Nieveen's Approach to Evaluating Prototype Quality



in order to con people into doing things they inherently don't want to [41].

In developing this system, the core view was taken that the student should be the focus of all interventions, and as such all precautions should be taken to protect them and not exploit their natures to achieve project success. As there is no objective test that can be done for this, it is incorporated into the interview questions and feedback sessions with students and experts. Ethical design is considered sufficiently important in this work that it should be reflected on before the full system is introduced and the following sections and chapters should be read with this in mind.

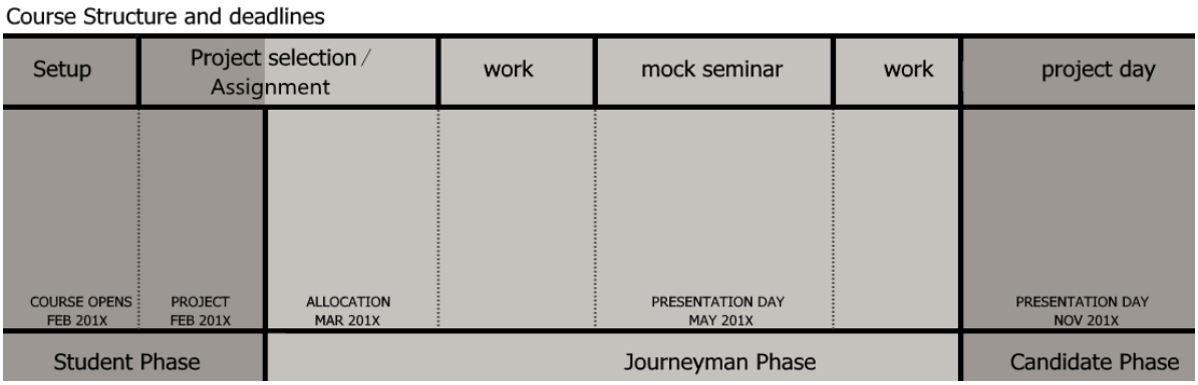
3.3.6 Time Frames of Artefacts

During the preliminary investigation into the requirements for the system, it became clear that the interventions needed by students would not be the same throughout the course of the year. In exploring this concept with McGonigal's "Life is a game" approach firmly in mind, with heavy inspiration taken from /r/Outside, the time frame shown in Figure 3.8 was put forward as a way of viewing both the module and the mindset of the students through the year.

In this view, the student is seen as a young engineer that develops through the following three phases:

- **The Student Phase:** Here the student is still in the mindset of writing tests and examinations from their previous modules, and they have not yet been given

Figure 3.8: The PJE Timeline



a large project to do in their studies.

- **The Journeyman Phase:** In this phase, the student has moved past the student mindset where they can cram for the exam. They are realising that a large project needs a different approach. For most of the students, this will be their first large project.
- **The Candidate Phase:** In this phase, students have completed their first large project, and if successful they are now one step closer to their professional registration. Candidates have a professional responsibility to also be examples to the students who will come after them, so in this phase students will have the chance to show off what they know to junior students.

The three phases are mapped onto the academic year in Figure 3.8 where a number of time boxes have been identified where the set-up of the module, the project selection, seminars and project presentation times are highlighted as times when students will need support. As features were added to the system and the prototypes matured this timeline was used as the canvas to show the capabilities of the system.

3.4 The DSR Timeline

As this study is undertaken with a DSR approach, it makes sense at this point to talk more about the timeline and how the designs above were implemented as the project moved forward. DSR is an inherently iterative process, so some of the design components went through more iterations than others as the timeline progressed. Figure 3.9 shows how the focus in the design, develop and test phase of the DSR approach now moves more into the implementation and migration space of the ADM. The work started with a conceptual design cycle and was then done over four prototypes spanning the following time span:

1. Prototype 1: Second semester 2016

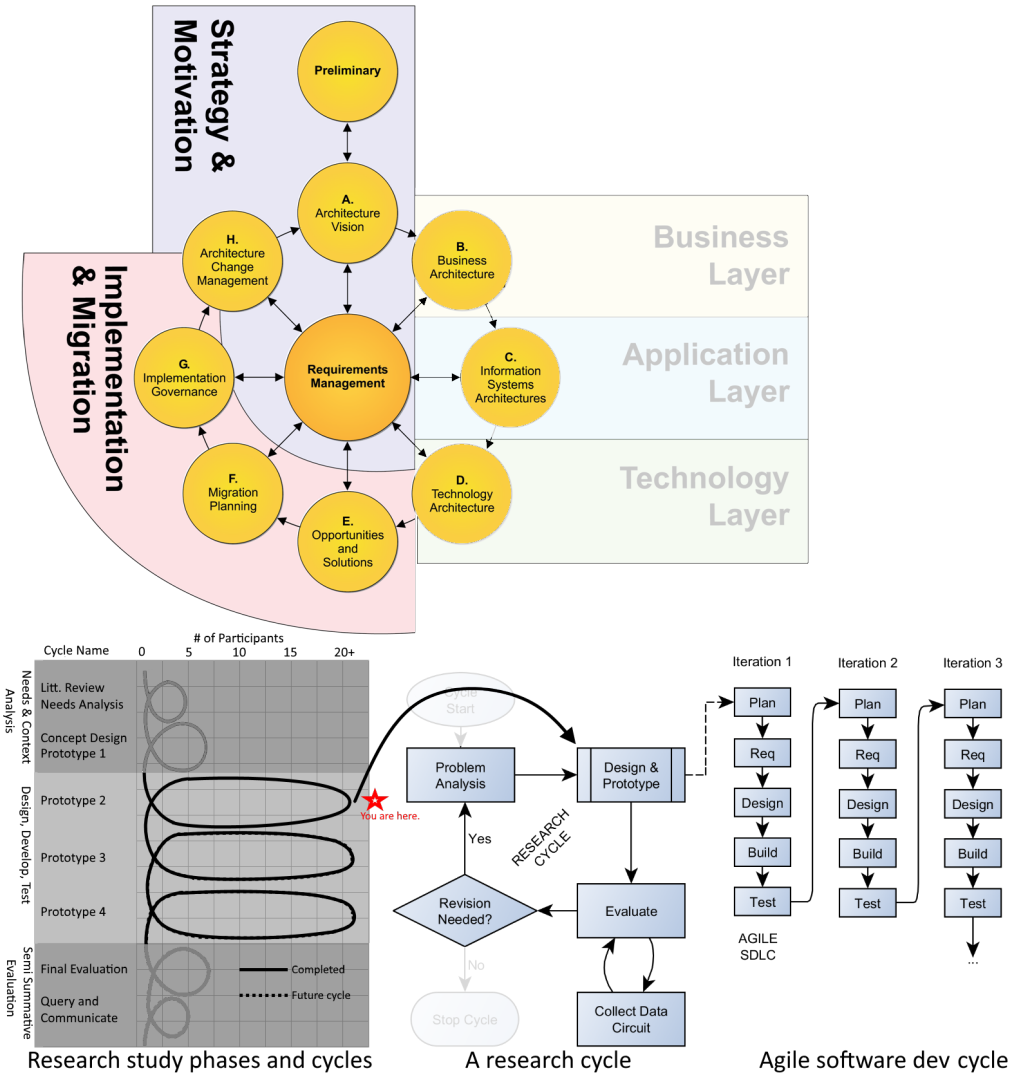
2. Prototype 2: First semester 2017

3. Prototype 3: Second semester 2017

4. Prototype 4: First semester 2018

Each of the prototypes had different sub artefacts added, as well as increasing or modification of the sub artefacts and base system that was already in place. Each prototype is now discussed with regards to what work was added in each.

Figure 3.9: Design, Develop and Test Focus in DSR

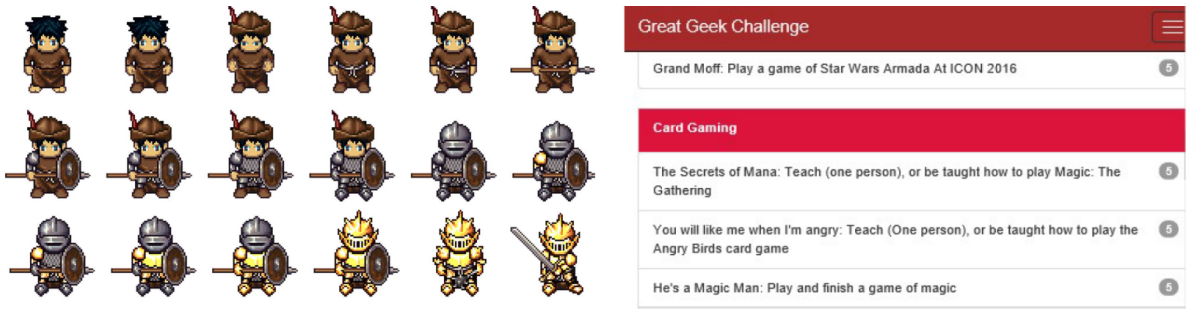


3.4.1 Conceptual Designs

Conceptual designs were done based on some literature review, inspiration from reading the work of McGonigal and based on the personal experience of the author. In 2016,

the author was involved in gamifying a number of systems commercially, and one of them specifically "The Great Geek Challenge" which was a location based game used during an annual tabletop gaming convention held in South Africa. Based on this positive experience the seeds of the PJE system were laid. This experience translated well into some of the design elements and wireframes presented during the first pitches for implementing the system. Figure 3.10 shows some of the design assets and art style used during "the Great Geek Challenge" so it can be seen how this style has propagated throughout. From this idea, the concept of moving it into the educational space were explored, and the initial design for the location based game created is presented in Chapter 4.

Figure 3.10: The Great Geek Challenge



3.4.2 Prototype 1

In the second semester of 2016 the first prototype of the system went live and was tested on the project day. The first Location Based Game served partially as a proof of concept of the platform, as well as to establish the idea in the minds of the students that would participate in the project in the following academic year. The feedback from participants was focussed more on study leaders and experts as this was new territory. Prototype 1 is presented in Chapter 5.

3.4.3 Prototype 2

In the first semester of 2017 the issues raised in the previous prototype's design were addressed, and the second sub artefact was added and field tested for the first time. The Tender Game gave students the ability to look at the projects that study leaders put forward and then also evaluate their peer's work in an authentic learning experience. The results from the initial field trial were positive but highlighted an issue with the amount of data required to make an accurate match of student to project which would be explored in the following prototype. The Challenge System was also introduced but the results were not favourable. Prototype 2 is presented in Chapter 6.

3.4.4 Prototype 3

In the second semester of 2017 the changes to the Location Based Game were finalised and updates were made to the Challenge System. Previously challenges could only be added by the module coordinator or administrators, making it overall not particularly useful. This was updated to allow more freedom to the users. Continued work on administrative back end abilities also started becoming more refined. Prototype 3 is presented in Chapter 7.

3.4.5 Prototype 4

The final prototype which became the working release version included the change to the Tender Game to now make it have a larger focus on the positive job application process students would have to go through instead of the tender process envisioned initially. Additionally, by changing the focus from projects to study leaders, the data could be used to gain better insight into matches between students and study leaders. The Location Based Game and Challenge System were also finalised into a much more dynamic form that was in the control of the study leaders rather than the module coordinator and administrators. This final prototype is presented in Chapter 8.

3.4.6 Conclusions and Contributions to the Knowledge Base

The final chapter of the work will contain the knowledge that was gained through implementing the artefact through all of its prototypes. Conclusions are drawn and a proposed model is put forward that could be used in future projects of this nature as a contribution to the knowledge base. Conclusions and a summary of the evaluations that were done on the artefact is presented n Chapter 9.

3.5 Conclusion

In this section the research and design methodology that the author used was introduced, and an introduction was given to the system that was developed. The following chapters will give a more in depth look at the work done in the conceptual design phase as well as in each of the individual prototypes.

Chapter 4 - Conceptual Design and Architecture

4.1 Introduction

In the previous chapters an introduction to the problem, literature and approach to research was presented. In this chapter the work shifts to the things that were done, rather than the things that were referenced. When looking at the DSR approach put forward in Chapter 3, the first three chapters of this thesis represent the first cycle of literature review as well as the needs and content analysis. At this point we move on to the second DSR phase of conceptual design and prototype development. To set the tone however, the researcher puts forward the following quote:

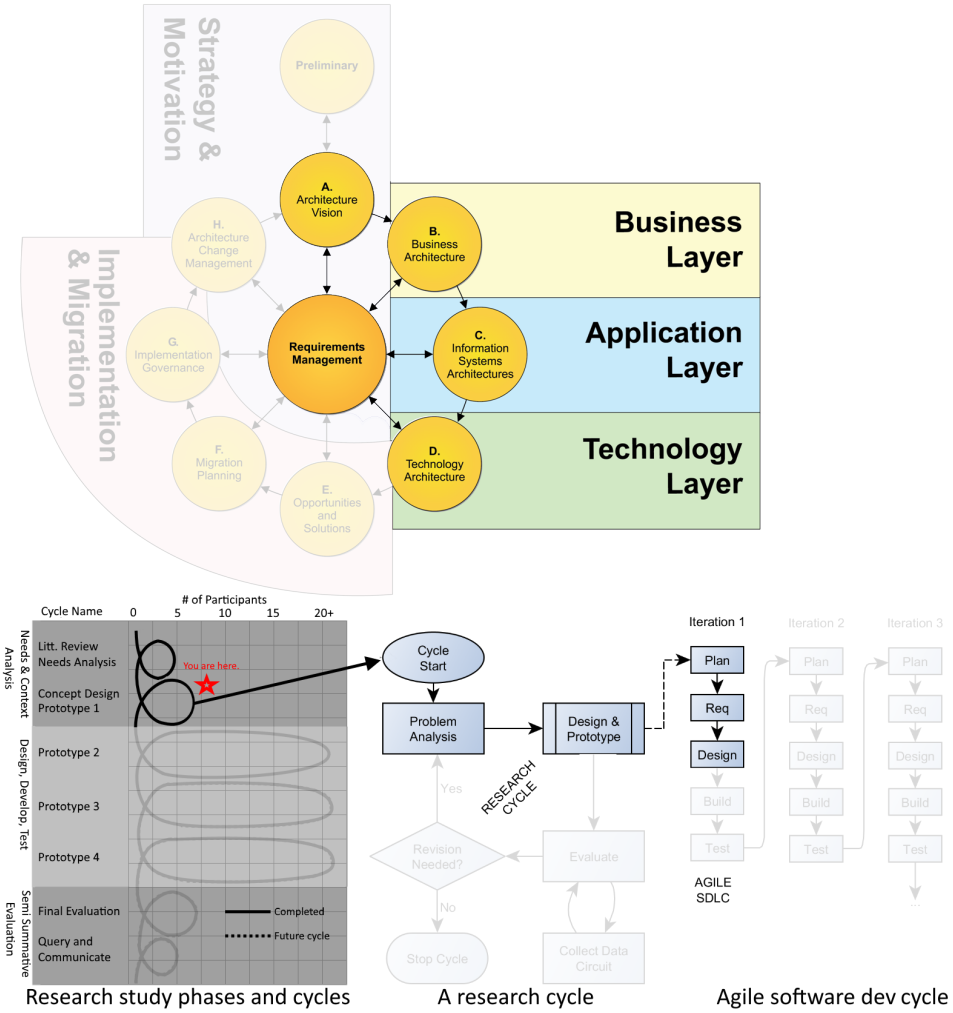
> *"Research has also revealed an influence in the design of online learning courses that often militates against the effective use of situated learning, namely, learning management systems. The tendency for universities to place courses on the web (using systems such as WebCT and Blackboard) has often resulted in the focus being placed on information delivery rather than learning (Herrington, Reeves, & Oliver, 2005). Teachers often yield to the seductive appeal of a learning management system, where it is easy enough to populate a weekly schedule with readings and activities, rather than create a complex and engaging task as a vehicle for substantial learning in the course. Their role can be trivialized by the technology, and many become preoccupied with the summary statistics readily available in the system, and frequency of access can be equated with learning."* - Herrington [77]

In this work, an electronic intervention is presented, but it is important to realise that this intervention can only ever be a supplement to the work that is done by the module coordinator, study leaders and project sponsors that already partake in the process of training new engineers.

In designing information systems, a heavy emphasis is often placed on the field of enterprise architecture, even when a more agile approach is being taken. Although it would not seem to be an area that has a heavy cross-over appeal with education, the concepts of seeing the abstract similarities between problems to re-use previously established solutions is something that any field can benefit from. Viewing educational interventions in this way is not a new idea however as can be seen in [121].

In this work, although an agile and iterative approach is taken during the intial planning stages and during the initial stages of each of the iterations heavy use will be made

Figure 4.1: Positioning the State of the Design Work



of the TOGAF 9.1 standard, in particular the Architecture Development Methodology (ADM) [10]. In this chapter, the conceptual design of the system is presented alongside the architecture that was eventually put forward for all of the prototypes to be built from. The underlying architecture presented changed very little between prototype 1 - 4 and as such it is presented here and only where changes were made in later prototypes are they highlighted in the subsequent chapters.

4.2 Conceptual Design

In the first section of the ADM, the business processes, data, technology and application space is analysed to gain an insight into the context that the artefact will be deployed into. The acronym often used for this style of analysis is Business, Data, Application and Technology (BDAT) layer analysis. Using the approach defined in Section 3.3 the

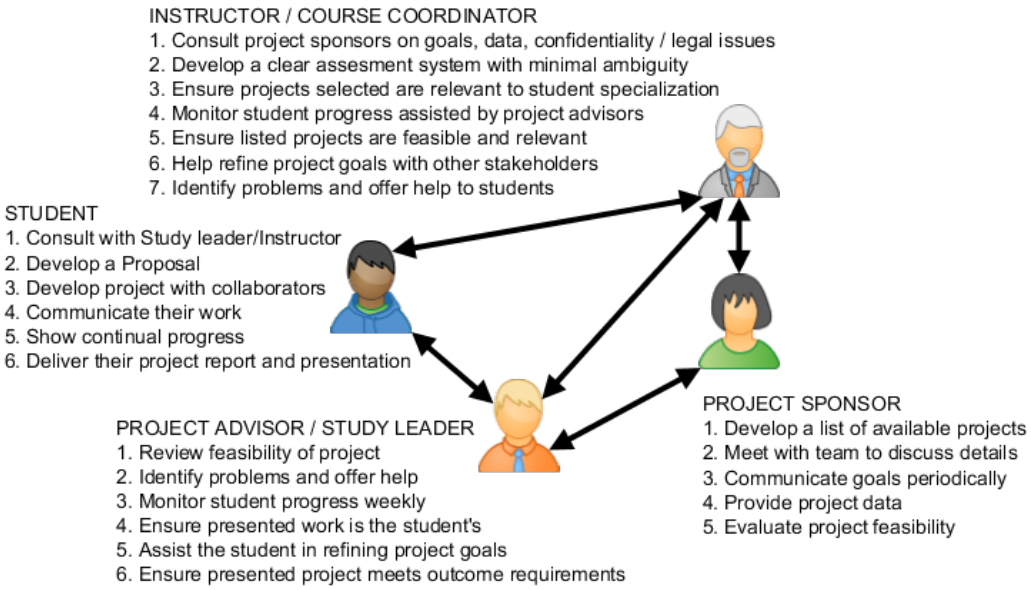
current position of the study in the DSR process can be seen in Figure 4.1. Using the traditional TOGAF approach, the design is now analysed in terms of the overall vision that needs to be achieved (as it was at this point in time), then seeing the problem through lenses of the BDAT domains. Each of the cycles of the DSR approach goes through a similar process, but for the sake of brevity it will be described fully once and then in future cycles only the deviations from the approach, scope and results will be discussed.

4.2.1 The Business Layer

The business layer of the problem relates to the stakeholders, business processes and data that are relevant to each of them that will be used in the creation of the artefact. The first step as always is to define the stakeholders, their appropriate views and viewpoints and the data that they are the custodians of. The identified stakeholders are:

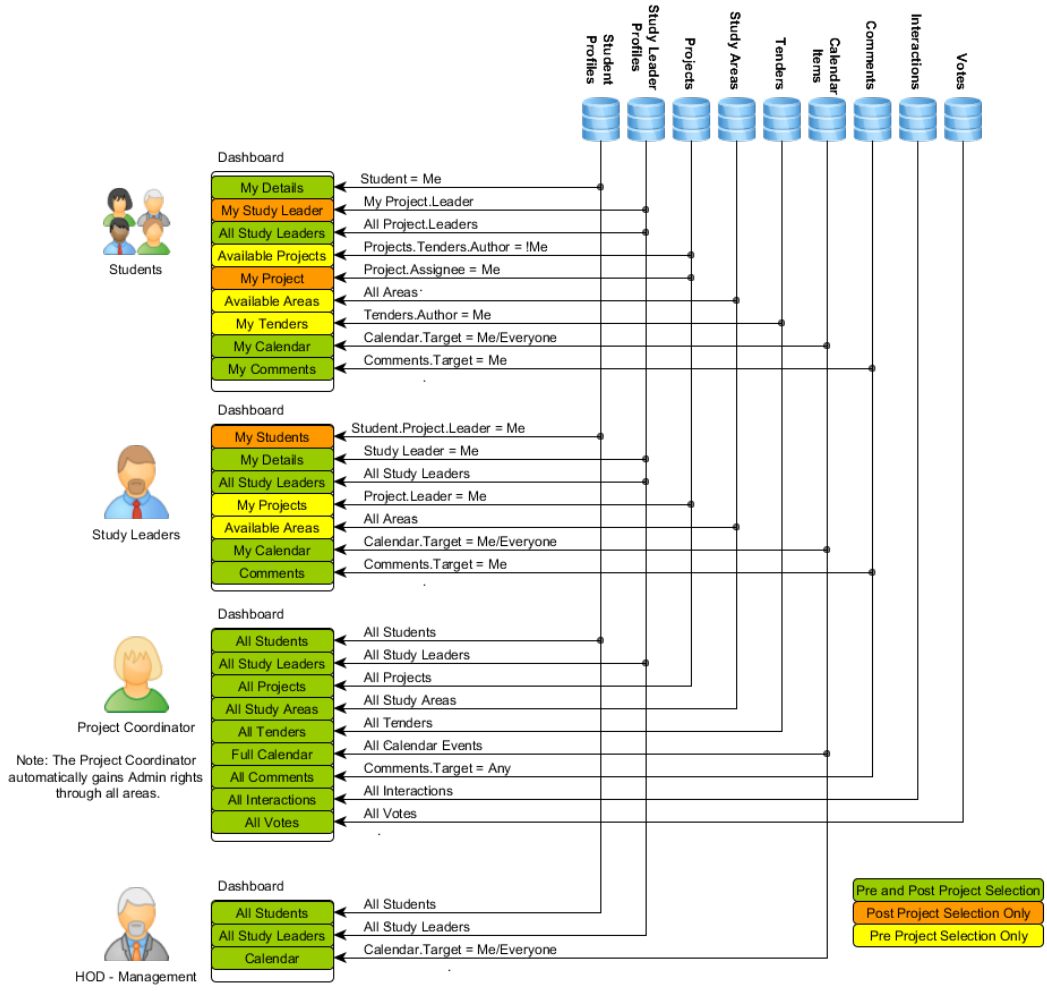
- Students
- Study leaders
- module coordinator
- Project sponsors
- External users (head of department, visitors etc.)
- Administrators

Figure 4.2: Stakeholder Activities



These stakeholders are the "players" in the gamified elements of the system. For each of the stakeholders, to understand what views and viewpoints they will need, an activity diagram is first put forward to see how the different stakeholders will need to interact through the processes, some of which are shown in Figure 4.2. A key thing to note here is that although interactions happen between project sponsors and study leaders, none of these actually happen on the system being designed and as such are not brought into the design space. Administrators are also not brought into the activity diagram as their heightened permission simply allows them to perform all actions, and as such include all named activities. In creating the vision for the system, a preliminary viewpoint and data map was created during the planning activities which could now be combined with the identified views into a single data map to dashboard diagram which can be seen in Figure 4.3. In the final implementation the calendar was instead replaced with a notice board style of site messages that could contain more general notifications.

Figure 4.3: Stakeholder Viewpoints and Data Map



The population analysis performed took into account the fact that although there is

a large difference in individual students and their needs, in terms of the overall access to activities they would need, the student population would be largely homogeneous with the same being applicable to the study leaders. Since this was the case, it made more sense to focus on the change that would happen in the system, rather than in the users through the academic year to ensure it would present relevant information when it becomes available, rather than forcing the user to request it based on their needs. Having said that, the population assumptions made were:

- Students
  - Are between 21 and 35 years of age
  - From all racial and socio economic backgrounds
  - Familiarity with ICT systems, both on computers and mobile
  - Reaching the end of their initial engineering studies
  - Each student only has one study leader
- Study leaders
  - Very technically capable (work in an engineering department)
  - No demographic information is of relevance (wide difference in user base)
  - Only a small number of focussed specialisations
  - Each study leader has a number of students
- External users
  - Various levels of technical ability
  - No demographic information is of relevance (wide difference in user base)
  - Only need access to the system during designated periods
  - Largely only need access to the system via mobile

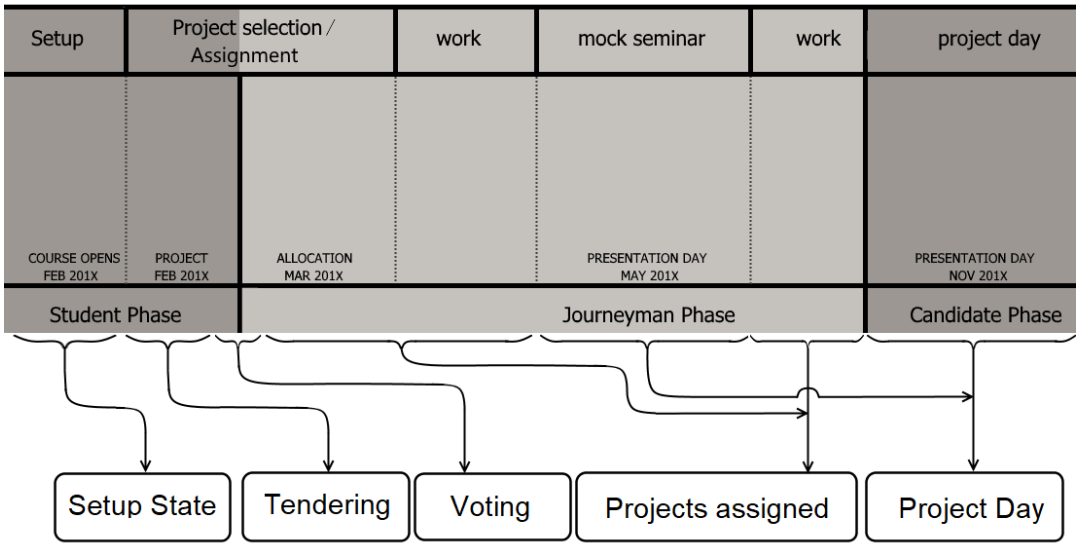
Stakeholders don't work in a vacuum though, and the application itself then needed to also be aware of the processes and users that would interact with it.

4.2.2 Application Layer

In terms of the system as a whole, the business sub processes were broken down and mapped onto the envisioned sub artefacts in such a way that they reflected the needs of the users at the different times and this was also mapped onto the site state. Site state is set by administrators or the module coordinator to transition the site through the different phases of the academic year. Figure 4.4 shows the five application states that can be set, with each state defined as follows:

- Setup State: Enabled during the start of the year before students are given access to the system for the academic year. This is meant specifically for the study leaders and module coordinator to ensure all of their information, study area information and project information is correct before opening up the system to students.
- Tendering State[10] : In this state, students are given the opportunity to get familiar with the system and the projects/study leaders available to them. Tendering and voting states are used intensely in the Tender Game.
- Voting State: In this state all stake holders are given the opportunity to vote on the tenders/applications that they feel are the most applicable to the projects that have been set. This is done during the Tender Game.
- Projects Assigned State: In this state students have been assigned a project and study leader and their work should begin in earnest. In later prototypes this is also where the semester challenges can be used to assist students in gaining skills and insights needed for their projects.
- Project Day State[11]: In this state the students, study leaders and external visitors are given the opportunity to also log in and access the Location based game functionality of scanning QR codes and voting on their favourite projects seen during the day in the quest for badges and points.

Figure 4.4: Application State Mapped to Academic Year



[10]In the first two prototypes the tendering concept was still used, but in the later prototypes this was applied to the application state

[11]The Location Based Game was initially used during both the mock presentations and the project day itself. After testing however it turned out that the mock seminars were a very bad fit for the game as will be explained in detail in Chapter 6.

The application layer together with the business layer also help to define what views and viewpoints need to be added or removed. At this step in the design process (for prototypes after the first), it is also where the wireframe designs become real, or the real implementations become updated. A delta overlay is used which is simply the marking of the current screens with the changes that need to be made between iterations as defined by the gap analysis done in accordance with the TOGAF principles. The application itself is based on the .NET MVC5 architecture, meaning that the presentation layer (the views themselves) need not be static and are instead laid out using Razor markup. This makes the delta overlay method especially useful as the application pages can be pulled in dynamically on page load so edits on a single pulled in section will not effect the view as a whole.

As stated previously the application is built on the .NET MVC5 stack. The architecture diagram of the system can be seen in Figure 4.5. There is not a lot of departure from the standard .NET MVC5 stack, with some small exceptions:

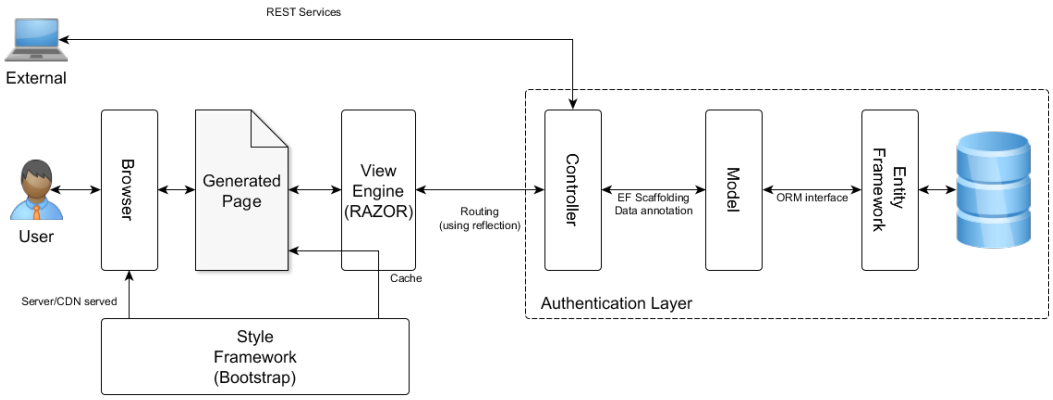
- The REST services are used in conjunction with the Razor markup engine to give a single page application experience as well as to allow for access through an API. This is done to simplify the use of the multiple client devices so that some content can be injected into the page directly, as well as allowing some actions (for example completing quests or triggering badges) to trigger without causing the page life cycle to initiate.

- Reflection is used heavily between Razor and the controllers so that the routes that are triggered by the action links generated in the HTML are dynamically redirected to the correct controller depending on user authentication level. For example, editing a student's project details will present the user with the standard edit form, but the study leader will have more information available to them - the administrator however will have an entirely different form which will allow them to both edit as well as move or re-assign the project completely, which is done through the administrative controller. Reflection simplifies this process greatly.

4.2.3 Technology Layer and Architecture

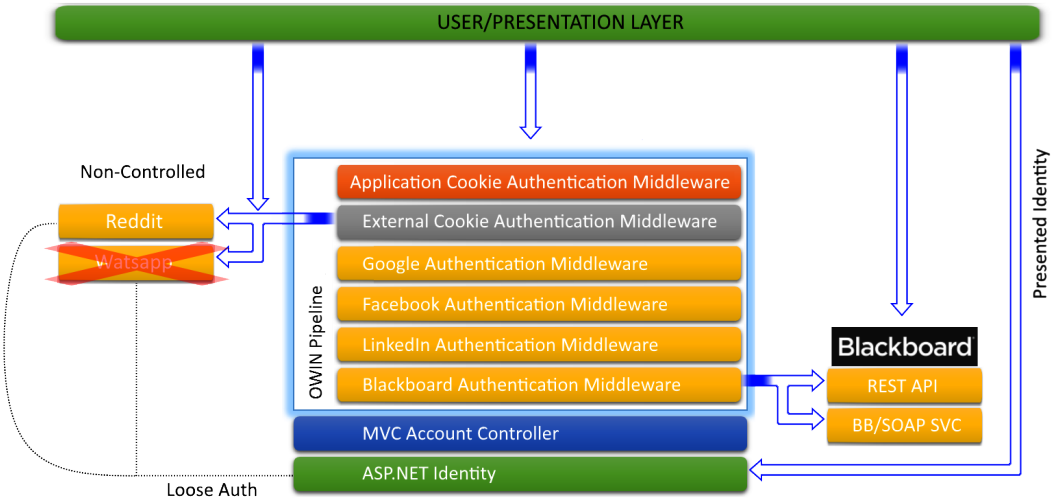
Figure 4.5 shows everything below the Razor markup engine being protected by the authentication layer. The authentication layer is based on the approach put forward by Microsoft [122] with the Katana project [123]. The open Open Web Interface for .Net (OWIN) standard provides an interface between web servers and web applications that is sufficiently dependency free that it can be used not only in the web domain, but rather by decoupling the server and application allows for any kind of application to use the server back end in a standardised way. OWIN makes heavy use of OAuth 2.0 and REST concepts [122]. The use of the OWIN middleware in supporting federation with other authentication sources can be seen in Figure 4.6. Google, Facebook and LinkedIn middleware is supplied as standard when setting up an MVC application and needs only to be registered with the relevant providers. Authentication cookies are controlled

Figure 4.5: Architectural Design



through the OWIN authentication manager, and can be modified as shown to also use non-controlled sources of authentication. This is done in order to allow users to register on project days without having to share any personal information whatsoever. Figure 4.6 was part of the initial design in prototype 1, but it was found during implementation that WhatsApp does in fact not support OAuth authentication making it unsuitable for this style of authentication work. Blackboard originally supported only SOAP authentication when the project was initially envisioned, but during 2016 started rolling out OAuth support and by 2018 fully supported OAuth 2.0 style authentication [124].

Figure 4.6: OWIN Pipeline



Although it is a slight departure from the BDAT approach highlighted initially, the author prefers to keep the data requirements with the business layer, but delve deeper into the table layout in the technology layer. The reason for this is based partially on the technology stack used. As seen in Figure 4.3 the data mapping between stakeholders and data stores is done in the design step, but by using entity framework the model

that is presented in the MVC view can be tied directly to a generated data table in the database. This approach is referred to as the code first approach as opposed to the model first or database first approaches [125]. The database however still remains intact and an example entity relationship diagram drawn from it can be seen in Figure 4.7. Understanding the model in this way also allowed for the creation of the required views that would be used by different stakeholders based on their role as can be seen in Figure 4.3.

Once the states of the system that would be required were mapped as in Figure 4.4 it became possible to create the breakdown of access by state as seen in Figure 4.8. Creating a state based view system allowed for the creation of views that could be contextually aware hiding and revealing different fields on forms based on the global state of the web application. Figure 4.8 shows the mapping of views based on roles as well as the state of the system.

Additionally, as views were injected into the page based on the contextual information now mapped it required the creation of a flexible master page template that could be populated with relevant data on page load as can be seen in Figure 4.9.

4.3 Gameful Design Philosophy

From the start of the design process there was the common balancing act of gameful elements vs standard elements. When something is gamified too heavily, it starts to feel less serious, but if there are not enough game elements added then there is no benefit to be gained from Gamification. In order to make the Gamification non-invasive, it was done with the following ideas in mind:

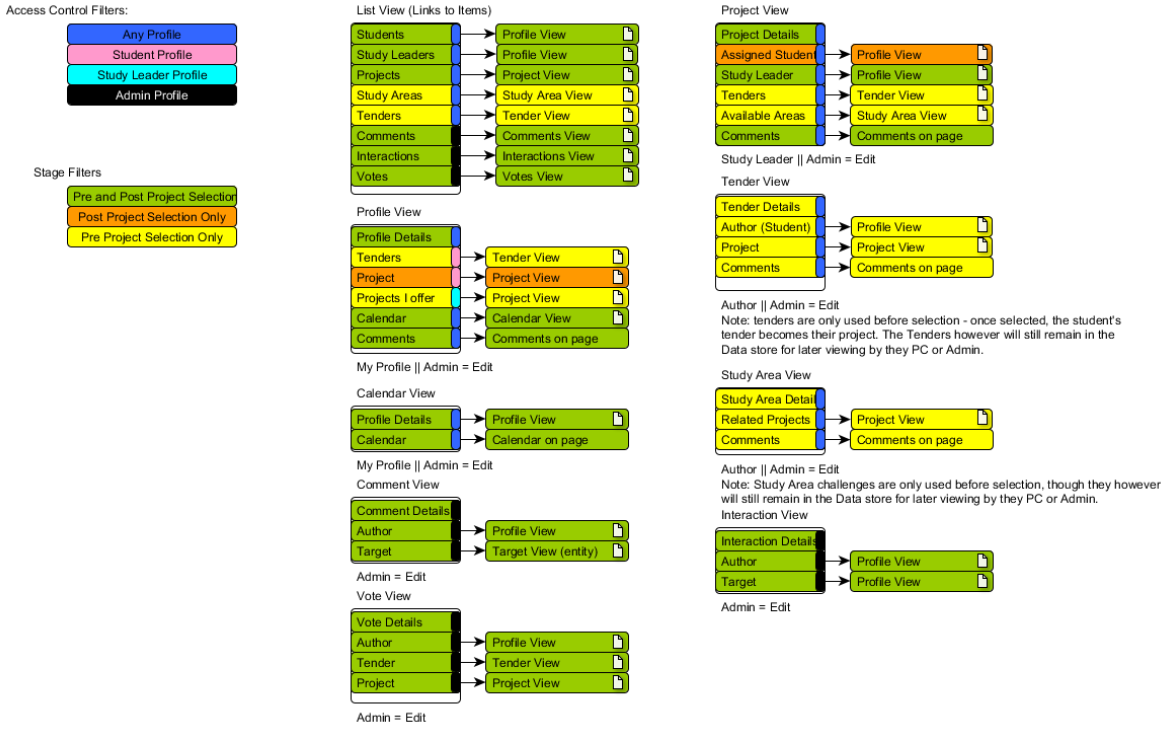
- Keep graphical elements external: As students did not have avatars as a requirement in the gameful design space the researchers aimed to have elements like the avatar for the system kept in posters and other communications with students and study leaders, rather than forcing it into the web design. Students and study leaders still have the capability to present whatever avatar they wish, but it does not get effected by game events as it did in the initial conceptual designs.

- Autonomy focussed: As the goal of the system was to increase student motivation and engagement, it was paramount from the reading of Self-Determination Theory (SDT) literature that the autonomy of students to participate in the game be respected. As such, the Gamification elements were kept contained and tied to the student's profile page, meaning that all information held on the system could be interacted with even if students chose not to partake in the Gamification itself.

- Incidental learning focus: It is the author's opinion that students gain a large value by just being exposed to certain concepts subtly. For example, one of the badges that can be gained by having a focus on the telecommunications study area is "Son of Shannon". The idea being that subtle cues in the design could help students gain a familiarity with names, concepts or ideas not by learning directly, but by

Figure 4.7: Entity Relationship Diagram.

Figure 4.8: Breakdown of Access by Time Frame



having them injected alongside the content that is presented as part of the module. It is difficult to measure the effectiveness of this however in this sort of context, so it is presented as a design preference by the author, rather than an educational decision.

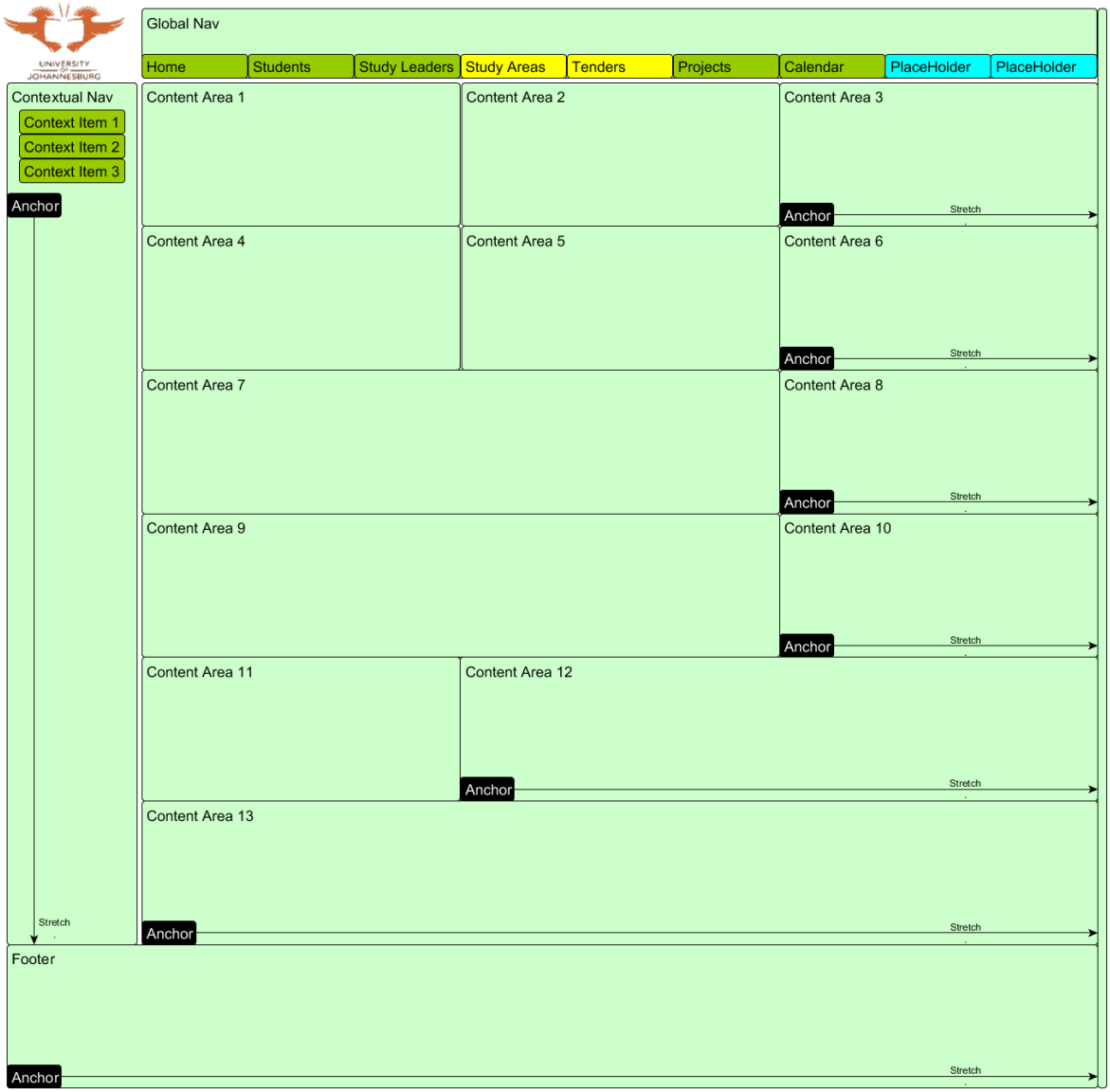
With this in mind, the main game elements included in the system are:

- Points, Badges, Quests in Profile: Users should access their gained points, badges they have earned and their quest log from their profile on the system. Interactions with a project will earn users a point, and each time a unique study area is interacted with it will earn the user five points. Quests require interaction with a whole set of related study areas that are tied together with a theme.
- Intervention specific elements: Each of the subsystems forming part of the full system would have elements that were specific to each of the interventions and these would become available to the user once that intervention becomes available.

4.4 A Design for Learning

The PJE web portal presented here, named after the module code, is the vehicle for the interventions that will be presented in the prototypes presented in the following

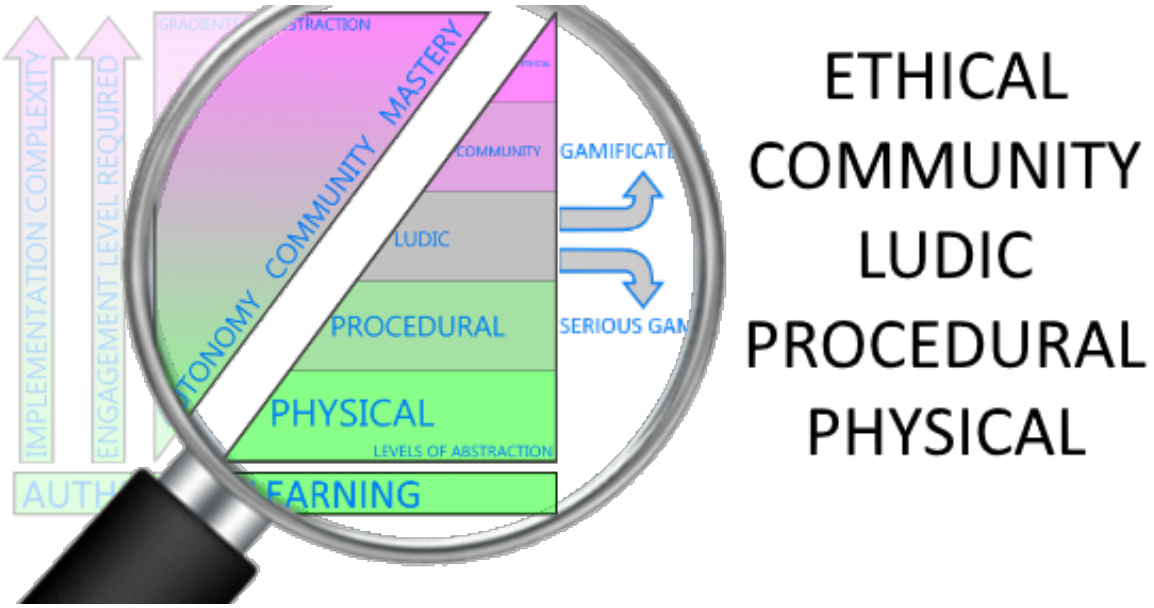
Figure 4.9: Master Page Design by Wire Frame



chapters. First the concepts that brought about the artefact are presented, and then the design process is described. As mentioned earlier, use is made of the TOGAF principles due to the author's familiarity in it's processes.

In Section 2.5 the educational approach of the research team was put forward, but in this implementation section there will now be a special emphasis placed on the Levels of Abstraction (LOA) that were presented as the areas in which students could be supported as seen in Figure 4.10.

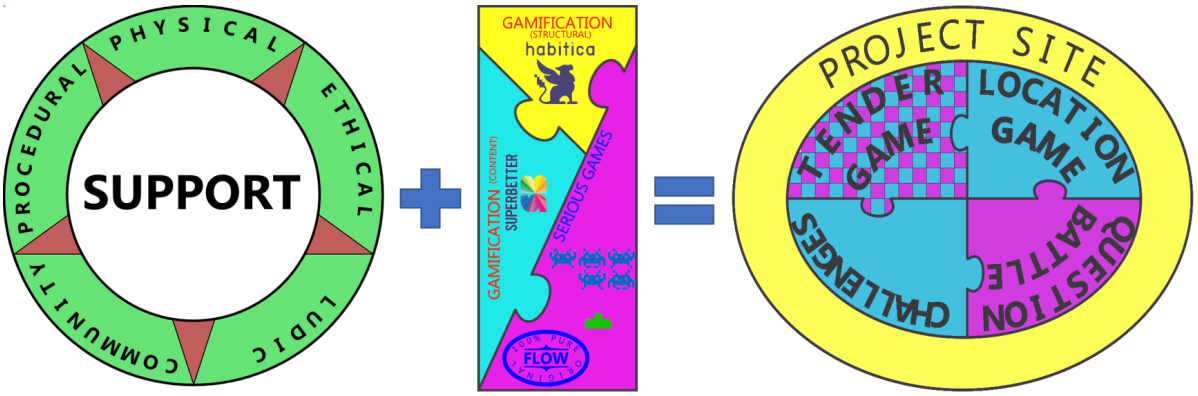
Figure 4.10: Levels of Intervention



Each of the five levels were evaluated in the context of the module and were explored in how support could be given with reference to the journey the students go on in completing the module. As the author believes that Serious Games and Gamification both had a role to play in the design of the system, a conceptual design summary was done as seen in Figure 4.11. In this way, it shows how the different styles of Gamification and Serious Game design would be brought together through different sub components in order to support the student on all fronts. As this was part of the initial conceptualisation of the system, it did change as the artefact went through multiple prototypes, but also captures the design ideal that the researchers started the project with. In section 1.1.4 a distinction was made between Serious Games and Gamification. In implementation however, Kapp makes a further distinction between structural and content Gamification [37] [126]. Structural Gamification is used to shuttle the student through the flow of the module or training presented, where as content Gamification is used to inject an element of fun into the actual courseware itself.

The best way to understand the difference between the two approaches is to look at two illustrative examples of each. The example of structural Gamification is best instantiated through the Superbetter approach by McGonigal [87] and content Gamification through Habitica [127].

Figure 4.11: The Overhead Design Summary

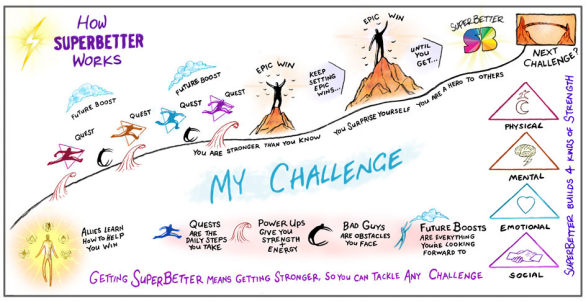


Superbetter started as a project called "Jane the Concussion Slayer" and was built as a system to help someone overcome a very large life challenge by first building up their mental, physical, emotional and social resiliences. This is done by creating small tasks for oneself that are used as powerups along a journey where you battle your own personal bosses (large obstacles that you need to overcome in your personal life) to score epic wins while getting through to the end goal of overcoming the original challenge you set. The Superbetter web portal illustration of this can be seen in Figure 4.12a. This is all done with the idea of shuttling you through the process of beating the big final goal you have set. Daily activities are present, but they are only a means to an end for defeating the large final goal you have set for yourself. Superbetter is made available freely via both the web portal as well as mobile applications.

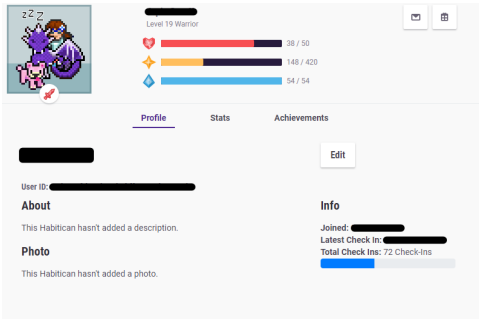
Habitica started as a project called HabitRPG where the goal is to break bad habits and encourage good habits through daily focus [127]. Daily tasks are set by the player, and the difficulty of those tasks are editable. Tasks are split up into habits (positive or negative things to be focussed on daily), dailies (tasks that need to be completed on programmable days that are done or not done), and to-dos (once off tasks with a deadline). Not completing tasks on time or sufficiently often results in damage to an avatar, whereas repeated success is rewarded with gold and experience points. These are used to level up the avatar that represents the player in a fantasy world. A large focus is then placed on the community aspect of the game, and players are encouraged to join guilds where they can encourage others with similar goals in their daily activities, or can take on quests that allow them to pool resources. The goal is not to overcome some pre-determined challenge, but rather to focus on the good or bad habits (in this case the actual content) and gamify that. The author's Habitica avatar is shown as an example in Figure 4.12b.

Armed with this, the researcher then set about creating the conceptual parts of the system. Instead of one monolithic design that would constantly be available, the system would be split up into a number of sub-artefacts. The PJE web portal design consisted of the following 5 components:

1. The web portal itself, a responsive design based web portal that can be used from



(a) How Superbetter Works - From [128]



(b) A Habitica Avatar - From [127]

Figure 4.12: Two Styles of Gamification

any device to access the information and sub interventions that form part of the artefact.

2. The Location Based Game, a game played during project presentations to encourage interaction between all stakeholders that attend.

3. The Tender Game, a game played at the start of the year when project allocations are done to attempt to find the ideal student to project/study leader match. This eventually transformed in the final prototype into the application system.

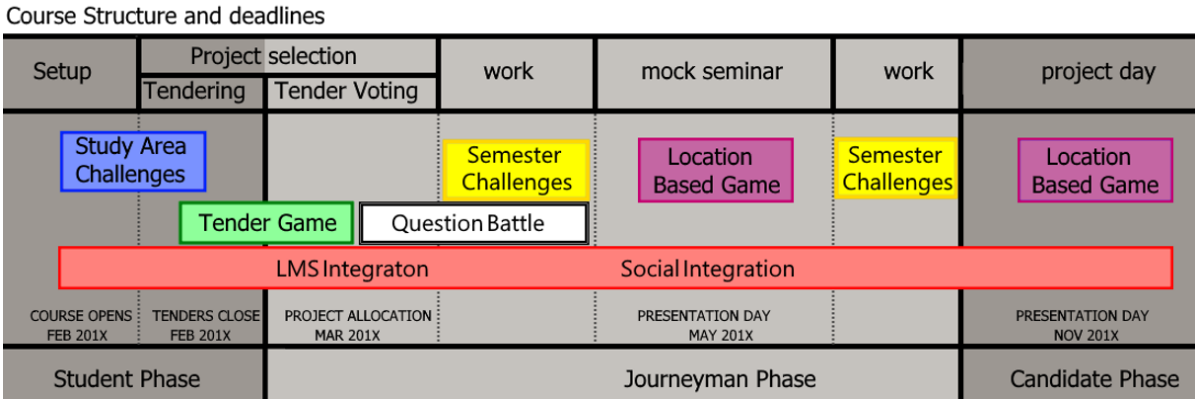
4. The Challenge System, a system put in place to allow study leaders to add optional challenges for students in order to encourage them into specific areas of interest, test their knowledge or to find common interests

5. The Research Question Battle, an envisioned game that would let students compete to create their ultimate research questions. This component of the system never became a reality however due to the change in focus of the projects to allow for an approach that doesn't force all students to follow a research project style of documentation.

Each of the sub components could use a different style of Gamification, or be more akin to a serious game however, so in putting all of these concepts together the overarching design idea emerged as set out in Figure 4.11. Armed with the conceptual design, this then needed to be translated into a more concrete design so that it could be implemented. In section 3.3 the concept of the ADM was introduced, and this conceptual design served as the high level vision (A) required to kick off the design cycle for the conceptual design and prototype DSR cycle.

The initially envisioned system did change through the different iterations as is expected of a DSR project, but the initially envisioned final system would slot the sub system artefacts into the timeline as seen in Figure 4.13.

Figure 4.13: Initial Vision of the Final Timeline



4.5 Results and Feedback

The conceptual designs were predominantly done in an abstract form through diagrams and notes. The next four chapters will now go into deeper detail on the design, implementation and testing of the system as it was envisioned in a more concrete form. As this was the first phase in the design process however, feedback was obtained from experts on the overall conceptual design. Feedback on the conceptual design was obtained initially from the author's academic supervisors who are also:

- The module coordinator,
- A senior academic,
- An engineering education specialist.

Feedback was obtained on a number of other conceptual designs that didn't make the cut at this point in the project, among them were implementations of narrative based games that could be built from the open source story generation designs found in the NanoWriMo project, a discussion on Ingress that could be used as a blueprint for a more long term Location Based Game as well as the design of board games like "keep talking and nobody explodes". From these discussions, it was also the start of the discussions on ethics in game design where the following questions were brought to light:

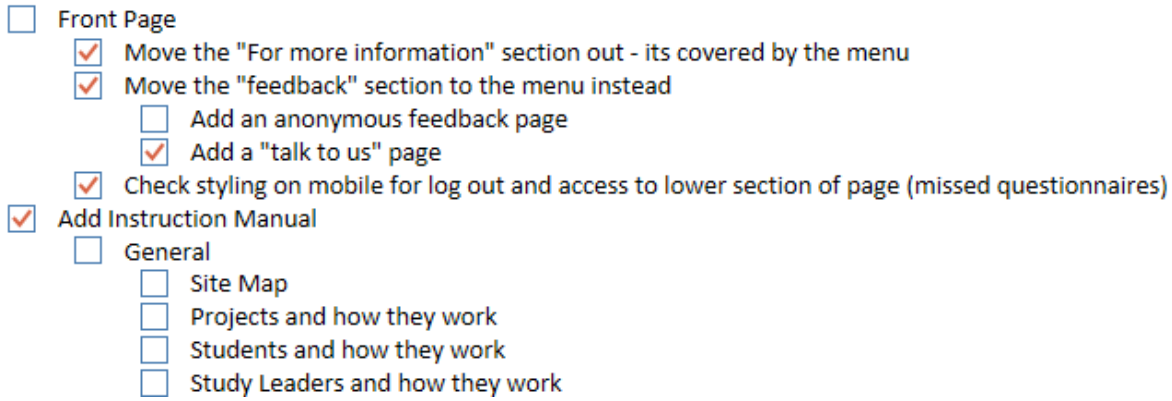
- In what way will your "gamification" affect students ethically?
- Will there be a closed form expectation and assumption of implicit ethicality?
- How will ethical violations be handled (if at all)?
- Even good games can be subverted, how will you deal with cheating.

It was through this feedback and discussion that the overall design was brought about and it was also from where the ethical application in its current form came about. In the

initial conceptual designs there was an assumption that the the system would be built on the framework of Sharepoint as opposed to the more open design that eventually emerged. This was scrapped due the the cost that would be involved in getting the university on to that platform. It also came with a number of limitations that would have been difficult to deal with later on in the project.

This feedback was obtained through a number of meetings between July 2016 and October 2016 when the implementation switched over from conceptual to the implementation phase and building of Prototype One kicked off. Using the notes and overall design the build tasks were translated into small "To-Do" lists that were done in OneNote and used to implement the decided on features in all of the feedback sessions. An example of this is shown in Figure 4.14.

Figure 4.14: Checklist Created for Feature Implementation



Some of the discussions held also resulted in some of the components and ideas in the system being spun off into their own projects that happened in parallel to this work, specifically the implementation and testing of the serious games "Codebreakers" [34] and "Enigmai" [35].

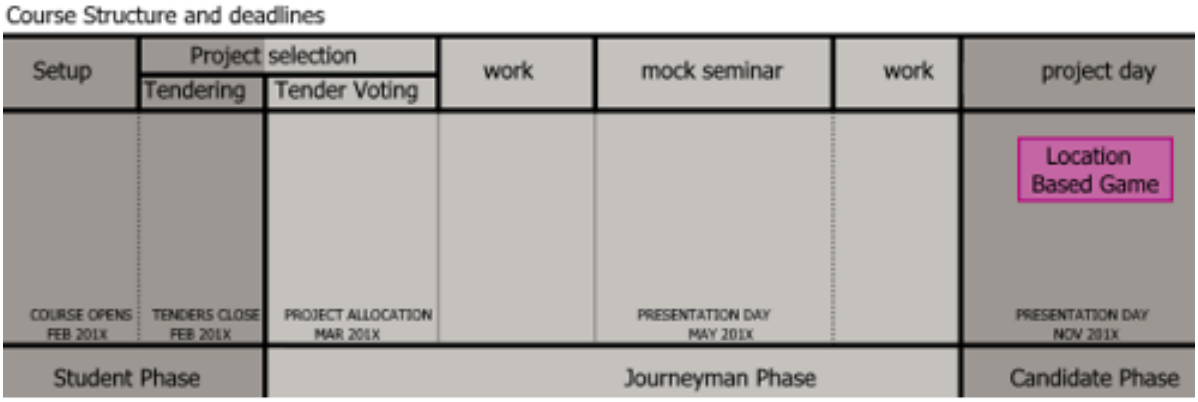
In the following four chapters prototype one to four are presented.

Chapter 5 - Prototype One

5.1 Introduction

In this first protype of the full system the base of the PJE web was implemented as well as the first version of the Location Based Game (LBG). The system went live during December 2016 and the first field trial of the system and the LBG sub artefact was tested. The responsive design was realised successfully and the first version of the LBG rollout was a success increasing the opportunities for interaction between current students, future students, industry visitors and faculty during the project day. In this chapter further detail will be given on the creation of the first LBG as well as the results of the use of the Jen Ratio for the measurement of social health of the location in question. The first prototype feature set included only the LBG as can be seen in Figure 5.1.

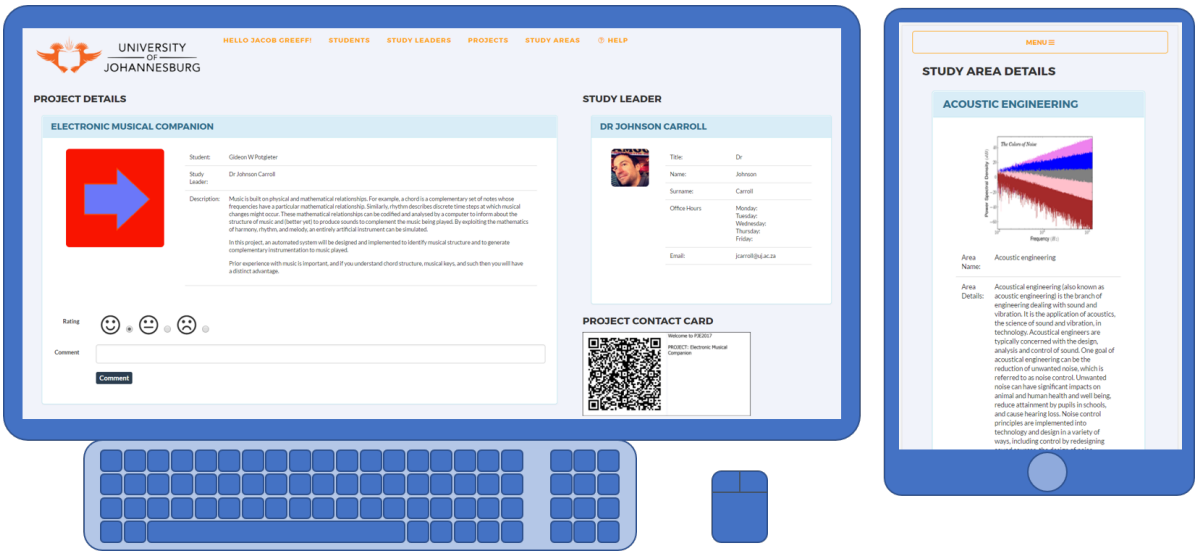
Figure 5.1: Prototype One Features



5.2 Realising the PJE Web

Based on the conceptual designs done, the live view of the system was realised and can be seen in Figure 5.2. The base of the system was put in place as described in chapter 4, and a number of the core features were added. In addition to the responsive design base of the system the gamification features were added that allowed for the gaining of points and badges that could be viewed from the user's dashboard. The core mechanics of adding points was implemented. The user dashboard can be seen in Figure 5.3.

Figure 5.2: The PJE Web Portal



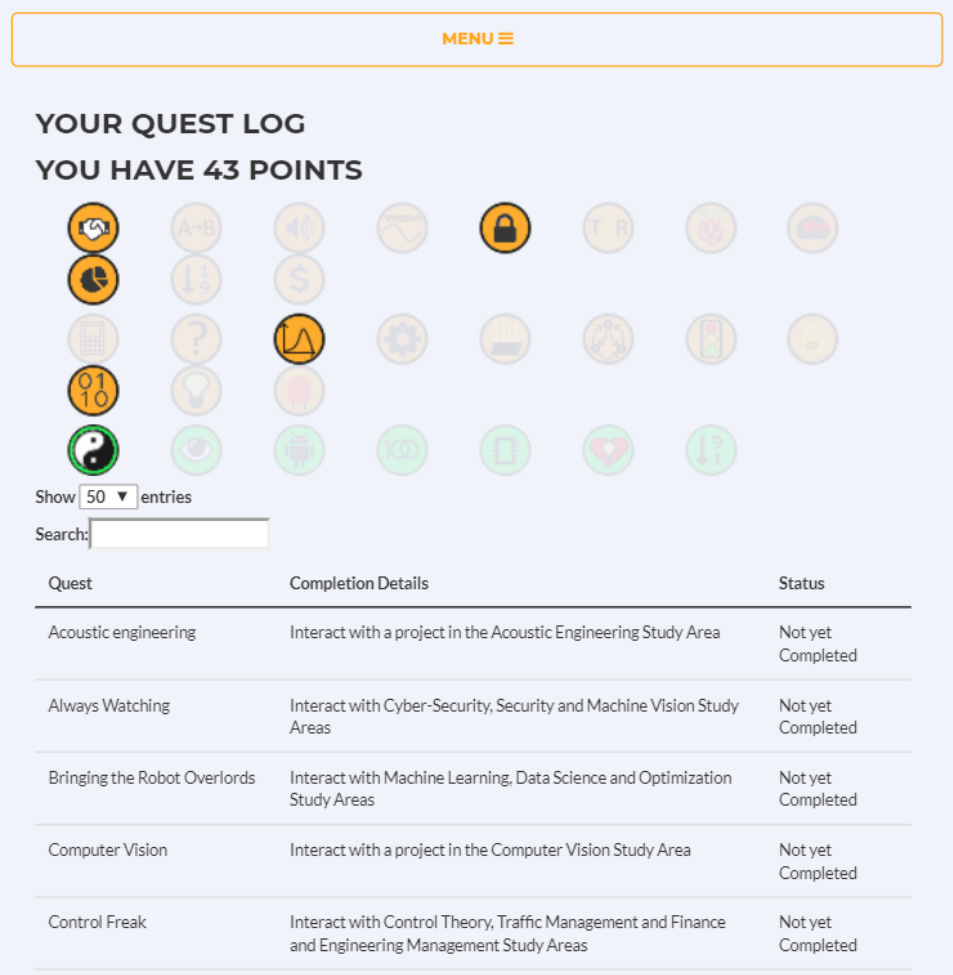
The basic site layout was implemented as follows:

- Home
  - user dashboard
  - student listings
    - student view
  - study leader listings
    - study leader view
  - project listings
    - project view
  - study areas listings
    - study area view
  - help

As pages were dynamically created however, the views for the students, study leaders, projects and study areas all contained listing pages that would allow the user to navigate from anywhere in the system. For example, opening up a study leader view will also show the students being lead by that study leader, the projects they are involved in, and the study areas they specialise in; all as filtered listings.

As each of the views also contained a reference record (be it a project, study leader or student). A QR code generator was added to allow users to access the view of that record from anywhere. This was also the core game mechanic that was used for the LBG presented as the first of the sub artefacts in the system.

Figure 5.3: Gamification Elements Accessible from the User's Profile.



5.3 The Location Based Game

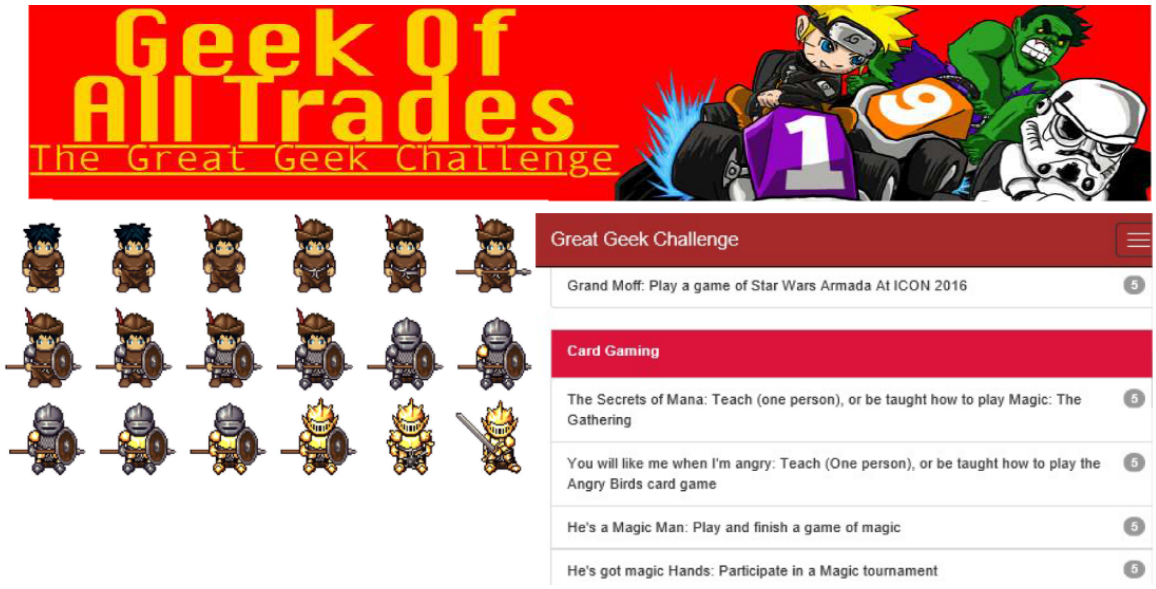
It was fortunate that the first sub artefact started on was the LBG since the project day is an exceptional opportunity for students to show off their mastery, interact with their community and move about freely while having a constant stream of engineering knowledge to interact with in a very short timeline. In short, it was the perfect opportunity to test out the SDT principles found.

To gamify the project day, the researchers chose to create a LBG which would allow players to move about between the projects being presented while being rewarded for their interactions with the students that were presenting. In this chapter, LBGs are presented and the design of the intervention is explored in detail.

This design was based on a system that was done as part of a preliminary exploration of Gamification during the ICON 2016 expo in Johannesburg 24 - 26 June 2016 by the author and a colleague. The concept was slightly different in that the idea was more to track human movement at the time, rather than motivation, but the design style was

already starting to take shape. The avatar used during this period was an anonymous villager that becomes a knight through the accumulation of points during game play, but pixel art based design of the villager was done in the same way as the Ilsa mascot used in Protype One. The mood board for that design is shown in Fig. 5.4.

Figure 5.4: ICON Great Geek Challenge 2016



For the Protype One field trial version deployed in 2016, the human movement studies elements were removed for ethical reasons (the Great Geek Challenge was built primarily for commercial reasons), but the scanning of QR codes for the completion of quests was kept as a fundamental feature.

LBGs are known by many names, among them location-based experiences, pervasive games, and ubiquitous games or alternate reality games. For the purposes of this work, the terms can be used interchangeably. As a working definition, LBGs are games that specifically partake in what Jenkins terms transmedia storytelling, in that the game plays out both in virtual world(s) as well as the real world [129]. There are also multiple different kinds of LBGs with McGonigal identifying the following five broad categories [6]:

- Life-management LBG,
- Organizational LBG,
- Conceptual LBG,
- Live event LBG, and
- Narrative LBG.

The common thread with all of the different kinds of LBGs however is that part of the game play actions are triggered when events in the real world happen or are caused to change by the player [6]. In this work, the approach that was taken was a combination of the live event and conceptual LBG design approaches with players consisting of capstone students, third year students, study leaders and members of the public. During the project day capstone project students demonstrate the work they did during the academic year to obtain feedback from a much wider audience. Presentations are done across various locations on the university campus and visitors are invited to interact with students and each other to increase awareness of work done by capstone students as a whole, as well as to allow students to take pride in their accomplishments. The goal of the game was to try and not only encourage those kinds of interactions, but also to attempt to capture the general feel of the day.

This project is not the first application of LBGs to the educational context, with case studies found in literature ranging from educational applications at universities [130] to ones in zoos [131] and museums [132]. No version was found specifically for the application of LBGs to supplement students presenting their capstone projects, but sufficient work was found to expose students to projects in the references above to indicate that the application would almost certainly be successful.

5.3.1 Design Considerations

The Magellan Consortium puts forward a number of things that need to be considered upfront when designing an LBG with regards to the physical environment that it will be played in [133]. The specific considerations are listed below along with reflections on the game presented here.

- *Extent: What are the physical limits and boundaries of the game field?*
  The game will play out in the Electrical Engineering laboratories at UJ. This means that a measure of care needs to be taken due to the layout of the building and it's staircases, as well as having some displays that would be inherently dangerous when walked into by players not paying attention. The game should not require full focus to play.

- *Hazards: Are there physical dangers players may encounter?*
  The main hazards are in the building layout and in the displays that are in the building. It is worth noting, however, that as students will set up their projects in the morning before the game, the control of hazards resulting from setups cannot be controlled for a priori.

- *Conditions: Will there be a problem for players should weather conditions turn?*
  The majority of the displays will be set up indoors (with the only real exception being projects that require solar energy to demonstrate).

- *Physicality: Will players need to travel long distances or require a high level of fitness?*
  A high level of fitness or physicality will not be required.

- *Focus: Will players need to focus on their mobile device for long periods and miss potential hazards?*
  Due to the issues raised above, a player should be able to interact with the game with a very low level of focus, and should only need to use their mobile device when they are explicitly scanning a QR code or marking an interaction. For detail on QR code use see the following subsection.

- *Technology: Will a failure in the technology cause players to be effectively abandoned in the environment?*
  The game should supplement the experience of the project day, but there should be no penalty given to players or students should the technology fail on the day. The game only intrudes on the original idea of the project day through the addition of the QR codes students place on their posters, and if abandoned the day can continue as it did in previous years.

In the overall context of the project, the LBG is relevant to the timeframe shown in Figure. 5.5 which references the envisioned full time frame that was put forward in the conceptual design in Chapter 4.

Figure 5.5: LBG Active Period

5.3.2 Measuring Interaction

In trying to measure the affective experience of players in LBGs, various authors have proposed methods of capturing instantaneous emotional states. One of the most advanced put forward by Baillie, Morton, Moffat and Uzor is the use of physical gestures to indicate game actions being taken, capturing those using the accelerometer on a mobile phone and mapping the acceleration measured in various axis onto an emotion wheel to gain insight into the player's instantaneous state of mind [134]. McGonigal highlights the benefits of using the Jen Ratio originally described by Keltner [117] as a simple way to test the social well-being of an environment [6]. In exploring what needed to be measured in the context of the LBG explored here, it was deemed that the interaction

itself was the main parameter that needed to be measured - as creating a healthy and collaborative social space was key to the success of the game. As such, the approach proposed by McGonigal was followed with a slight modification. The Jen Ratio (Jr) in the social space is simply calculated as:

$$Jr = \frac{\sum I_{pos}}{\sum I_{neg}} \tag{5.1}$$

where:

$Jr =$ Jen of the social space
$\sum I_{pos} =$ Sum of positive interactions
$\sum I_{neg} =$ Sum of negative interactions
$\sum I_{neutral} =$ Sum of Neutral Interactions

Generally the Jen Ratio is measured over a short period of time. This measurement however does not take into account interactions that are not positive or negative but merely neutral. Additionally, if only a single interaction is measured, then a situation arises where the Jen Ratio will be undefined. As such, we used an adjusted Jen Ratio Jr_{Adj}:

$$Jr_{Adj} = \frac{\sum I_{pos} + 1}{\sum I_{neg} + \sum I_{neutral} + 2} \tag{5.2}$$

This equation starts off in a situation where there is assumed to be one positive, negative and neutral interaction already captured. The baseline measurement of Jr_{Adj} therefore starts at 0.5 when no measurements have yet been made in a period and will go below 0.5 in a negative space or more positive in a positive space. As Jr_{Adj} is expressed as a fraction, it is important to note that it is not a linear measurement but rather a logarithmic one.

5.3.3 Principle Mechanics

When looking at LBGs as Location Based Experiences with an emphasis on learning, Jones et al. proposed a framework for evaluating the feedback mechanics presented to players called SCAMP (Social, Cognitive, Affective, Motivational, Progression) [78]. In exploring this work, Anastasiadou and Lameras further classified different game mechanics used in LBG into activities, actions and conditions and showed how these could be mapped onto Bloom's Taxonomy to indicate what kind of cognitive behaviour is taking place [135]. Table 5.16 shows some of the mechanics used in this game, and how they map to the taxonomy put forward by Anastasiado and Lameras.

Players arriving for the project day were invited to join the game by posters placed at the entrances to the play area (which was easily demarcated as the building used has a finite number of entrances). The posters also held additional information about the wider project being implemented as well as the project day specifically. This approach was taken to ensure that gameplay was non-intrusive, and that players would be willing to try it out on their own terms.

Table 5.16: Examples of the SCAMP framework

Element	Remember	Understand	Apply	Analyse	Evaluate	Create
Social	Profile Registration(A), Interactions Between Players(X) Discussions(X), Public/Private Comments(A)					
Cognitive	Study Area Introductions (C) Interacting with Research (A)			Chosing Favourites(A)		Present(A)
Affect	Positive Social Interaction (C/X)			Interact/Comment and Rating (A/X)		
Motivation	Scores and Prizes(C/X) Collect Badges(X)		Focus(X)	Interact(A)	Favourite(A)	Questlog(C)
Progress	Move/Find Others/ Interaction(A/C/X)		Favourite(A)	Comment/Interact/ Favourite(A)		Questlog(C)
Legend: Actions(A), Conditions(C), Activities(X)						

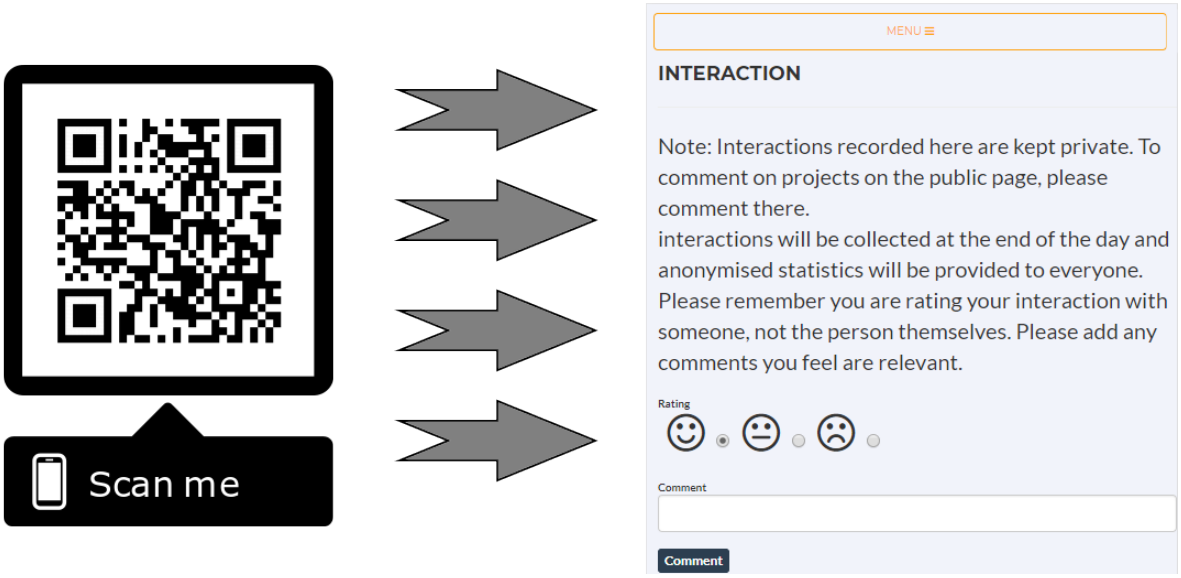
Interactions are captured by allowing players to access the information both through browsing through their mobile device to the information, or by scanning the QR code which would redirect them to the interaction screen. The goal of the interaction screen was to allow players to record both positive and negative interactions with others in private. Interactions were counted in the same way as comments, but were not publicly visible. All interactions are also marked as positive, neutral or negative as can be seen in Fig. 5.6 with a simple three face system. This interface was chosen as a middle ground between a positive / negative system and a five star system based on the experiences of a number of online systems that have called the rating system into question, most notably the complete abandonment of it by Youtube [136]. There is evidence that either a simple favourite system or a thumbs up / thumbs down are both superior to a five star rating system, but in this specific instance a neutral option was required. The researchers found the three faces approach to be a good alternative.

From the interactions measured, users earned badges which encourage the discovery of related projects based on related fields. For example, to gain the "Son of Shannon" badge, users would need to interact with projects in the areas of information theory, visual light communication and power line communication. The taxonomy of project study areas was created to cover all of the projects done in that academic year in a logical way to highlight similar themes between projects. Users were also able to vote for their favourite of the projects they had interacted with a simple button that was added to the project page when the game was active as can be seen in Fig. 5.7. The presenter of the best projects as well as the most social players won sponsored prizes during the closing ceremony of the project day.

5.3.4 Points, Badges and Leader Boards

The mechanics of the main gameplay is focussed on interacting with student presenters and then scanning their interaction tokens using the QR codes placed on their project posters, or interacting with other players by scanning their QR codes and rating inter-

Figure 5.6: Interactions Interface



actions. By interacting with presenters in different study areas and gaining more insight into them, players are invited to explore different study areas through the collection of badges (for single study area interactions) and focus badges (which are gained by collecting multiple study area badges presented as quests to the user). Table 5.17 shows the badges that were available for collection on the day. Interactions are the main way for the game to keep track of what players are doing, and this is also what accumulates score and badges. Inherently, this is a multiplayer game as interactions should be two way (although, both players do not actually need to mark the interaction). This is done so that players can choose to play or not play as they wish. The game is competitive as well in that the projects that had the most favourite marks as well as the most active players won sponsored prizes.

This link between the quests the players are trying to complete and the study areas of the university is part of the incidental learning approach taken, but is also an attempt to introduce students in the third year to the study leaders they may meet in their next academic year. They can use the opportunity to gain insight into the study leader's style from students that have studied with them in the current academic year. The same study areas are passed along to the next academic year as well so new students are familiar with the study areas if they attended the project day in the previous year.

5.3.5 Players

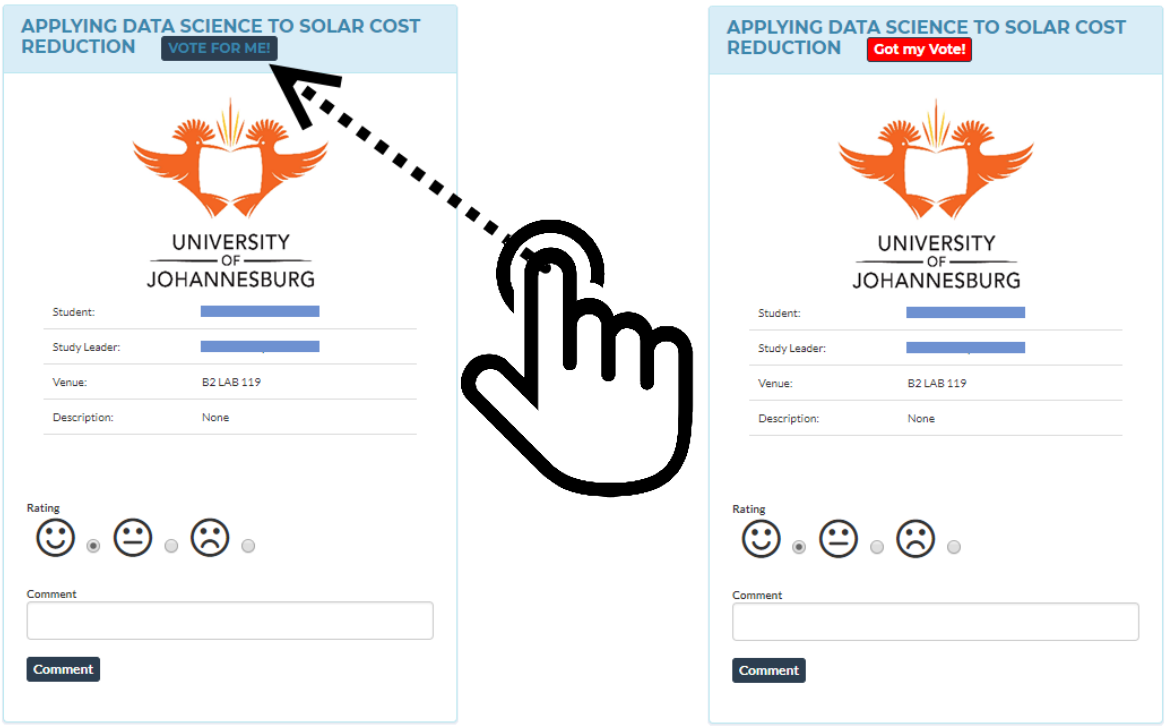
Players could interact as one of four different player types, namely students, prospective students, visitors and study leaders. The available quests are the same for all players, but study leaders and students have access to slightly more information as their interactions are inherently part of others players' quests.

The play area is very flexible as students get to set up wherever they want, and just

Table 5.17: Study Areas And Badges

Study Area	Badge	Focus
Cyber Security		Always Watching 
Security		
Computer Vision		
Machine Learning		Bring the Robot Overlords 
Data Science		
Optimization		
Control Theory		Control Freak
Traffic Management		
Engineering Management		
Internet of Things		Embedded or Bust 
Product Development		
Power Line Comms		
Visual Light Comms		Light Hearted 
Solar Power/ Photovoltaics		
Optoelectronics		
Information Theory		Son of Shannon 
Digital Signal Processing		
Acoustic engineering		
Energy Management		Power of Change 
Electromechanics		
Transducers		

Figure 5.7: Select a Favourite Project



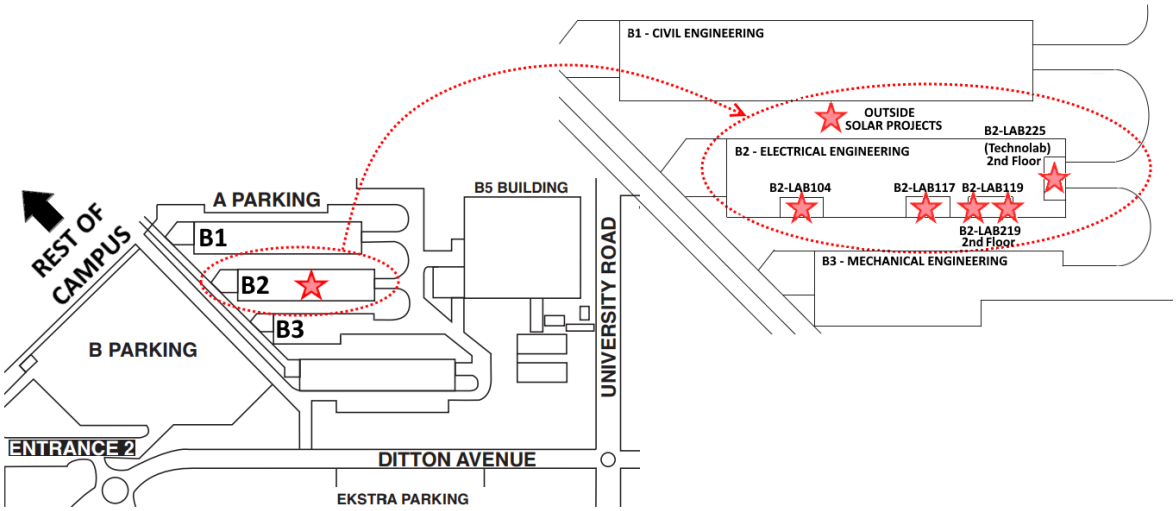
update their location on the site. This way, it is fast to set up and can be very dynamic if students choose to move. This is in contrast to a physical beacon based system where the physical locations of play areas and checkpoints need to be more controlled. Physical markers to indicate the play area are achieved with posters to show where you enter the building (and play space) and to give you a quick way of signing up by simply scanning a QR code.

As the game is played in real time, post-event moderation is impractical. In taking this into account, an admin dashboard was created for the moderators that funnels all comments through a single page, in addition to the normal reporting channels being made available to players. Although not scalable, should the game be played with significantly more players, the very quick response possibility was considered a sufficient justification for creating the dashboard. User registration is opened on the day, and players simply scan one of the QR codes on the posters which takes them to the registration page. The only real requirement is an email address so that some sort of reference is held should player information need to be purged, but beyond that no additional information is required from players. As the game play area was not physically unmanageably large, technical support could be given from one of the offices inside of the building being played in. Although some prizes were given based on the game performance of players during the day, other prizes were given during the same ceremony to those students that performed well on the day as was the case previously on project days. The quality of projects from an academic perspective was judged in the same was as it was done in

previous years by faculty members.

5.3.6 Environment

Figure 5.8: LBG Play Area Map



As was seen initially, the actual physical location that a LBG is played in has a large impact on the game itself. Since students set up their projects in and around the engineering buildings at University of Johannesburg (UJ) for the project day, this is naturally the environment the game is played in. Fig. 5.8 shows the map of the facility where projects get set up and in turn where the "venue" field can be set by the student so players can find them.

A design trade off here was that additional information in the form of human movement studies could be done from this platform, but that would be more effective when using a beacon based system that continuously tracks players as opposed to the less invasive optional scanning system presented here. This trade off was considered appropriate by the author.

5.3.7 Mascot and posters

To entice users onto the system, Ilsa was created as a mascot for the gameful elements in the PJE system. Ilsa is used specifically during the LBG interactions when players move around the campus and interact with the game via scanning QR codes on student project posters. Although updated from a pixel art version of a mascot to a 3D design, the 3D design version was never used (this is however purely due to the author's preference). Pixel art was done predominantly in Piskel and based on the Liberated Pixel Art guidelines for creating JRPG style art, and the 3D version of Ilsa was created in Makehuman 1.0 with clothing assets obtained from the open source makehuman community gallery.

Figure 5.9: Pixel Art Ilsa vs. 3D Ilsa.

External visitors, students and study leaders are invited to partake in the game that takes a measure of the positivity of the interactions between players. Figure 5.10 shows an extract from the posters used to show people what is expected from them during the game play.

Figure 5.10: Visual Instructions For Playing the Location Based Game.

5.4 Results and Feedback

As it was still early on in the implementation that Prototype One went live, as can be seen from the features implemented in Figure 5.1, most of the feedback received was from expert opinion from the module coordinator, engineering education expert and academic study leaders. It did however also include the first field trial of the system. The quantitative data collected comprised of the results of the field trial as well as the results of the Jen Ratio measurements that were taken through the day.

5.4.1 Field Trials

The full system went live during December 2016 and the LBG was tested for the first time. With this students had the opportunity to load their projects onto the system and all students could therefore see what their peers were doing. The system was designed to give students control of their own project page, while also creating an online community where they could show off their mastery, in an attempt to reach the goal of a higher level of intrinsic motivation felt by students as was described in the literature on SDT. Additionally the system was built to create more opportunities for interactions.

Field Trial: Location Based Game

For the field trial the LBG was tested on the 2016 Project Day held on the first 1st December 2016. Data was collected from all players on the day, and was also interpreted immediately afterwards to allow for prizes to be awarded to the most active students during the day. As part of the analysis of the data, a measure of social happiness in the space called the Jen Ratio proposed by Keltner was used [117]. Data collected for the 2016 field trial can be seen in Table 5.18.

Table 5.18: Data Collected, LBG 2016

2016 Field Trial	#	Notes
Student participants	65/84	Student registrations/total students
Locations Marked	29	Project presentation set up locations captured
Study leader participants	17/20	Study leaders with presenting students pre-registered by admin/total
External participants	51	External parties, self registered
Interactions captured	211	Total
Good interactions	195	
Negative interactions	5	
Neutral interactions	12	

The Jen Ratio captured through the day is presented in Fig. 5.11 at 30 minute increments for the LBG played in December 2016. A Jr_{Adj} value above 0.5 indicates a positive value. As can be seen interactions on the day as a whole were seen as very

positive. Fig. 5.12 shows a cumulative value of Jen Ratio for the full three-hour period, with the final values for the project day $Jr_{Adj} = 10.89$ and $Jr = 16.33$. Additional comments were captured on the day which would make the overall day appear higher, but this analysis is concerned only with the experience during the game. As can be seen from Fig. 5.12, the shorter the amount of time Jr_{Adj} and Jr are measured over, the smaller the impact each individual interaction will have. It is therefore important to gauge not only the final measure of the day, but also to analyse it over smaller sections throughout the day to ensure the data is a true reflection of the health of the social space.

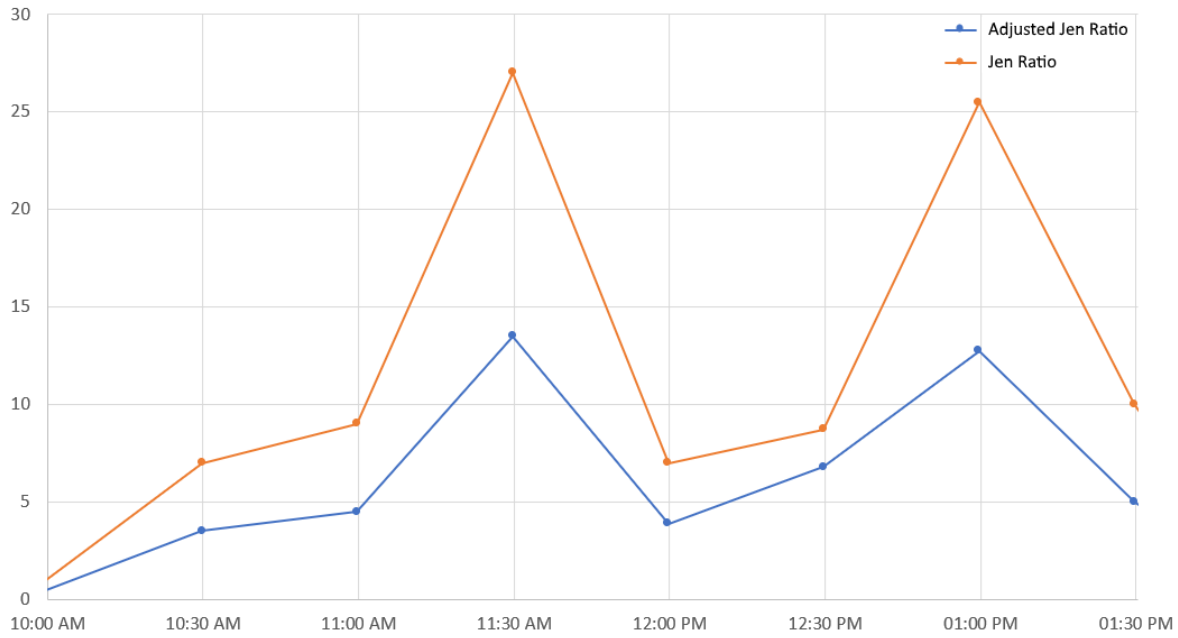


Figure 5.11: Instantaneous Jen Ratio Logged Through the Day (Dec 2016)

From the results obtained, it did appear to be a successful first run. The author was available as technical support through the day if there were any players that had trouble with the site, and all issues except for one were resolved. There was one player using an iPhone that didn't seem to be able to save their credentials at all and was repeatedly asked to log in. This was strange as it was only one user and could not be replicated on any of the other player's iPhones.

During the field trial students were questioned on the system and notes were made about what they thought about it and whether they had any suggestions. Changes that were recommended included making the registration process a little easier, as well as expanding the profile pages for the students and study leaders so that more information could be contained in them.

The results of the first field trial were published in [137].

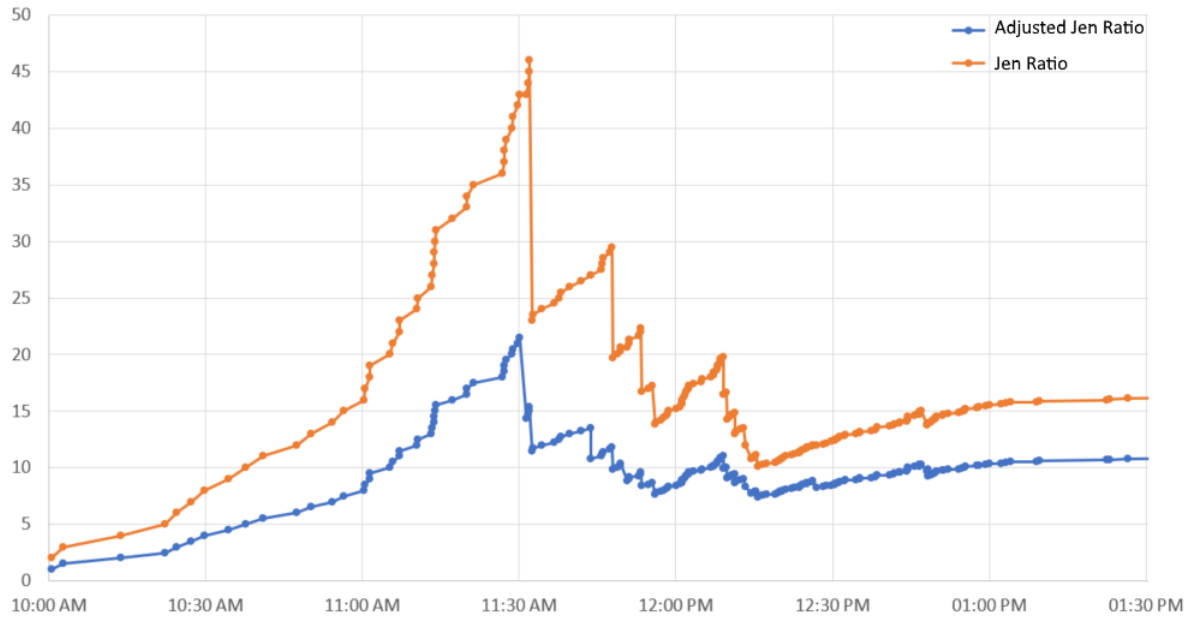


Figure 5.12: Accumulated Jen Ratio Logged Through the Day (Dec 2016)

5.4.2 Expert Reviews

Expert review of the system was very positive as the perception was that it did seem to get the level of interactions much higher than was the case in previous years, and the conversation shifted very quickly to the following prototype as the allocation of projects happen early in the year and would need to be rolled out only a month and a half after the field trial of Prototype One.

The following points were raised during expert feedback that were rolled into the next version of the system:

- More data analytics would be useful, for example which third year had the most interactions, which fourth year, which visitor etc.
- Prizes would be useful for each of these classes of player, and not just a general prize.
- The question was raised as to whether the interactions were all as positive as they were reported - were students not trying to appear more positive?
- A "quit" process was required for people that signed up but chose to later on deregister.
- More detail was needed on the study leader pages and they should be enabled to add more of their own details, for example adding their office hours.

Additionally, as the expert review after field trial one had already shifted to the tender game that would appear in the following prototype, it was decided that tendering should start as soon as possible and the Facebook page would be used as a means of communicating the availability of projects to students so that they could get onto the system.

The following time line was created for Prototype Two.

- 6th of February - first day of class
- 9th of February - first PJE class
- 13th to 17th February - finalise and load projects, tendering starts
- 24th of February - tenders close
- 27th February to 4th of March - voting
- 6th of March - project allocations.

This time line kicked off the start of the creation of Prototype Two that will be presented in the following chapter.

5.4.3 Personal Reflection

The first prototype of the system performed well, but as expected also brought forward many new requirements that would need to be brought into the second prototype. Students seemed to actively engage with the system, and barring one or two small bumps it worked as well as could be expected for a first prototype. The results obtained from the LBG were encouraging, and having a first prototype working and giving a baseline to work from meant that conversations with experts and study leaders could start from a more concrete point of reference.

The design hypothesis that Gamification would increase interaction seemed to be proven correct. Focusing on the SDT principles by creating an environment that gives students autonomy, a sense of community and an opportunity to show of mastery seemed to be a good design decision. The author was also of the opinion that increasing interaction and intrinsic motivation would lead to an overall increase in engagement in students.

At the time of creating the first prototype the author had been working in industry for 14 years and was a little removed from the academic context. Gaining input on the current experiences of students in their capstone projects, as well as seeing the quality of the projects being presented gave good context for the work that would go into the following iterations of the system. It was also very useful to the author to meet many of the faculty members in a less formal way.

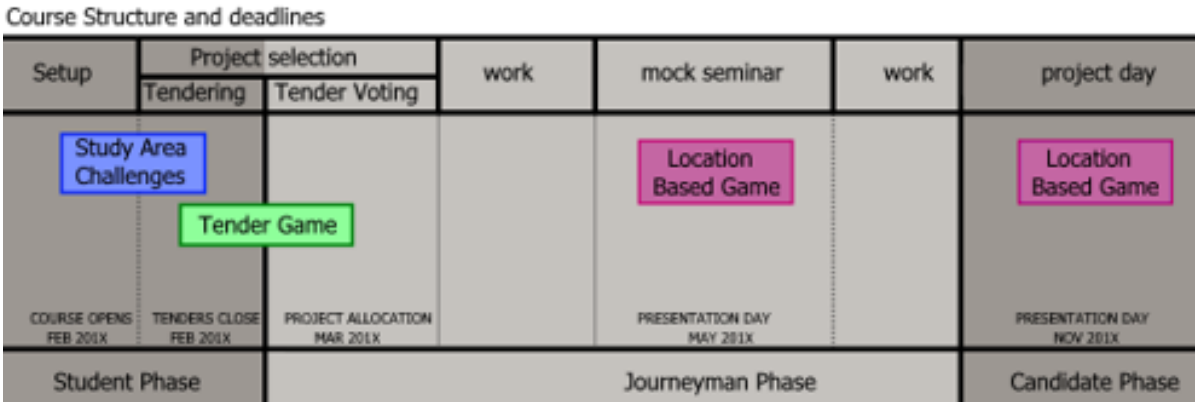
Chapter 6 - Prototype Two

6.1 Introduction

In the second prototype of the system, identified issues with the first prototype were corrected and the first version of the Tender Game was realised along with the first version of the Challenge System. The system went live during February 2017 and the first field trial was held between February and March 2017 where student allocations were done successfully. In this chapter further detail will be given on the techniques used for updating the system, as well as the creation of the Tender Game and the Challenge System. The feature map of Prototype Two can be seen in Figure 6.1. In 2017 an Action Research approach was taken so that the author was inextricably involved in all aspects of the process. This was achieved by acting in the role of study leader for three students during the allocation process and for supervision throughout the academic year.

In this second prototype the issues raised by students that there is a lack of fairness and transparency in the allocation of projects was taken on by creating a system that would take in the preferences of all stakeholders and algorithmically allocate the projects in a stable way based on an algorithm found in the literature.

Figure 6.1: Prototype Two Features

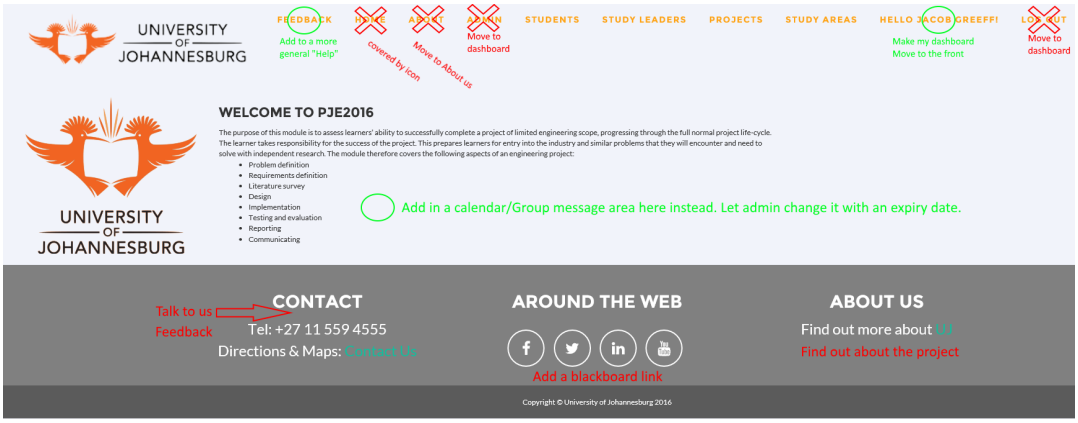


6.2 Delta overlays

In updating the feature set between the first and second prototype the technique of delta overlays was used for the first time. This technique was also used on the later prototypes

but is only described here to highlight the technique. With a delta overlay, a screenshot is taken of each of the views that can be presented to the user and it is compared to the actions that the user should be able to perform from that area. This is done for each of the roles that are represented if they have different requirements. The actions that need to available are determined from the expert reviews of the system, as well as the heuristic evaluation done by the developer. An example of such a delta overlay is presented in Figure 6.2. Delta overlays and heuristic methods were used throughout to make the small front end changes. From the second prototype it was expected that no further changes were to be made to the underlying system and style sheets other than to add in new features.

Figure 6.2: Delta Overlay Highlighting View Changes.



6.3 The Tender Game

The Tender Game was envisioned to solve the three core problems identified by students and faculty members in the allocation of projects:

- A lack of input taken from students during project allocations,
- A lack of transparency on the assignment mechanism, and
- Sub-optimal assignments[12].

In previous years, the project topics were allocated according to the following process:

1. Study leaders proposed projects they wished to offer in the following academic year.

[12]sub-optimal in this context meant that the students and staff were dissatisfied with the way the assignments were done, but no clarity was available on how this could be done "better". The author chose to interpret this as a less than ideal matching between students and projects at this point in the project and this is what guided the design for this second prototype.

2. Students received the proposed projects on the learning management system.
3. Students indicated on a Facebook group which projects they were interested in.
4. The module coordinator assigned projects manually to students taking into account their preferences and any other available information.

Students were not simply randomly assigned projects, but rather manually assigned by the module coordinator. This placed a large administrative burden on the module coordinator in addition to leaving many students dissatisfied with the final results. With this in mind, the decision was made to attempt a more integrated and automated process that took into account student and faculty preferences. As the South African context was used as one of the design inspirations, the game was designed as a gamified version of the tender process that is ubiquitous in the South African engineering practice context.

6.3.1 Design Considerations

Design guidance was taken from the experiences of the author, but also from the concepts of authentic learning. The Magellan considerations are not applicable, but due to the nature of the game a greater focus was placed on the privacy of information since tendering can only work efficiently when the proposers and information supplied is anonymised. The main goal was to ultimately get the best overall match between student and awarded project.

In the overall context of the project, the Tender Game is relevant to the timeframe shown in Figure 6.3 as this is where projects are presented and allocated to students. The goal for this subsystem was to increase the autonomy of students while simultaneously creating a system that is fair and transparent and increasing engagement by presenting it in a gamified way. Before the mechanics of the game are described it is prudent to first give some additional detail on the student allocation problem and the stable marriage algorithm used for the allocation actions.

Figure 6.3: Tender Game Active Period

6.3.2 Principle Mechanics and the Gale-Shapley Algorithm

The stable marriage problem consists of finding a stable matching between two sets of equal size given the preferences of each element for the elements in the opposite set and is a specific type of allocation problem [138]. The problem is most famously approached by Gale and Shapley who presented a simple iterative algorithm in "College Admissions and the Stability of Marriage" for solving problems of this nature [72] as follows:

Given $a \in A$ and $b \in B$ with both sets of size N, for all a assign an ordered preference list Pa for all elements of b and for all b assign an ordered preference list Pb for all elements of a. The matching set $\mathcal{M} \subset A \times B$ contains N pairs (a, b) with no element of A or B belonging to more than one pair in $\mathcal{M}$. $\mathcal{M}$ is deemed *stable* when there is no possible match $(a, b) \notin \mathcal{M}$ that is preferred by both a and b over their current matches in $\mathcal{M}$.

The Gale-Shapley algorithm guarantees that the set of matches will be stable, but the stable solution is not guaranteed to be optimal from all points of view. To achieve this, Gale and Shapley put forward the problem in the form of marriages between an equal number of Men (M) and Women (W) [72]. In the application presented here the match is made between students (S) and Projects (P) taking into account the Student Preferences (PS) and Project Preferences (PP). The algorithm works iteratively as follows:

Algorithm 1 Stable Marriage Algorithm

Input: Arrays $S[]$,$P[]$,$PS[][]$ & $PP[][]$ of size N holding the names and preference lists of the Students and Projects

Output: $Tuple[]$ of size N with matched elements of S, P

Initialisation :

1: $M = [...]$ initialise empty Match array of size N
2: $E = [...]$ initialise empty Engagement array of size N
LOOP till all proposals are accepted
3: **while** M contains empty elements **do**
4: for each $m \in M$ that is empty, pop next $ps \in PS$
5: **for** $i = 0$ to N **do**
6: **if** M[i] is not empty **then**
7: $S[i]$ tenders to $p \in P$ in $M[i]$
if p prefers $S[i]$ in $PP[p]$ to current $E[p]$, $E[p] \leftarrow M[i]$
otherwise $M[i]$ becomes empty
8: **end if**
9: **end for**
10: **end while**
11: **return** $[S, M]$

- Initially each unmatched student in S tenders to the project in P he prefers the most. Each project in P provisionally accepts the student if they have no current match or they are more suitable than their current match and declines all others.

- In each subsequent iteration this process is repeated with each of the unmatched students proposing to the projects they most prefer whom they have not yet tendered to. If a project receives a proposal from a student it would prefer over its current engagement, it will reject the current engagement.

- This process continues until all students and projects are matched.

It is important to note that the Gale-Shapley algorithm guarantees a stable set of matches, but is not guaranteed to match every element with their most-preferred choice. There is an inherent asymmetry: the students in the example get to choose from the full set of projects, whereas projects only get to choose from the limited set of students each round that proposed to them. This can be seen clearly from Figure 6.4a and Figure 6.4b which show the average position in the preference list that the algorithm will assign to students and projects. Curves are generated by creating N students and projects, assigning random preferences, executing Algorithm 1 500 times, and taking the mean match position for each student and project created for each value of N.

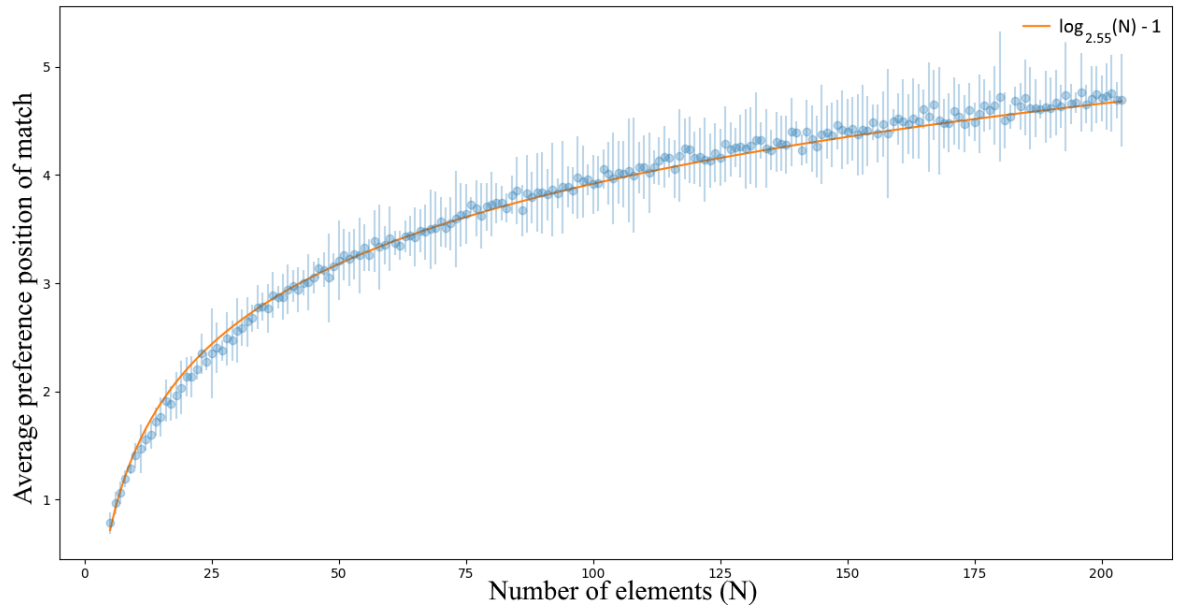
Additionally, the algorithm requires that both students and projects above have a fully ordered list of preferences for every single one of the members of the opposite set. The original Gale-Shapley algorithm was modified by Irving to incorporate the concept of indifference [73]. In a matching that includes indifference, students and projects order the preferences they have, but may have an indifferent opinion when confronted with two options that are equally suitable or unsuitable. In these cases, ties in the preferences of students and projects are broken arbitrarily, but strict preferences are still respected. In matches where indifference is allowed, Irving defines three different levels of stability:

- *weakly stable:* a matching is weakly stable if there are no two matched pairs that prefer each others' partners. The Irving algorithm can calculate weakly stable matchings in similar runtime complexity to the Gale-Shapley algorithm, $O(n^2)$.

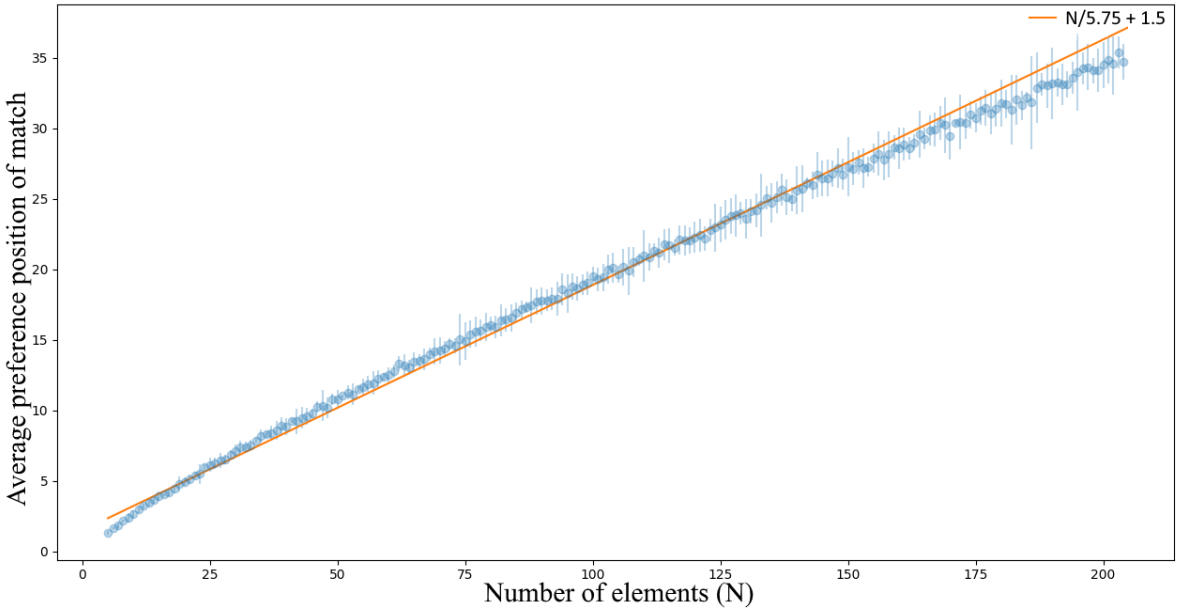
- *strongly stable:* a matching is strongly stable if there is no matched pair such that the student prefers another project, or the project prefers another student. To determine if a strongly stable matching exists, the Irving algorithm requires a runtime of $O(n^4)$.

- *super stable:* a matching is super stable if there are no two matched pairs that prefer each others' partners or are indifferent to them. The Irving algorithm can be extended to indicate in $O(n^2)$ if a super stable matching exists.

As can be seen from [73] Algorithm 1 will reach stability in $O(n^2)$ time, but for the range of data being used in the context of the Tender Game it is important to point out that the bias towards students is very apparent with the average preference of students being assigned increasing logarithmically and the average preference of projects being assigned linearly. In the simulated case above, the average position that a match can be expected at for students and projects can be calculated as:



(a) Average Preference Assigned to Students. $M_{\mu r}$



(b) Average Preference Assigned to Projects. $W_{\mu r}$

Figure 6.4: Average Preference Assigned to Students and Projects

N = Number of elements in each set
$M_{\mu r}$ = Average ranking that will match for students
$W_{\mu r}$ = Average ranking that will match for projects

$$M_{\mu r} = log_{2.55} N - 1 \tag{6.3}$$

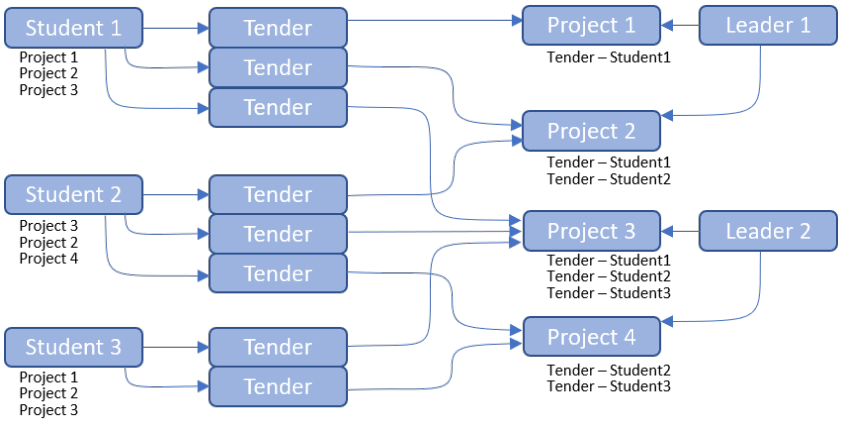
$$W_{\mu r} = \frac{N}{5.75} + 1.5 \tag{6.4}$$

It is important to note for Eq. 9.12 and Eq. 9.13 that these curves are based on simulation with preferences assigned randomly. If there is an element that is clearly more attractive than the others, it will change the characteristics of the curves. In this study these curves are used as the baseline situation for comparison purposes. As the system had at this point only been applied once, the normal distribution was used, but if it is apparent from future implementations that a logarithmic distribution would be superior for simulation purposes then that will be used. In the context of the Tender Game, only stable matches with indifference that are weakly stable are used.

6.3.3 Players

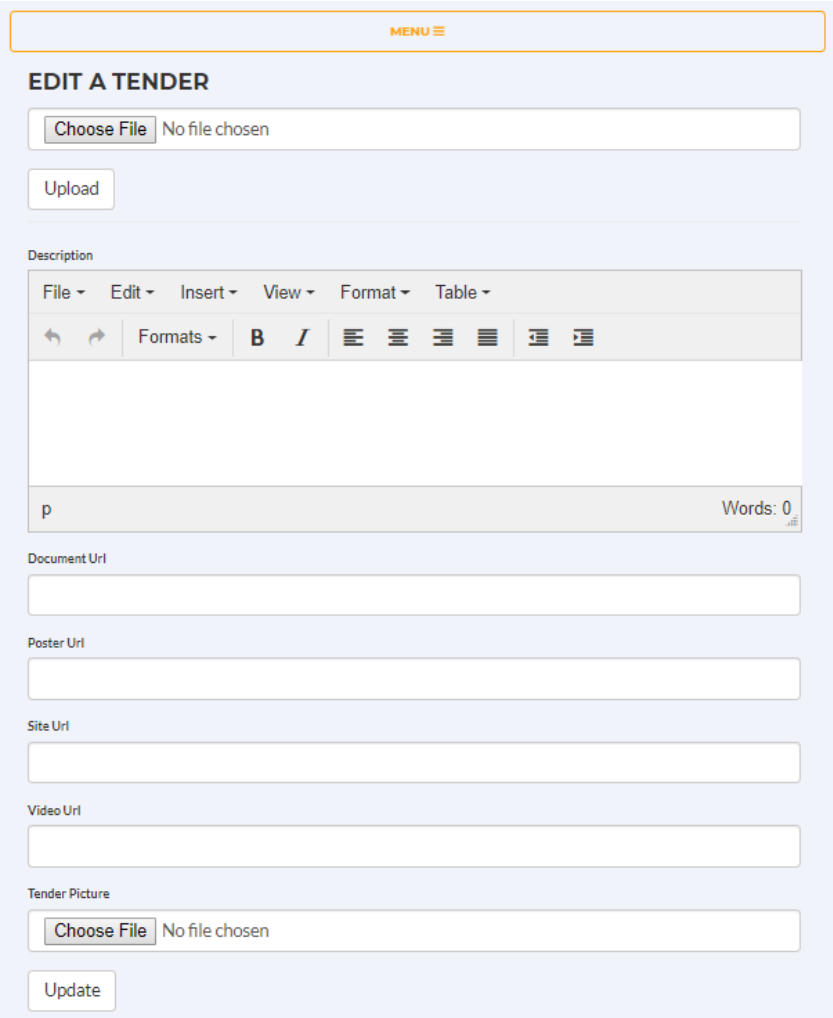
The principle ways in which players will interact with the game are shown in Figure 6.5 and Figure 6.7. The following steps were followed:

Figure 6.5: Tender Game Principle Mechanics (Prototype Two)



- **Preparation:** Study leaders load projects that they are willing to supervise for the year on to the system.
- **Step 1:** Projects grouped by study areas are presented to students.
- **Step 2:** Students have two weeks to write a short (two- to three-page) tender indicating what their approach to the presented problem would be, as well as to indicate their preference for projects they have tendered on. Figure 6.7 illustrates this process and Figure 6.6 shows the tender upload form.

Figure 6.6: Tender Create/Update Form



- **Step 3:** Tenders are anonymised.
- **Step 4:** Students and faculty all have an opportunity to vote on which tenders they feel are the most applicable to the problems presented. Figure 6.8 shows how students get to rank their tenders based on their most to least favourite in their dashboards with voting for tenders by other students working in a similar way.
- **Step 5:** Votes are tallied, and each tender and project is assigned a preference score based on the votes they received. Eq. 6.5, Eq. 6.6 and Eq. 6.7 are used to assign the score which in turn is used as an indicator of preference.
- **Step 6:** Tenders (and by implication students) are assigned to the projects using the Gale-Shapley stable marriage algorithm as described in the previous sub section.

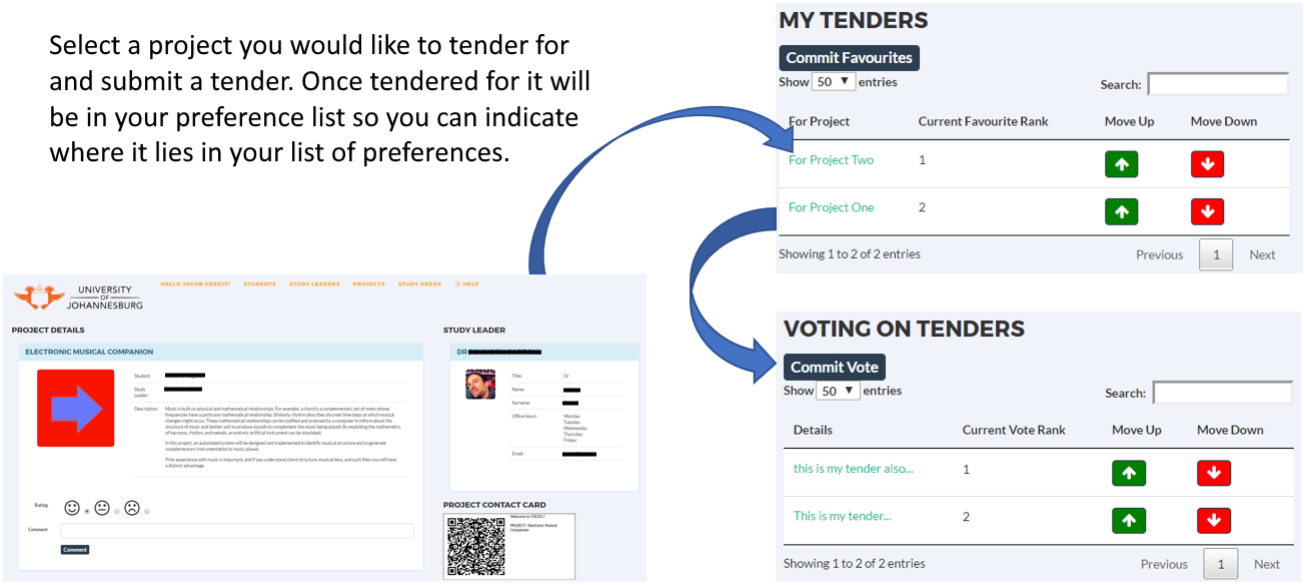


Figure 6.7: Tender and Voting Mechanics

- **Step 7:** The module coordinator is given a report on the recommended allocation with a stability level indicated.

S_m = Student multiplier
SL_m = Study leader multiplier
PL_m = Project leader multiplier
S_n = The number of students
SL_n = The number of study leaders
S_{rank} = Ranking a student gave the tender
SL_{rank} = Ranking a study leader gave the tender
PL_{rank} = Ranking the project leader gave the tender
N = Number of tenders for the specific project
T_s = Score for the specific tender

$$S_{sum} = \sum_{k=1}^{S_n} (N + 1 - S_{rank}) \times S_m \tag{6.5}$$

$$SL_{sum} = \sum_{k=1}^{SL_n} (N + 1 - SL_{rank}) \times SL_m \tag{6.6}$$

$$T_s = S_{sum} + SL_{sum} + PL_{rank} \times PL_m \tag{6.7}$$

Allocations are written out to a csv formatted file via the admin dashboard so that the module coordinator can review them and make any changes (should they want to). Once that is done a SQL script is run that assigns all students the allocated projects.

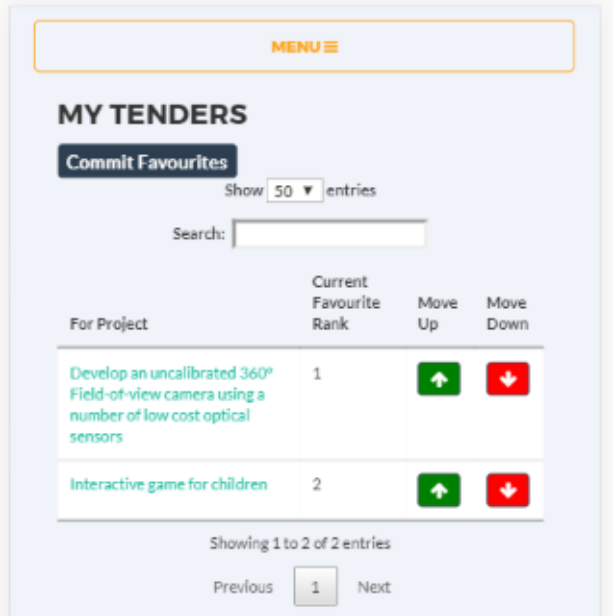


Figure 6.8: Student Selection of Preference on Tenders They Submitted

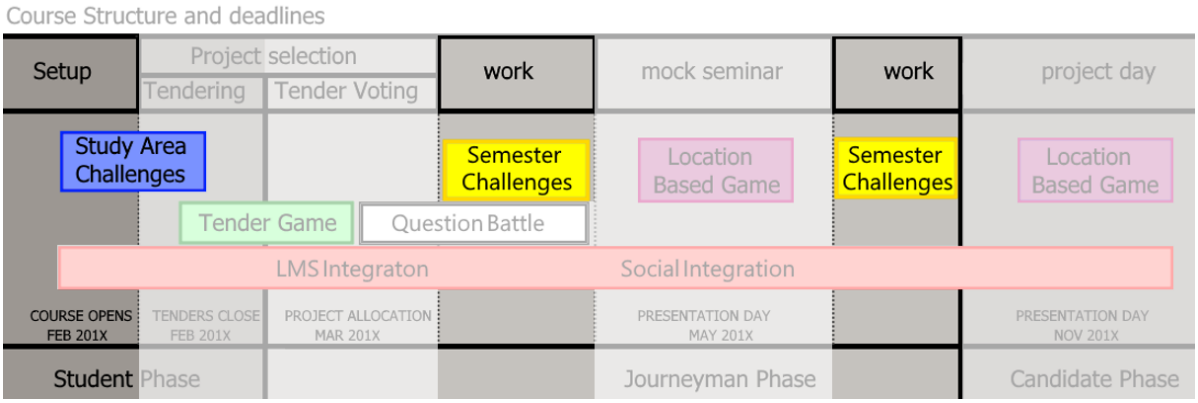
6.4 The Challenge System

The Challenge System is inspired by the Superbetter approach put forward in section 4.4. In Superbetter, McGonigal puts forward that to overcome a large life problem it is much easier to overcome a series of much more controllable smaller problems thus increasing your resilience to a point where you are strong enough to overcome your large challenge. The trick however is recognising that not only will each large challenge be different for every person, but even the smaller challenges that are used to build up resilience will differ from person to person. With this in mind, a challenge based subsystem was developed so that students could take on smaller challenges related to the study areas they are interested in to increase their knowledge in those areas, or to take on other challenges related to things like writing to increase their academic resilience. In the overall context of the project, the Challenge System is relevant to the timeframe shown in Figure. 6.9.

6.4.1 Design Considerations

In the original Superbetter system resilience was strengthened along four core strengths viz. physical, mental, emotional and social strengths. For the Challenge System, the underlying idea was to strengthen students in the areas where study leaders most often feel they are lacking. The initially chosen areas were writing, programming, building and mathematics. These are also seen by academic staff as the core strengths engineering students would require in practice. The open ended nature of the system however allowed study leaders to propose challenges based on any other area they feel would be relevant to their students as well.

Figure 6.9: Challenge System Active Period



6.4.2 Principle Mechanics

In this first version of the Challenge System study leaders would create challenges that were sent to the module coordinator for vetting, and once approved would be uploaded onto the system with points allocated based on the amount of time it would take to complete the task. To ensure the number of points assigned to the challenge remained consistent in terms of the overall system study leaders would submit their challenge to the module coordinator or admin who would add it to the system. Once created students have the opportunity to perform the task. They can mark it as complete and it will appear on the study leader's dashboard so they can mark whether they received appropriate evidence to indicate the student completed the task as indicated in Figure 6.10.

6.4.3 Players

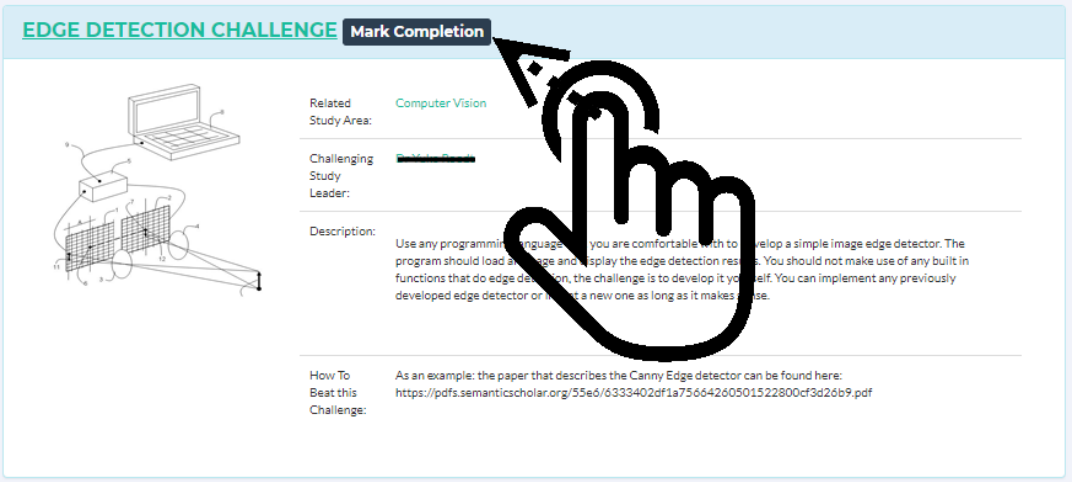
The Challenge System is the part of the system that most easily can have content duplicated between years. The overall goal of the system is to allow students to have a number of challenges that they can undertake to increase their confidence in engineering tasks. The ultimate hope was to open the Challenge System up to students as potential challenge contributors. This way a repository of relevant tutorials, open courseware and projects could be shared across academic years. In this academic year however the uptake by study leaders was very low leading to a very low number of challenges being loaded onto the system, which in turn created few opportunities for students to use the system.

6.5 Admin Dashboard

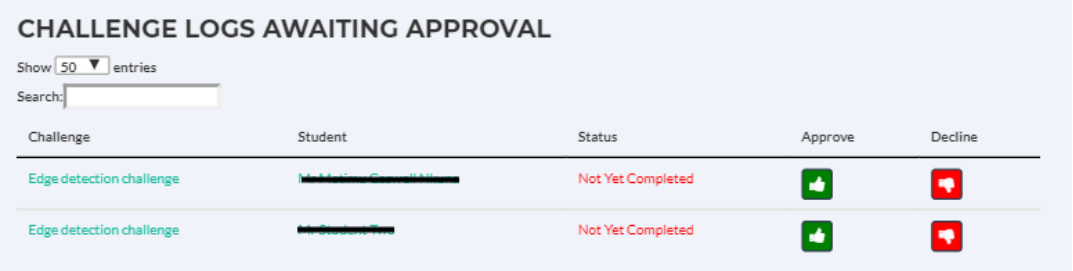
To simplify many of the tasks that were done on the dashboard and to more easily allow the module coordinator to change the web application state and add site messages a

Figure 6.10: The Challenge Cycle

(a) Completing a Challenge.



(b) Challenge Completion Log Requests.



simple admin dashboard was created to perform bulk actions and admin tasks. The dashboard can be seen in Figure 6.12.

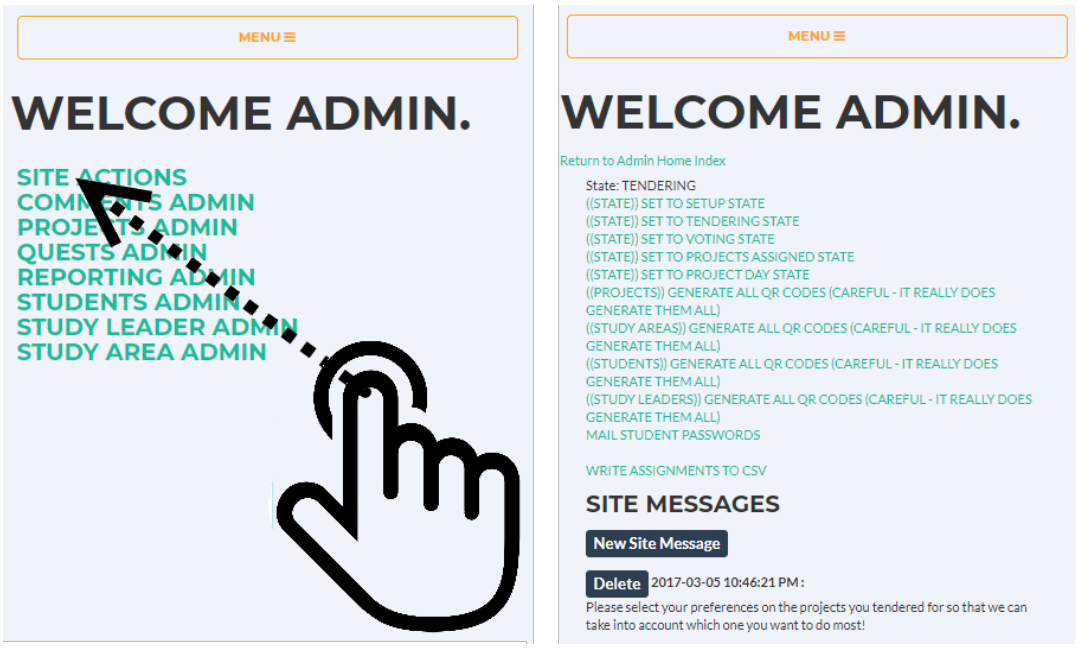
6.6 Results and Feedback

The results obtained from students, study leaders and experts were invaluable in problem resolution in the system and to develop recommended changes that could be rolled into the following prototype. Prototype Two was the first prototype to have feedback not only from staff and experts, but also the more intimate feedback gained from students under the author's supervision where an Action Research approach was followed. The main feedback obtained during the cycle is presented next.

6.6.1 Action Research and Lessons Learned

During the 2017 academic year when the system was in place and field trials were being run the author acted in the capacity of study leader to three students completing their capstone projects. This was done as co-study leader in collaboration with the module coordinator. Throughout the year a number of interactions were used as checkpoints

Figure 6.12: Admin Dashboard



for the design to make sure that changes being incorporated were relevant from both a student and study leader perspective.

Each of the three students were given the same project to implement in different ways, specifically a serious game and low cost companion device to help children with special needs. The project was assigned through the Tender Game in 2017. Two of the students focussed on physical fitness style interventions, and the third focussed on an occupational therapy type intervention. Two of the students passed with distinction from their external examiners but the third student failed the module.

This approach allowed the author more interactions over an extended period of time with these students than would have been possible if interactions were only had through interviews and participatory design sessions. Although a sample of three would be insufficient to gain an insight to the problems faced by all of the students, the following were some of the problems that came out from working intimately with these students:

- These students were enthusiastic about the idea of game based design in general modules and not just the capstone module,
- All three students felt ill prepared for their capstone projects,
- For the weak student the time given to the capstone project was insufficient for them to catch up on foundational knowledge that they seemed to have missing.

Tender Game Feedback from students

Once implemented a consideration on the side of the students was whether direct interaction was a valid way of canvassing support for the votes of students. It was felt

Table 6.19: Statistics of Tenders Received 2017

Students		**Projects**	
Tenders Submitted	**No.**	**Tenders Received**	**No.**
Zero Tenders	**None**	Zero Tenders	**19**
One Tender	**15**	One Tender	**18**
Two Tenders	**32**	Two Tenders	**21**
Three Tenders	**39**	Three Tenders	**12**
Four Tenders	**8**	Four Tenders	**8**
Five Tenders	**2**	Five Tenders	**2**
		Six or more Tenders	**9**
Total number of Tenders received			**238**

that the more popular students would get the projects they wanted very easily because they bypassed the system and simply asked other students to vote for them. It was an interesting concept to play around with whether social "cheating" should be allowed or not going forward. This was a large point of discussion between the author and the students he was supervising.

6.6.2 Field Trials

Prototype Two went live during February 2017 and the two main parts being tested were the Tender Game and the Challenge System. The Location Based Game was still part of the system, but during this section of the academic year the feature would not be used.

Field Trial: Tender Game

The Tender Game allowed the author the most opportunity to directly address the student issues that were raised in 2016. As described in section 6.3.2, the Tender Game employs the stable marriage algorithm with indifference over a number of iterations to find the optimal pairing of students to projects

For this field trial held during March 2017, a total of 92 projects (three were withdrawn before assignment) were proposed by 20 study leaders to 89 students. As the concept was that the allocation was to be done in a gameful way students had the opportunity to also pitch their own projects which they would automatically get allocated to them should they choose not to participate. Eight students followed this route successfully for an adoption rate of 91% among the student population. For the students that did not participate, they were still given the opportunity to cast their votes during the tender evaluation stage of the game should they choose to.

During the setup step of the game, study leaders put forward projects they were willing to supervise for the year. After that students had two weeks to tender for as many projects as they wanted to. Table 6.19 shows the number of tenders submitted by students and the number of tenders received by project.

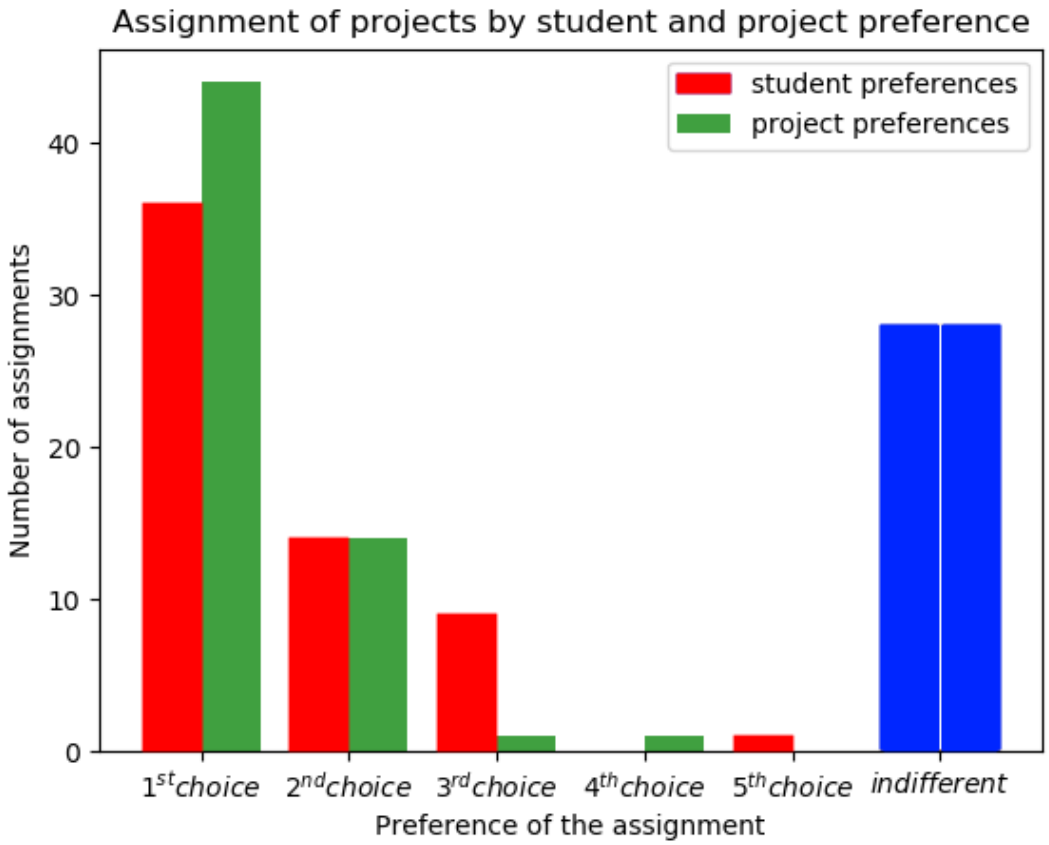


Figure 6.13: First Iteration of Matching (March 2017)

In terms of student engagement all students that chose to participate submitted tenders as requested. After the tendering section was complete the tender voting state was activated which allowed students to rank their tenders based on their preferences as well as to allow students and study leaders to vote on what they feel would be the most appropriate tenders to address the problems proposed in each project. For the first iteration the allocations of students where students received a project that was in their top 4 choices is shown in Figure 6.13. In generating the projects preference list, 70 of 97 students and 8 of 20 study leaders partook in the voting process. The S_m, SL_m and PSL_m required by Eq. 6.5, Eq. 6.6 and Eq. 6.7 were set at 1, 3 and 5 respectively.

The reasons for the match not being optimal in this first iteration was found to be as follows:

- Initially it was suggested to students that to have a good chance of getting a project they want they would need to do at least 3 tenders to give the algorithm sufficient search space to match with a project. However after the first iteration it was found from the simulations after the fact that for 89 participants $M_{\mu r} = 3.8$ is needed. In this instance, $M_{\mu r} = 2.67$.

- Students submitted 238 tenders to the projects, but what was unexpected is that

19 projects simply had no students who were interested. This means that the 19 projects automatically fell into indifference immediately.

- When voting on the tender panel students all participated, but only 40% of study leaders followed on to the next step. This was partially found to be because the game fundamentally took into account the student preferences and study leaders felt their votes were not as valuable. For example, if a study leader had one of the projects that had zero tenders it would not only demotivate them, but also gave them a lot less autonomy as to who would eventually be allocated to them.

To overcome the problem that some of the projects were simply not wanted a number of the study leaders who had very popular projects were asked if they were willing to duplicate some of the projects that had the most interest to ensure an optimal second round of allocations where all students were eventually assigned. This raised an interesting question as to whether the needs of the module should trump the needs of the gamified elements, as in doing this it would ensure all students are given the opportunity to do a project they had a preference for, but also meant students that got allocated the first time around could feel that the benefit they received was diminished in game terms. This conversation took place only between the the author and his supervisors as expert reviewers, but it was ultimately decided as the best way forward as the ultimate goal was to create the most engaging experience for the students and not to gamify simply for the sake of it. It was highlighted that if the game was proposed in this way initially, where the stable matching would allow polygamy (multiple matches), that player strategies like waiting for the second round would be a viable approach to gaming the system.

Field Trial: The Challenge System

The Challenge System went live along with the Tender Game in March 2017. The Challenge System was introduced to give a parallel education stream that students can use both as a way to increase the resilience of their skills as well as to create a portfolio of knowledge. Study leaders needed to submit challenges to the module coordinator to be approved before they could be added to the system during the project set up state. The field trial was a disappointment as only two challenges were eventually sent through to the module coordinator. The main problem seemed to be that it was seen as too much effort to actually write up everything to send through, so after review a different approach was recommended for prototype three which will be seen in the following chapter.

6.6.3 Expert Reviews

In April 2017 an expert review session was held with a study leader that had a strong interest in the matching algorithm approach as his approach was to attempt a similar problem with a neural network. Valuable information was gained on the effectiveness that can be expected and it was useful to try and play with other algorithms that could solve the same problem optimally. In the end the Stable Marriage Algorithm was kept as

more data than was available would be required to be able to develop a neural network, and it was deemed unlikely that an ant colony or genetic algorithm approach would generate superior matches once the data was evaluated.

The module coordinator, engineering education expert and senior academic were also consulted heavily on both the system as a whole, but also on the best way to do supervision of the students in the context of the school. It was also interesting to note that although students were taught that the best way to do their capstone project document write-ups was to follow the same process as what they would do in a masters programme, this opinion was not held universally. The author chose to stick to the more conventional approach when giving guidance to the students, but it was interesting to see how many other study leaders were following a more product design based approach.

Finally a number of sessions were held with the module coordinator, engineering education expert and senior academic to review the parts of the system already in place. Small changes were suggested that could be rolled into the following prototype, including a field trial to be held in the middle of the year for the Location Based Game and ways in which study leaders could be encouraged to be more actively engaged in the system their students were already engaging in. The changes suggested were implemented in Prototype Three which is presented in the following chapter.

6.6.4 Personal Reflection

During the first prototype the author was still employed in industry but at the start of the academic year the author joined the ranks of full time academia by accepting a lecturing position at a different university. This was interesting in that it showed that the experience of students and staff are different in many ways but there was also a lot of similarity between institutions. It also showed the author that the work was kicked off through rose tinted glasses and the experience gained by supervising students as well as having more interaction with study leaders and students was illuminating.

The second prototype had more moving parts than the first and instead of being developed all at once from an envisioned system it was more iteratively developed as ideas and requirements became apparent. This was seen clearly in the decision to allow polygamy in the Tender Game after the first attempt ended with 30 projects in indifference (not allocated in the first round). Where the first prototype was definitely successful, the second felt less so, especially with regards to the failure of the Challenge System to have much impact which was deeply disappointing to the author. The Tender Game was a much greater success and the gamified approach did seem to add significant value.

Approaching the project largely from the literature in the first prototype meant that the expectation for the author was that all the study leaders would be focussed largely on the success of their students, but in reality it was found through feedback obtained that there were a lot of demands on the time of study leaders meaning that capstone project supervision was often seen as a burden rather than an exciting prospect. This was seen especially in the engagement level of study leaders in the Tender Game. This experience was valuable however as it allowed, through many discussions with the author's study leaders and other faculty members, insight into how the project could be taken forward

more effectively by considering the needs of all of the individual stakeholders and not just the students. Interaction with the tender game from the student perspective was very positive and giving the students more autonomy and a say in what projects get allocated in a transparent and gameful way did seem to prove effective.

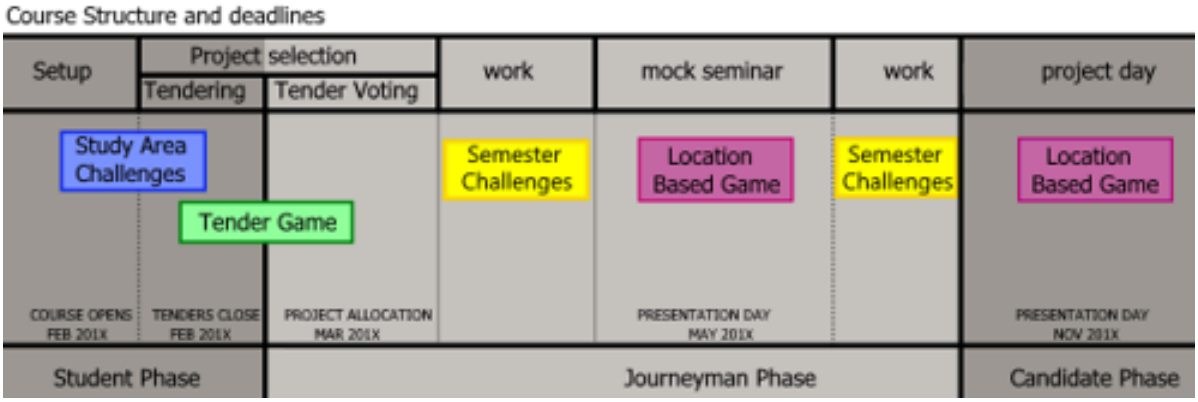
It was clear both from the experience of the author, as well as from the literature that a context driven approach was ideal as each institution will have it's own unique culture and norms. The second prototype highlighted for the author that the DSR approach followed was indeed the correct approach, but that a more structure was needed in the way the author collected contextual information from stakeholders. By having a larger focus on the technical aspects of the project, the author missed some of the human elements, specifically relating to motivation and engagement relating to the study leaders.

Chapter 7 - Prototype Three

7.1 Introduction

In the third prototype of the system, identified issues with the second prototype were corrected, the Location Based Game was updated and two field trials were run. The Research Question Battle was explored but ultimately abandoned and the Challenge System was changed based on feedback obtained in the second prototype. The system was already live as the second prototype was running during this cycle, and as such deployment was done to the live site whenever changes were made using a dev ops approach where the changes were first deployed to a test server and then once tested deployed to the production server. In this chapter further detail will be given on the explored designs and the lessons learned with designs that did go live. The feature map of Prototype Three can be seen in Figure 7.1. The Action Research approach was maintained throughout the year and in this cycle the first participatory design sessions were held with both students and study leaders where the Situational Motivation Scale (SIMS) was used for the first time.

Figure 7.1: Prototype Three Features



7.2 Updating the Challenge System

The Challenge System went through three design phases which will be discussed in the following subsections, with the fourth being an open question as to whether it is better to gamify in this way, or whether a much more heavily gamified external system would be a better approach. The main design changes were:

1. Version 1: Study leaders would create challenges that were sent to the module coordinator for vetting, and once approved would be uploaded onto the system with points allocated based on the amount of time it would take to complete the task.

2. Version 2: Study leaders could create tasks based on their own discretion against study areas that are made available. Challenges would be used during allocations to give students more points to break ties on allocation. The focus here was to do the challenges during the tender game.

3. Version 3: Study leaders could create challenges based on study areas or not, and challenges could be done any time of the year when the study leader felt the students under their supervision would benefit from it. Challenge completion logs were approved by the study leader setting the challenge or the module coordinator. Points were removed from the challenges so that they didn't need to be benchmarked to ensure points are allocated fairly giving much more flexibility to the study leaders creating the challenges.

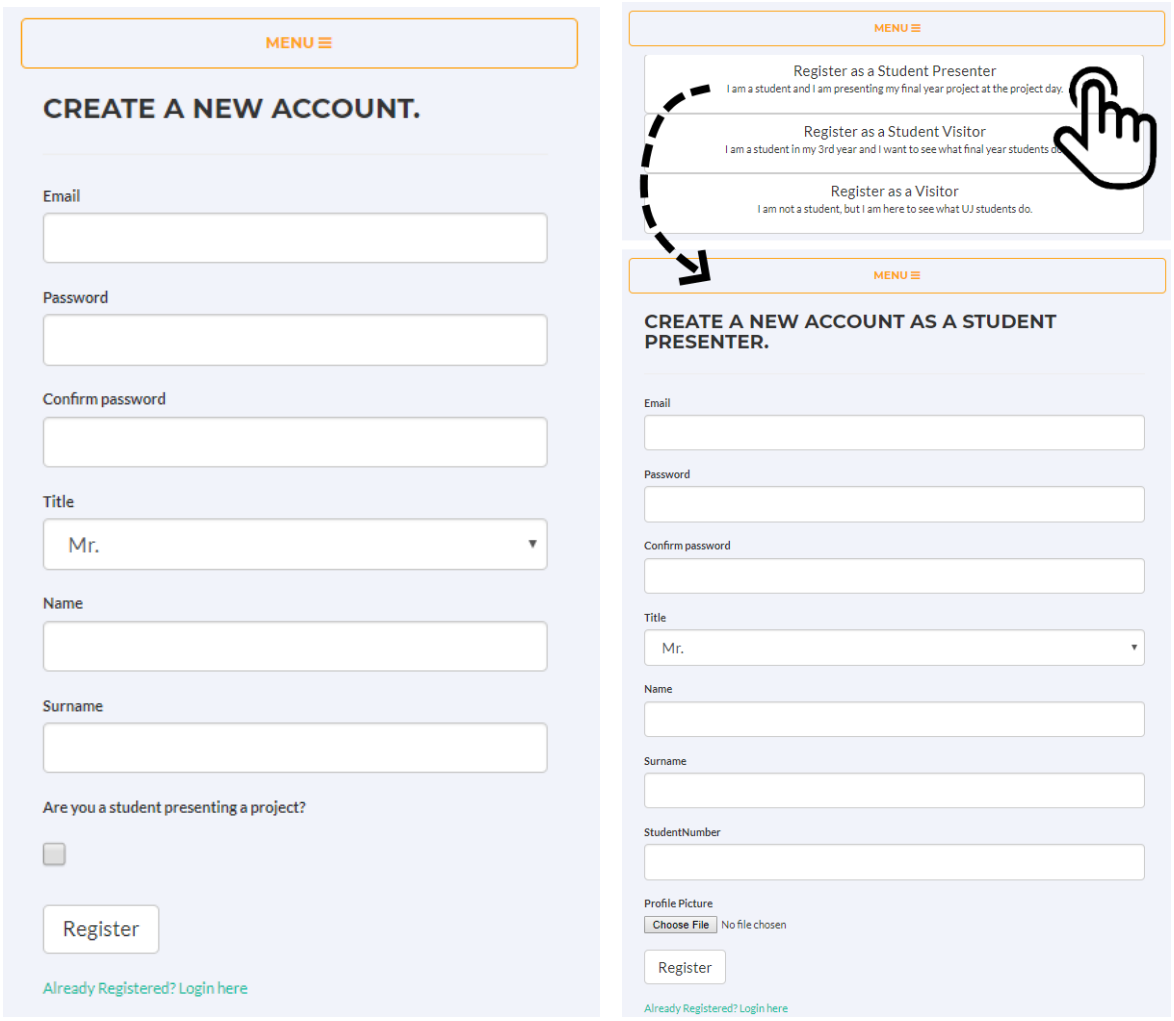
This third version was ultimately the one that won out and was implemented in Prototype Three. As the change was made quite late in the year, it was not field trialled during this cycle however, and the testing as such rolled over into Prototype Four.

7.3 Updating the Location Based Game

After feedback both from the previous run of the LBG and from the expert reviews, the main problem seemed to be the registration workflow that new users needed to go through to register on the system and join in. Students in 2016 were new to the system, but they did have the opportunity to register before the field trial simplifying things, but for players on the day it was unclear to them whether they were presenting students, students or visitors - especially if they were actually registered students at UJ.

To rectify this, instead of using the single registration form seen in Figure 7.2a which uses a tickbox to hide or show the student specific fields, an updated workflow was created that first asks the new user what describes them best before presenting them a tailored registration form as can be seen in Figure 7.2b.

The field trial of the LBG updates during May 2017 did not make any new data available due to the structure of the project presentations. Instead of presenting their projects physically in multiple locations, students presented slide decks to a group of their peers who were sorted into a number of groups. As there was no physical movement of people, the concept did not make sense. It was a good learning experience however as the author learned a valuable lesson about not assuming ahead of time. The second field trial held at the end of November 2017 was a success however and the results are presented at the end of this chapter.



(a) Prototype One and Two Registration Form (b) Updated Registration Workflow

Figure 7.2: Registration Workflow

7.4 Research Question Battle

The final sub-artefact envisioned initially was the Research Question Battle. The goal of this sub artefact was to assist students in the process of selecting their research questions as this was seen as one of the largest stumbling blocks in their capstone projects by interviewed study leaders. However as the project progressed it became clear that this was only relevant to research style projects, and a large number of study leaders felt that this was not the route most students go (as only a small percentage of them stay on to do master's studies). As this was only done as a conceptual design, no data was collected with it, but the design is still explored here for completeness.

7.4.1 Design Considerations

The initial idea was to assist students in the process of shaping an appropriate research question as this was highlighted as particularly problematic by study leaders. This would be achieved by using a corpus of MEng and BEng projects that had previously been submitted to the University to attempt to teach a neural network to recognise good and bad research questions, and then from there to use an adversarial neural network to generate new questions that could be used by students as a baseline. This could be gamified by allowing students to "attack" other student's research questions by submitting fixes to questions that are posted, and if accepted would count as a valid attack. This design however was based on the initial idea that BEng projects being explored would be similar in structure but smaller in scope to MEng style research questions. With the project moving forward, it became clear that application, product, process or research based projects are all valid approaches to capstone projects, and some study leaders felt a more commercial focus would benefit students and could also be made to fit the requirements of the capstone project. This change in focus made it difficult to fit to an existing corpus, and the idea was shelved.

The design was based on two main concepts. First to try and emulate the game play of the Pokemon battle system as seen in Figure 7.3. The concept being that instead of pokemon, students would put forward their research question, and other students could "attack" them by pointing out a flaw in the question which would then count as a hit if the student being attacked accepted the criticism and then changed their research question accordingly. And the second concept being that to give a baseline of "strength" the research questions would first be run through a neural network trained on a corpus of theses text available from the UJ library of MEng work produced in recent years.

The conceptual design and demonstration of technology was based around using "Julia" Text to Speech along with a Unity front end and a Makehuman developed avatar that would give students feedback on research questions they submitted before going into the battle. The high level system design can be seen in Figure 7.4. This is work that will still be attempted at a future point but was shelved for the moment.

Figure 7.3: Pokemon Yellow - from [11]

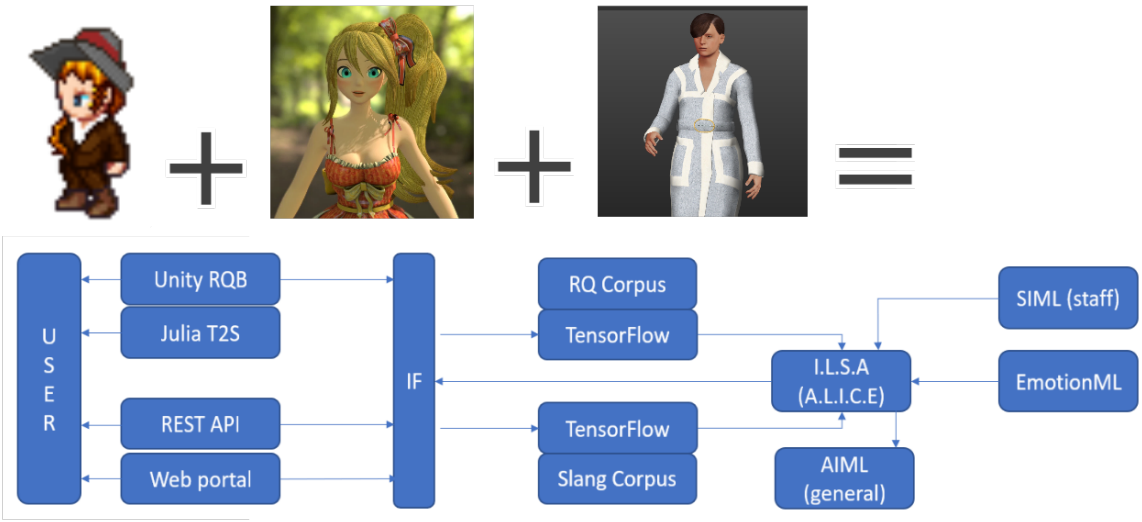
7.5 Results and Feedback

At the end of the third protype a lot of feedback had been obtained through interactions with students and study leaders using an Action Research approach. It was also at the end of the academic year that a number of participatory design sessions were held with students and study leaders to attempt to get more input from them as to how the system could be modified to meet the requirements of all stakeholders involved. In this section the results of these participatory design sessions, the expert reviews done and the field trials run are presented.

7.5.1 Participatory Design Sessions

Some of the small group interviews were done with participation of studyleaders and also some where the study leaders were interviewed separately. The main point of discussion with the study leaders revolved around the concept of whether the student engagement or study leader engagement was the most important. This became one of the driving forces behind the change in the design of the allocation, as in the first implementation, all students participated in the allocation process by giving their vote, but only 40% of study leaders did. After the fact, students were very satisfied with their allocations, but study leaders were not as happy because some of them were allocated students they didn't feel were a good match. In understanding this problem it was specifically highlighted that although they can vote, they can only vote for students that applied to

Figure 7.4: Conceptual Design of the Research Question Battle



projects they put forward, but they didn't have the ability to choose to not work with students. This was one of the great successes in the project from a participatory design perspective, because in changing the system to allow study leaders to simply skip out on an allocation in a multi round approach, in effect also giving them some measure of autonomy in the system pushed the participation of study leaders to 100% in the following year. This change lead to a much more effective allocation process. Some of the more useful and striking comments to come out of the sessions are highlighted here:[13]

> **Question:** "Is the project itself a true reflection of the student as a graduate of a BEng project at the end of the day? We are measuring it now, and conceptualising it now as the final capstone, is it the best place to do it"?
> **Study Leader:** "I would say absolutely, it may not be the only one but it is definitely a good one. These students go through three years with us, and we are finding too often that they have no insight".
> ...
> **Study Leader:** "We take students through all of these courses and they pass them, but when they are asked to assimilate the knowledge, it falls flat. I don't think they are ready for this project in many of the cases. The training needed for this work is not always there".
> ...
> **Study Leader:** "A capstone is that I will be your supervisor, but we should be getting closer to a point where you approach me with the work you have done, and you can show me what you have done as an engineer. If I need to guide you day after day after day, whose project is it then? At this point it

[13] Where required quotations are translated by the author from Afrikaans to English

is no longer a capstone project, and rather simply still part of your learning experience".

...

Study Leader: "If a student arrives with something they want to do and has passion, then they may not need the knowledge. Consider this in contrast to a student that is capable, but simply never shows up".

In many ways the interviews with study leaders, educational experts and senior academics involved in the capstone project gave the author a lot of insight into the purpose of the capstone project in engineering education. From a Design Science Research (DSR) point of view, this is important to highlight that the participants in the study should not only be the final users in the system, but also the experts in the context that exists to allow the designer to gain deeper insights into the context. Combining interviews with the Action Research approach allowed the author a unique experience that was of great personal value.

The reason for taking in a wide variety of input in open ended design discussions like this is to also allow students to come with innovative ideas that can be implemented later and ensure that the researchers do not simply get tunnel vision in the design of the system. During the time this study was undertaken, the author also helped out on Serious Games that were used in various other modules where the input of students was often reflected on as can be seen in [139] [35] [34]. Not all feedback can be applied directly to the problem at hand, but having an insight into the problems students experience is invaluable in trying to address their issues holistically.

A full thematic analysis is out of scope for this project, but for future work this would be a valuable process to go through to be able to understand in the current context how large the gap is that exists between the expectations set by ECSA and SAQA in the ELOs and CCOs, the module outcomes set by the university, the understanding of what it means to supervise a capstone project, and the student's expectation and experience coming into and leaving the module.

Situational Motivation Scale

The SIMS questionnaire was given to participants during the participatory design session where both students and study leaders were present to gauge how the participants experienced the session. The nature of the SIMS is that it needs to be presented to participants within two hours of participation as it is situational, and as such it was made an integral part of the participatory design sessions.

The SIMS was presented to participants during the mixed participatory design session in November 2017 (n = 5) with results obtained as in Table 7.20. It was clear that participants felt a high level of intrinsic motivation to participate in the participatory design session. It is worth noting however that since students were not forced to participate, this may be a biased result in that students that are already motivated to have a hand in participating in the design process were then the ones that would put forward their willingness. It is however in line with the expected results found in the literature and as such is interpreted through the instrument.

Table 7.20: SIMS Results for the Participatory Design Session November 2017 (n=5)

	Average	Median	Max
Intrinsic motivation	20.2	20	/28
Identified regulation	22.4	23	/28
External regulation	13	11	/28
Amotivation	9.5	6	/28

7.5.2 Field Trials

Two field trials were held, but the first held on the 26th June only generated 33 interactions throughout the entire day as the mock presentations didn't follow the same approach as the project day would at the end of the year.

Field Trial: Location Based Game

For the LBG field trial on the 23rd November 2017, data was collected from all players on the day, and was also interpreted immediately afterwards to allow for prizes to be awarded to the most active students during the day. The Jen Ratio was not analysed during this trial as it was already shown to be ineffective in the way it was implemented in the previous prototype. Data collected for the 2017 field trial can be seen in Table 7.21.

Table 7.21: Data Collected, LBG 2017

2017 Field Trial	#	Notes
Student participants	106/106	Registration ran through the year
Locations Marked	59	Project presentation set up locations captured
Study leader participants	20/20	Study leaders with presenting students pre-registered by admin/total
External participants	77	External parties, self registration
Interactions Captured	138	Total
Good interactions	129	
Negative interactions	2	
Neutral interactions	7	

An interesting interaction that came up in 2017 was from a single third year student that seemed to get completely engrossed in the game aspect of the system logging 59 interactions on the day, to the point where it is debatable as to whether they actually achieved the initial goal at all. By becoming completely engrossed in the act of collecting badges, the student interacted with and viewed more projects than the researchers thought possible, but on reviewing the time stamps it appears that it was such a quick interaction and scan it was not likely the student learned anything. Although it is flattering to think that the experience was fun, it is worth reflecting on whether too much

fun actually negatively impacts the learning experience. In this instance, comparing this activity with what was previously in place would make one believe that for that particular student merely walking around and interacting randomly would have been more beneficial. It was only a single instance but did present an interesting anomaly. In this field trial there were no posters placed to guide students to register and show how to interact as this was explained in class and two student assistants were hired to help with registration on the day. In retrospect this was a bad idea as this meant that the assistants helped people register, but visitors weren't actually enticed to play the game at all, they simply registered and used the system to find projects they were interested in leading to lower levels of captured interaction.

7.5.3 Expert Reviews

In order to get the most out of interviews in November 2017, of the study leaders that participated in the first full year, the two most negative study leaders were identified and invited to participate in a separate expert review of the system so that they could give input on what is not ideal. The main take away from this session was that there needs to be a focus on the study leaders themselves and the way in which they guide the students as there seems to be a misalignment of expectations. Students want to be spoon fed all of the answers which the study leaders feel is counter to the goal of the capstone project. It was also clear from the review that the focus on capstone projects as mini research projects should not be the only way to attempt a capstone projects and both study leaders felt that a more product based approach was more suitable to the South African market for engineers. Additionally, valuable input was gained with regards to the allocation process where it was felt that multiple iterations is in fact a better way of doing the assignments. With multiple iterations students who are not ready can be guided to a point where they are ready to digest the requirements of a capstone project through other means. They were both adamant that the study leaders should not have a choice to take specific students, but the concept needed to be clear that it was the student's project and not the study leaders.

An additional separate session was held with an additional study leader. This was of interest specifically because the study leader was also working on Gamification in one of the other modules and it was useful to get another practitioner's input on the design of the system. This approach was based on Moodle and used open badges in the classroom to show mastery of certain concepts.[14]

Expert reviews were also undertaken with the module coordinator, engineering education specialist and senior academic with regards to the experiences in the year as well as the design concepts that came about as possible solutions to some of the problems experiences. Specifically, the following points were discussed:

- The idea of changing to a system where each student had multiple study leaders, or even no study leaders, where all study leaders would act as "oracles" was discussed.

[14]It was useful to get input from a fellow practitioner and reviewing each other's approaches was a process the author would highly recommend to anyone undertaking a similar project.

This was ultimately abandoned however as not having a single person to take accountability in the event of a failure was seen as too high a risk.

- The capstone project is outcomes based by it's very nature, but it was felt by some of the students that it is the first time that this is the case. It was possible to get to this point in the degree by doing well at theory and having practicals as an afterthought. This again highlighted the value of the system in that could be used to identify and assist these sorts of students through the challenge system which could be used to increase their resilience during the allocation period.

- The allocation algorithm seemed to function as expected but the way in which the preferences were determined needed to be changed to allow more information to be fed into the algorithm. The discussion on the approach here will be presented in the following chapter.

7.5.4 Personal Reflection

During the third prototype the system as a whole started taking shape as all of the sub components were put in place already and a larger focus could be placed on tweaking the performance of each of the subsystems. It was also here that the scope of the project started to retract a little as it seemed more logical to focus on the parts of the system that worked effectively than add on more and more functionality. The author believes this was the best course of action as well, and although the Research Question Battle may emerge again as a different project in the future it was a good exercise to remove a section of the work from the scope of the overall project due to early identification of problems that would be experienced with it. Considering the nature of the capstone projects the author experienced it became clear that it wasn't a concept that could be made to work in this context.

The LBG field trial that failed during the mock presentations was a good learning experience for the author as it showed that the LBG was working as it should have, but that changing one of the core mechanics of any game can lead it to fail - Removing the "Location" from an LBG removes a lot of it's charm.

Using the SIMS questionnaire was a new experience for the author as previously feedback was obtained only from semi structured interviews and themes that emerged were assumed to be the participants honest feedback. By adding in an instrument that also validated that the participants being interviewed actually were engaging with the participatory design session meant that there was a much higher level of faith in the results obtained and is something that the author highly recommends to any future researchers. The instrument is easy to use and score and gave a new level of confidence in the interaction with workshop participants to the author.

What was interesting to the author is the lack of clarity that is given in the literature on what it means for a gamified intervention to be successful. The literature would lead one to believe that most interventions are successful but the level of "success" that is reported on seems to be much higher than measured in this project. It would be difficult

to achieve in the context of this system, but a study that splits the class into a gamified and control group without gameful interventions in place would be a useful study to do to give clarity on what kinds of results can be expected from the ground up.

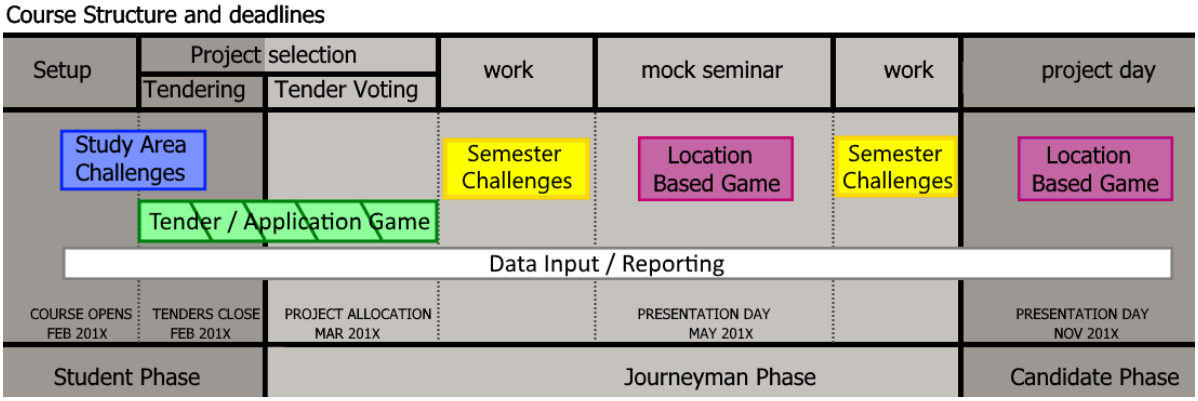
In laying out all of the subsystems in the artefact, interaction was now encouraged in the "student" phase with the Tender Game and study leaders were also dedicated in loading their projects onto the system. In the "journeyman" phase interaction could be encouraged using the Challenge System, and in the "candidate" phase interaction was encouraged through the LBG. Each of the subsystems attempted to encourage interaction and engagement through gameful design and a focus on the SDT principles. It also became clear that the artefact as a whole was useful not only for these subsystems, but also for the PJE system itself which allowed all users to display and take ownership of their profiles and project pages so that everyone could find information about all work being done.

Chapter 8 - Prototype Four and Generalization

8.1 Introduction

In the fourth and final prototype of the system, identified issues with the third prototype were corrected, the Tender Game was updated, the Challenge System field trial rolled over to this prototype from the third and the Location Based Game (LBG) was used to generalise the system to a different context to test its efficacy. The feature map of Prototype Four can be seen in Figure 8.1. The Situational Motivation Scale (SIMS) used in the previous prototype was again used during the participatory design sessions and additionally student intrinsic motivation was tested using the Intrinsic Motivation Inventory (IMI). To validate whether students could now see the value in gamification and to get a measure of whether gameful design in the module should be explored further the general questionnaire was presented to the class as a whole.

Figure 8.1: Prototype Four Features



8.2 Updating The Tender Game

The Tender Game was presented twice in the 2017 and 2018 academic year during the allocation process that happens at the start of the academic year. Where the first version of the LBG was already quite effective, there were two very different versions of the Tender Game presented. The underlying algorithm used for matching students

to study leaders was similar, but in the first version students were allocated to projects presented by study leaders (a problem commonly called the student allocation problem) where in the second version students proposed their own project and then competitively applied for supervision with a study leader to make that project become a reality. This was done with the idea that it is less likely that students will immediately have to tender for a project, but almost all students will need to sell themselves through a curriculum vitae and portfolio almost immediately.

Each study leader was allocated eight slots for potential students, and students followed the same process they did the previous year with tenders, but by applying to a study leader it automatically meant that the student will have eight slots on their preference list for the algorithm to work on guaranteeing that if there is a stable matching it can be done. What was added however for the study leaders was that they could not only rank the students that applied to them, but they could also "black ball". This meant that the study leader saw the application, but due to some technical reason they felt the student was not yet ready. This was different to the previous concept of indifference since that meant the study leader was indifferent to the assignment should it fall in that range, where as the "black ball" meant the study leader does not yet want to take the student on. Students that were not allocated in an iteration were given an additional week to fix the comments made by study leaders and attempt again. Problems ranged from technical issues down to writing or mathematical issues and this gave the module coordinator more information that could be used to support the students that stayed behind during each iteration with challenges and interventions from other sources like the writing center. In 2018 there were three rounds of allocation done to get all of the students placed with a study leader.

For the 2018 version the following steps were followed:

- **Preparation:** Study leaders create a profile page that includes not only who they are, but also what projects they have lead in the past and what areas they have the greatest knowledge in.

- **Step 1:** Students have two weeks to write a short (two- to three-page) project proposal that they will submit to their chosen study leader (they can do this as often as they choose) where they indicate why they would want to work with them personally and what sorts of projects they are interested in.

- **Step 2:** Once all proposals have been submitted, study leaders then select their preferences (as opposed to the project preferences they selected previously). This makes it a much more personal experience, but an additional mechanic was added that allowed study leaders to remove a student from their pool if they felt they could not work with them at all, this was done simply with a decline option as seen in Figure 8.2 .

- **Step 3:** Votes are tallied, and each applicant and study leader is assigned a preference score based on the votes they received. Eq. 6.7 is used to assign the score which in turn is used as an indicator of preference.

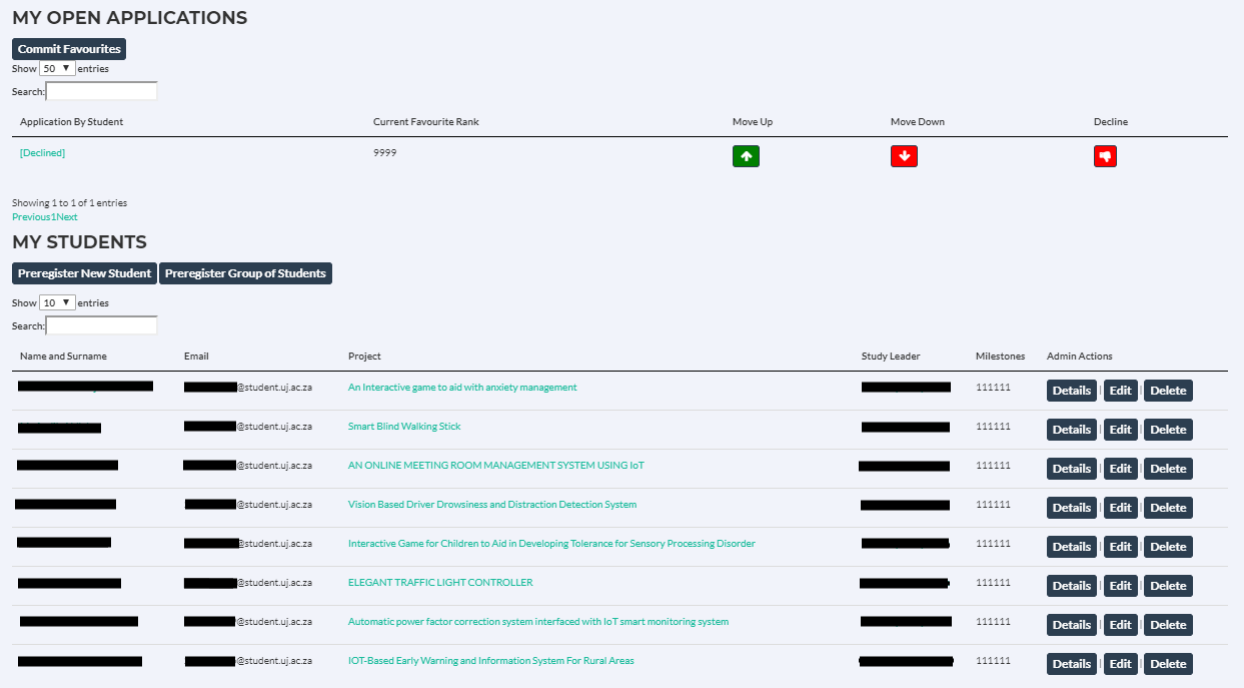


Figure 8.2: Adding Autonomy to Study Leader Decisions.

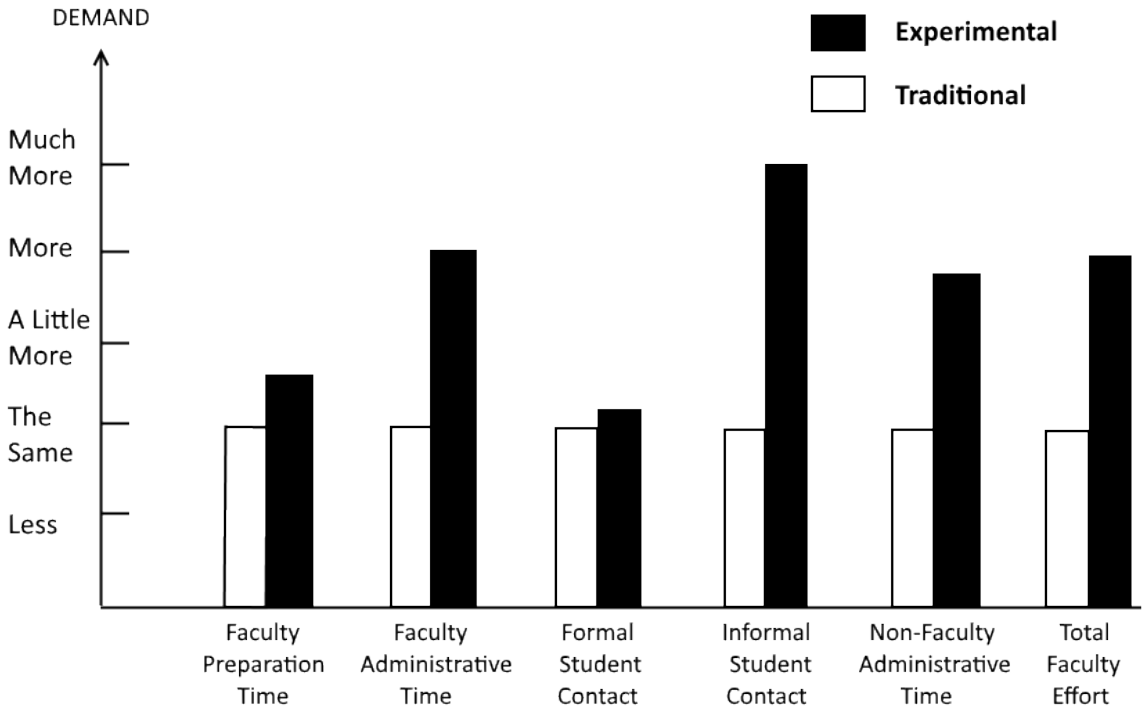
- **Step 4:** Where students and study leaders have a good matching, students are invited to present their work to the study leader more personally, and in the same sessions students that were not assigned have the opportunity to change their choices as well as go on to challenges that will allow them to sharpen their skills and applications in preparation for the next round. In the following round students can still apply to a study leader that black balled them in a previous round.
- **Step 5:** Step 3 and 4 are repeated up to five times. Students are given, in this time, intensive support in the form of writing centre support and feedback from the module coordinator on the most common errors and how to rectify them.
- **Step 6:** The module coordinator is given a report on the recommended allocation with a stability level indicated during each of the iterations.

8.2.1 Players

The second version of the Tender Game was a much greater success than the first for a variety of reasons that will be delved into deeply in Chapter 9, but the main take away for the researcher was that adding autonomy to ALL players is critical to have the highest level of success. Dutson showed in [12] that one of the problems with capstone projects was getting faculty involved. Supervising is a frequently thankless job that requires a great deal of input, and if forced, there can be resistance to any processes proposed. By

giving autonomy, a greater buy in can be gained from study leaders. Figure 8.3 shows the time demands placed on study leaders according to Dutson.

Figure 8.3: Time Demands of Experiential Programs Compared to Traditional Curricula [12]



In changing the approach to the Tender Game, not only was there an increase in the autonomy of study leaders and students in the system, but by applying to a study leader that can supervise eight students at a time it automatically meant that the number of datapoints needed for a preference as established in Section 6.3.2 can be reached easily as each application now represents eight preferences - one for each of the study leader's slots.

8.2.2 How Many Elements Make a Game

This idea will be explored a great deal in the final reflection chapter, but it is worth posing the question here. From a Gamification perspective, the Tender Game in its final form had minimal game elements attached to it. When the project initially started students were enthusiastic, but in the participatory design session following the 2017 iteration it was expressed that students did not want the social aspect of the game to play such a role in the allocation of projects. They are under sufficient stress due to all of the uncertainty that the social pressure to be "popular" was not a positive side effect of the system. As a DSR approach was followed, it was very easy to pivot the system to a less gamified version that then ultimately gave a very favourable result. It

is interesting to note however that game elements are not always positive, and this is critical to review when designing a system of this nature.

8.3 Architecture Updates

Single sign-on through federation turned out to be a less than useful feature since the system runs in parallel to the academic year, but needs to allow and dis-allow students separately from the official registration state of students. For example, in 2018, a registration issue arose where a number of students could not register for the module initially due to financial reasons, but were allowed to continue as if registered. Should Blackboard registration have been used as the single version of the truth, this would not have been possible. To compensate for this the admin dashboard was updated to allow for the bulk registration of lists of students or study leaders so the information need not be synchronised with the official registration process.

8.4 Results and Feedback

As this was the final prototype of the system, many of the results obtained and feedback given are of a summative nature.

8.4.1 Feedback and Participatory Design Sessions

A final participatory design session was held with students in May 2018 to establish whether the system did in fact achieve the intended outcomes. This session was focussed more on getting feedback from students as to whether the goals of the system were achieved, rather than getting a list of features that would be added to the following iteration as this was the final prototype of the system.

8.4.2 Participatory Design Session

The small group interview process was again used for the participatory design session with the main take-aways from the session captured as follows:

- Students would like more active supervision. This is a difficult point to bring up however, as from study leaders the feeling was that students should be able to work more independently. Although the focus was to try and understand the system and how it can support students, it was a very common theme in all of the interactions with students. The best way to overcome this, in the author's opinion, is to grow the challenges to a point where students do not need guidance only from their study leader, but can rather on their own time upskill through alternative developmental tasks.

- Students enjoyed being able to select their own project in the second version of the allocation system, but they felt that doing it this way meant some students took on much more challenging projects than others. The author would like to see this as a good thing however as it meant that the students who deliberately pitched tough projects got the maximum value out of the project. It was the study leaders' responsibility to ensure the scope of the projects did not extend beyond what would be expected from a capstone project, but it was still the case that there was a wide array of projects in terms of complexity.
- Students preferred proposing their own projects, but would have liked if there were more sessions up front to guide them in what kinds of projects they should be creating. This is where the challenge system would fit the role perfectly, but would require more input from previous students and study leaders to create a full bank of challenges. This could also be rectified by presenting more guiding lectures before the allocation of projects takes place.

The above feelings were not universal however, to put forward a quote from a student that experienced the higher level of autonomy negatively:

> Having an idea and implementing it are two different things. The project leaders must warn us about the feasibility of our ideas. I really had no idea what I was signing up for, and I regret my choice. I would have really appreciated project ideas from my project leader, what way he/she would have been of much more assistance. Honestly feel like I am in this alone.

Problems like the above are not easily solvable in a system like this, as different study leaders approached the requirements from students applying to them differently. There were some that wanted students to already come with a fully formed idea for a project, and others that preferred students to do some challenges, and then come with an interest in a specific area rather than a particular project. In the above student's case, he passionately wanted a project, and then when he got what he asked for felt it was too much. In future work it would be interesting to define a protocol for study leaders to present to their students throughout the year a small questionnaire that tests for these sorts of situations. Study leaders all ensured that the work being done was at the appropriate level, but as pointed out by another student:

> "I felt that projects chosen by students aren't always on the same level. I believe that deadlines are important to follow because not everybody is committed when there aren't any deadlines. Maybe a bit more leniency on the deadlines."

This approach was seen as appropriate by the research team and specifically the module coordinator however as, in principle, all of the projects that were undertaken should have been doable by any one of the students in the class. The goal was to ensure students get the most autonomy in choosing their project and getting what they want most effectively, but it cannot account for "buyer's remorse".

Parts that weren't addressed also came up frequently in the discussions. This is partially the goal of the challenge based system, but it is worth documenting the requests here for posterity:

> "Before doing project in final year, in previous years there were no guidelines or small assignments or small research projects that can be done so that we don't feel like this is a totally new thing to us when we get to the fourth year."
>
> "Practical work is most challenging, ie converting theory to practice."
>
> "Building of the systems, it is quite difficult when you have never done any previous project before finding relevant information specific to your project is also challenging."
>
> "If the course has something related to sports."
>
> "There should also be topics that are easy."[15]
>
> "Please try to make a game that will show interest of the learner in a particular field."
>
> "Create simpler games that could be given before the real game so that students could prepare more. Like exercises for the online laboratory."
>
> "Do more research on the kinds of games students like and try to improve on it to make it more interesting in this way."

Overall, the system itself was very well received, but students raised a number of points that relate to the kind of feedback they were given from study leaders. From this process it was clear to the author that a larger dialogue was needed to ensure that the students and study leaders could reach agreement on individual work much earlier in the degree process than in the capstone project at the end of the degree.

8.4.3 Situational Motivation Scale

The SIMS was again presented to students during a participatory design session in May 2018 (n = 7) with results obtained as in Table 8.22. As in the previous design session, the recommended group size of three to 16 participants with one to two facilitators as best practice put forward by the Mozilla foundation was adhered to [118]. From the data obtained it was clear that participants felt a high level of intrinsic motivation to participate in the participatory design sessions.

[15] This came up more than once but would be impossible to implement as it is in direct contradiction to the stated aims of a capstone project course.

Table 8.22: SIMS Results for the Participatory Design Session May 2018 (n=7)

	Average	Median	Max
Intrinsic motivation	20.9	21	/28
Identified regulation	22	26	/28
External regulation	15.6	15	/28
Amotivation	8.7	7	/28

8.4.4 Intrinsic Motivation Inventory

In addition to using the SIMS questionnaire, the IMI was also employed to determine the level of intrinsic motivation students experienced when using this final prototype of the system. The IMI was presented to students twice with regards to the Tender Game, once soon after the implementation of the second round in May 2018 (n=7), and once some time after allocation as a cross check in August 2018 (n=19) with results captured in Table 8.23 and Table 8.24. For the first round the IMI was presented to the students that participated in the participatory design session and in the second round convenience sampling was used by presenting the students with the questionnaire and an open ended comment form in class and allowing them to anonymously hand in their feedback.

Table 8.23: IMI for the Tender Game Allocations May 2018 (n =7)

	Average	Median	Max
Interest/Enjoyment	30.1	29	/49
Perceived Competence	20.1	20	/35
Perceived Choice	20.6	19	/35
Pressure/Tension	22.1	20.5	/35

Table 8.24: IMI For the Tender Game Allocations August 2018 (n=19)

	Average	Median	Max
Interest/Enjoyment	34.5	32	/49
Perceived Competence	22.8	24	/35
Perceived Choice	20.7	21.5	/35
Pressure/Tension	22.9	23.5	/35

The data was interpreted as being positive in both the May 2018 and August 2018 implementations, with the slight increase in the interested/enjoyment and perceived competence scales being attributed to students experiencing more competence due to being further into their projects and having more time to reflect on things. The level of choice and pressure experienced remained the time over time.

8.4.5 General Questionnaire

The general questionnaire was presented to participants in the participatory design session in May 2018 (n=7) responses and August 2018 to the general student body (n=19) responses for correlation. Respondents were all students currently enrolled in the capstone project module to get their feedback not only on the Gamification applied in the current module, but also more generally their views on whether game based interventions have a place in engineering education. Results of the questionaires received back are in Table 8.25 and Table 8.26 respectively.

Table 8.25: General Questionaire May 2018 (n=7)

	Average	Median
Do you think a gameful approach to coursework will help students in their courses?	1.7	2
Do you think projects in this course are of a high level of quality?	2	2
Do you think UJ is offering students the opportunity to work on projects that are relevant to the SA context?	1.9	2
Could university coursework also have an element of fun to it?	2	2
Do you think that gamifying coursework would dilute it?	3	3
What sorts of games do you enjoy playing most? (game genres most selected)	Sports Games (5) Strategy Games (3)	

1:Strongly Agree, 2:Agree, 3:Neutral, 4:Disagree, 5:Strongly Disagree

The general questionnaire showed conclusively that students did indeed agree with the idea that gameful approaches can work in the engineering education context, and they did seem to feel that coursework could be made fun. Whether the gameful approach will dilute the coursework they seemed to be neutral on this statement, which does also reflect the results found in the literature. In terms of the selected game genre's that students enjoyed playing the clear winners seemed to be sport games and strategy games. This information can be used by designers hoping to implement Serious Games in the field in the future to give a more appropriate style of game to students. In another module at UJ the adventure game approach has already been implemented and has found positive results [34] [35].

8.4.6 Field Trials

Two field trials were held to test the final versions of the Tender Game and challenge system respectively.

Table 8.26: General Questionaire August 2018 (n=19)

	Average	Median
Do you think a gameful approach to coursework will help students in their courses?	2.2	2
Do you think projects in this course are of a high level of quality?	2.1	2
Do you think UJ is offering students the opportunity to work on projects that are relevant to the SA context?	2.1	2
Could university coursework also have an element of fun to it?	1.8	2
Do you think that gamifying coursework would dilute it?	3	3
What sorts of games do you enjoy playing most? (game genres most selected)	Adventure Games (7) Board Games (7) Sports Games (6) Strategy Games (6)	

1:Strongly Agree, 2:Agree, 3:Neutral, 4:Disagree, 5:Strongly Disagree

Field Trial: Tender Game

The final Tender Game field trial was held between February and March of 2018. With the updated approach a 100% adoption rate was obtained from both students and study leaders on the process. The allocations obtained with three iterations of the matching system can be seen in Table 8.27. Between the first and second iteration a number of students that registered late were added to the system, hence the number of students going into the second iteration being higher than the roll over number. The final roll over was for 12 students that could be given individual attention as they did not seem to understand what the study leaders they were applying to wanted. For the majority of students the problem was that they simply handed in a few sentences (or nothing at all) repeatedly. The second version of the game worked significantly better than the first and the results seemed to meet with the expectations that were set. As there was now a dedicated way that interaction could be integrated into the system it also meant there was a lot more back and forth between students and study leaders which was taken as a very positive result.

Table 8.27: Statistics on Allocations 2018

	Student Preference				
	1st	2nd	3rd	4th	rolled over
Iteration 1	68	22	13	6	29
Iteration 2	16	4	6	5	13
Iteration 3	1	1	0	1	12

Field Trial: The Challenge System

The Challenge System again went live along with the Tender Game in February 2018. The Challenge System was introduced to give a parallel education stream that students can use both as a way to increase the resilience of their skills as well as to create a portfolio of knowledge that they can use to convince a study leader in the 2018 version of the Tender Game that they have sufficient skill/interest in a specific study area to complete a project in that area.

The Challenge System was used twice in 2017 and 2018 respectively with the main differentiator being that in 2017 study leaders needed to submit challenges to the module coordinator to be approved before they could be added to the system. An additional 12 challenges were created in 2018, and although many students attempted challenges only 15 successful challenge logs were approved in 2018.

The results in the Challenge System were the most dissapointing to the author, as from the literature this would appear to be the section that is the most likely to actually have the strongest impact to learning as opposed to the structural Gamification in the other parts of the system. The 2018 results were a lot more encouraging and correlate with the idea that more autonomy for study leaders leads to a much higher level of adoption. The advantage however of the Challenge System is that it is the easiest to roll over till the following year so an archive of challenges is something that can be built over time.

As described in Chapter 4, the design of the challenge based game was based on the Habitica approach to content gamification. In exploring the different versions however, it became clear to the author that although the principle is good, it does still place a lot of the work on the side of the study leaders and module coordinators. It also misses out on the opportunity for students to actually create their own challenges in the form of things that they did that they felt were beneficial to their own learning. It would be worth exploring in the future if it is simply more productive to create a Habitica guild[16] as opposed to maintaining the challenges on the system.

8.4.7 Expert Reviews

As this was the final prototype of the system the expert reviews relating to the system had as much content relating to this system as it had relating to where the project can go from here and what other changes and features can be added to the system or to other systems based on this work. The main points raised were related to the study of interactions between study leaders and students. It was useful to study interactions during the LBG, but as the students spent all year with their study leader it became clear that a more formal study of the time spent and interactions between study leaders and students would yield useful information. A second project based on this principle has already commenced. What came out from not only the implementation of the LBG on the project day but also from the expert analysis is that even if the Gamification

[16]Guilds are a feature in Habitica that allow users to create a common set of daily habits or goals that are shared by a community

aspect is removed completely from the system, simply having a project day app that indicates what can be seen by participants seems to add a lot of value to the users. In future work it will be explored whether this approach actually benefits the participants more or less by creating a parallel track of gamified vs non-gamified apps to be released at a conference or project day simultaneously to quantifiably measure the effect of the gamification elements individually.

8.4.8 Personal Reflection

The final prototype brought about the opportunity to reflect more on the overall success of the project and to finally test the intrinsic motivation that was generated. At this point all of the underlying parts had reached a level of maturity and could be deployed independently. At this point the author was content with the work that was done, and the results showed that there was indeed a positive impact brought about in the deploying the system to the context. The results seemed to reflect what was found in the literature where students did find a level of intrinsic motivation was generated in interacting with the system which was what was hoped by the author to be the case. What did come about however in doing this project and comparing with the literature is that there is a critical need for randomized control studies where similar users are used from different contexts to compare how well the gamification elements themselves bring about specific results. It is the author's belief that these elements bring only a portion of the value and that the greater level of autonomy brought about the greatest effect, but without a control group this is a difficult claim to make. What has also become clear is that many gamification studies claim full engagement with the gamified content in a less than honest way - ie. content gets gamified but students have little opportunity to opt out of the system, creating the illusion of 100% engagement when the numbers would be very different had there been an easy way to achieve the same goals without interacting with the gamified content.

Being able to place a stake in the ground however and call the project "done" was harder than anticipated as there were still components that the author would have liked to tweak to make the system better, but this is part of the nature of a DSR study in that the constraints of time and funding set the boundaries of the project naturally. This was simplified by collaborating with another researcher who was taking over the reigns to test a slightly different approach which meant it could end more naturally. The summative results from the IMI were positive and the author hopes that they show not only the potential but the concrete benefits that were gained from the system.

The main gaps in the literature that the author would point to relate to exploring the engagement and intrinsic motivation experienced by faculty in creating learning experiences for students in capstone project modules. If this was found from literature earlier in the project it would possibly have changed parts of the design by adding more faculty focussed interventions. It is left now to future researchers as well as future projects by this researcher to explore that area in much more detail.

Chapter 9 - Reflections and Conclusions

9.1 Introduction

In this final chapter a summative assessment is done of the research, and the final conclusions are brought forward as they relate to the research questions and hypothesis highlighted at the start of the project. As a Design Science Research (DSR) approach was followed all the way through, this chapter contains not only reflections on the project itself, but also the reflections on parts of the project as they came up during the creation of the artefact and comments and recommendations that can be rolled back into professional practice are presented. In this chapter I will switch to using I instead of "the author" simply because these reflections are more free form in nature and will include a great deal of information that is a personal and professional opinion rather than descriptions of work done.

At the start of this project I had the idea that Gamification would be an appropriate tool to increase the engagement of engineering students as it was raised as a concern by the module coordinator of Project Investigation IV. It was not my first foray into Gamification or the creation of games or enterprise software, and it was a really great experience in many ways to combine a number of my professional and hobbyist skills into one overarching project. In terms of whether the project was a success or not, the first thing to consider would be whether the research questions posed at the start of the project were sufficiently answered.

As the project was undertaken in a wider context, it is also worth reflecting on the methodology of DSR as it was used and experienced, as this reflection on practice is what can bring about new knowledge in the field. A reflection step is also integrally linked with the methodology.

After presenting my reflections I will put forward what I believe my contributions are to the larger body of knowledge and make recommendations as to what I believe future researchers should take into account when attempting a similar project.

As these reflections are my own, they are open to my own biases[17], but I believe this chapter will contain the useful knowledge I have gained throughout the study that I hope will help future practitioners avoid some of the pitfalls I was confronted by.

[17] A large part of this work was undertaken with the idea that if students are given better opportunities and interventions they will have greater levels of success. I also changed from being completely convinced of the benefits of gamification at the start of the project to now being more of the opinion that it is great in some instances but less useful in others.

9.2 Reflections on the Project

At the start of the project, the main concerns were the lack of student engagement put forward by study leaders and the issues put forward by students that they experienced as problems in the module were:

- A lack of input was taken from students in the assignment of projects,
- A lack of transparency in the assignment of projects was perceived and
- The assignments finally arrived at were deemed to be not ideal, due in part to the very manual process followed by the module coordinator.

In attempting to overcome these problems and to study the impact of gamification and what impact it can have on students, the artefact was developed over a number of iterations with the following design hypothesis in place:

- **Design Hypothesis 1:** Students will welcome the addition of gamification elements in the module and creating such a system would lead to higher levels of interaction between students, study leaders and external stakeholders.
- **Design Hypothesis 2:** Designing the system with SDT principles in mind will increase the levels of motivation felt by students towards their projects and enrich the student experience.
- **Design Hypothesis 3:** Designing the system intervention with authentic learning experiences in mind will enrich the student experience.
- **Design Hypothesis 4:** Drawing from the literature there would be a suitable solution found for the student project allocation problem that could be presented in a transparent, collaborative and fair way.

The following research questions were also asked and answered through the creation and application of the artefact:

- **Research Question 1:** What is the overall effect of the created intervention on student success? Does enriching the experience ultimately lead to a higher level of student success?
- **Research Question 2:** The student project allocation problem is a known problem faced in capstone modules. In using an algorithmic approach to solving the problem, how much data is actually required to reach a suitable assignment given a number of students?

With these design hypothesis in place and the research questions stated the following research goals were put forward:

- **Research Goal 1:** Solve the problems put forward by students and study leaders that are known to exist at the start of the study with regards to the fair and transparent allocation of projects, as well as to give students a voice to indicate their preferences with regards to this allocation.
- **Research Goal 2:** To create an artefact that will foster interaction and motivation in students to enrich their learning experience and lead to greater success.
- **Research Goal 3:** To document the design process used in such a way as to allow other researchers to gain value from the lessons learned.

Each of these design hypothesis and research questions will now be discussed along with an overall evaluation of the research goals.

9.2.1 Design Hypothesis 1

> *"Students will welcome the addition of gamification elements in the module and creating such a system would lead to higher levels of interaction between students, study leaders and external stakeholders."*

From all of the questionnaires and participatory design sessions and feedback received throughout the course of the project the addition of Gamification elements were very well received by students. What was not initially part of the research questions set out at the start of the project was the way in which ALL stakeholders would perceive the work done. Study leaders in the first year were not as positive about the project and the main reason for that seemed to be that they did not see a benefit to the overall process other than to students only. There was a bit of a feeling that we would be babying students too much as the capstone project was seen as a very serious affair (which in all fairness it is). The big turnaround came when study leaders and students could both give an active input into the way in which the projects were allocated during the tender game. In viewing the project time line in the way it was designed with the student travelling from student to journeyman to candidate, it meant that to actually Gamify the system it would first need to be seen in terms of the time line, and as such different levels of attention could be given to the needs of the students at different times. Making this a part of the design process turned out to be a very useful decision. In the literature the question is asked whether Gamification is simply "chocolate coated broccoli" [40] and in many ways I now see why this accusation is often presented. I believe that through the project it has been shown that there is value in breaking down the process into its component mechanics as one would for any game, and then viewing it through the different lenses that were presented in Chapter 2.

The level of study leader and student interaction was not only higher for the second version of the tender game (as study leaders and students now have to collaborate even before allocation), but I would suggest that it is a better type of interaction. Students that apply to multiple study leaders have the opportunity to interact with every one of the study leaders they have applied to before allocation giving a wider perspective on the work being undertaken in their capstone project once allocated.

9.2.2 Design Hypothesis 2

> *"Designing the system with SDT principles in mind will increase the levels of motivation felt by students towards their projects and enrich the student experience."*

From the feedback received it would appear that the project has met its goal of increasing engagement and motivation in students. The focus on autonomy was an important driver in conjunction with the Tender Game for the allocation. I believe that it is the double hook though that gets students interested - Gamification is a good way to get them actively engaged and thinking about what they need to present and gives them a target to aim for, but giving stakeholders autonomy, a platform to show off their mastery and a community to interact with brings about a much better experience. Self-Determination Theory and the five layers of abstraction gave a better understanding of how to implement the system, as well as how to understand the process as a whole.

Based on the feedback received during the participatory design sessions and the application of the IMI and SIMS instruments it did indeed seem to be the case that students experienced a high level of intrinsic motivation to participate in design sessions and that the system did generate a level of motivation in students to engage with their projects. That said, data did not exist for the previous academic years measuring the level of motivation experienced by students so it is difficult to measure the change in the level of motivation experienced by students empirically. From the literature however it is clear that a focus on SDT principles will lead to a higher level of motivation experienced. In no place is this shown to be true more clearly than in the change in adoption rates when additional actions were added for study leaders to perform. Allowing them to create their own challenges, actively partake in the tender game in the second version and allowing them to set up their own profile pages took the adoption rate from 40% to 100%.

9.2.3 Design Hypothesis 3

> *"Designing the system intervention with authentic learning experiences in mind will enrich the student experience."*

Authentic learning was another principle that was used to guide the design of the system and although difficult to measure as to the impact in isolation, by focussing on the kinds of activities students would have to do when they enter into practice as engineers allowed for experiences to be created that could foster interaction and hopefully lead to an increase in the level of intrinsic motivation that students experience, which did seem to be the case from the feedback obtained through the participatory design sessions and the application of the IMI, SIMS and questionnaire.

By conceptualizing the journey the student goes through in the academic year, it allowed for the system to be designed in such a way as to support the students with the right intervention at the right time while also creating experiences that reflect what

they would experience in practice in the future. The Tender game in its two different versions also reflected two different kinds of authentic experiences, both of which were well received. In future work it would however also be useful to allow students to translate their applications into more concrete portfolios continuously throughout the year so that those become valuable documents in their own right that can be used in their search for a job after they graduate. For the students the adoption rates were high from the start, but there was a notable difference in the adoption rate between the first and second versions of the tender game. In the first version projects were designed by study leaders and the students had to tender for them, but eight students chose to not participate in order to make their own projects themselves. In the second version students could design everything themselves and apply to as many study leaders with their ideas as they wanted leading to full adoption. This is however one place where caution is advised in analysing the adoption rates. In the first version there was a benefit in students suggesting their own project as they would simply get it if approved by the committee. In the second version there was no additional benefit to non-participation as all students got a project they proposed.

All in all, creating authentic experiences that also encouraged interaction between stakeholders through the design approach taken seemed to enrich the experience for students through the full academic year.

9.2.4 Design Hypothesis 4

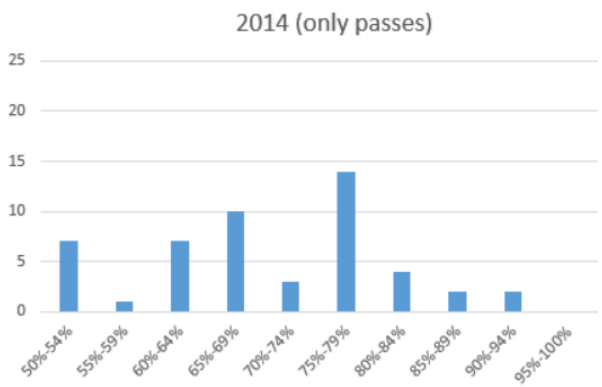
> *"Drawing from the literature there would be a suitable solution found for the student project allocation problem that could be presented in a transparent, collaborative and fair way. ."*

As was seen in the literature review the student project allocation problem is a well studied problem that can be approached in a number of different ways. The application of the Gale-Shapley algorithm found in the literature filled the need for a technique that would allow for a transparent and fair way to allocate projects to students taking into account the preferences of both students and study leaders.

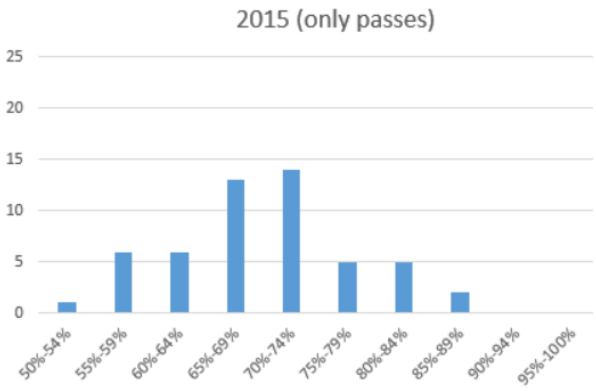
9.2.5 Research Question 1

> *"What is the overall effect of the created intervention on student success? Does enriching the experience ultimately lead to a higher level of student success?."*

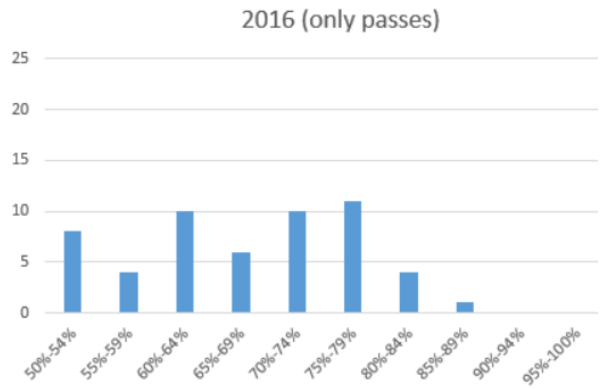
Although the goal was to enrich the experience for students, there is also an expectation that students with a better experience would have a better chance at success. Capstone projects however are more complex to evaluate than assessments in coursework modules. This was further complicated by the fact that student failure was not handled consistently through the various years that the module was presented, in that in some years a student would be capped at a minimum value of 40% if they only failed



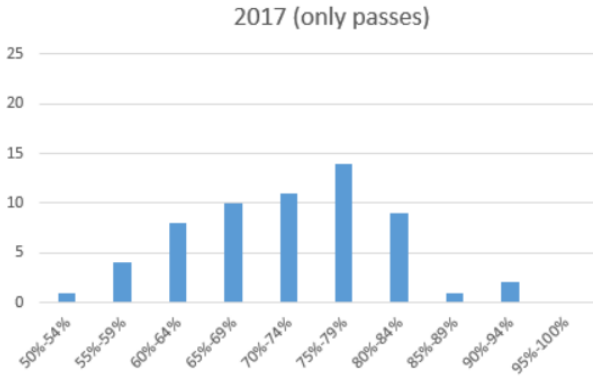
(a) 2014



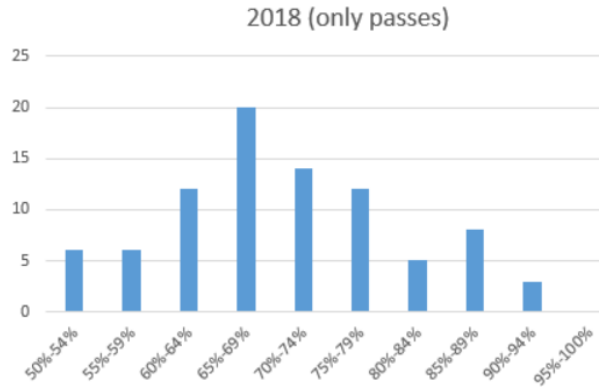
(b) 2015



(c) 2016



(d) 2017



(e) 2018

Figure 9.1: Marks for passing students 2014-2018

one of the outcomes of the modules but in other years not. This meant that the average value of the whole class could not be compared. To overcome this, only the success of students that passed the course were compared across the academic years of 2014 - 2018. This way, the inconsistent failure marks would not impact the comparisons, and it would allow for the measurement of the amount of success experienced by students.

Marks obtained by passing students are presented in bar charts in Figure 9.1. Descriptive statistics of the marks obtained by students are available in Table 9.28. The full system was made available to students in the 2017 and 2018 academic years, and although the students had access to the location based game in 2016, it would have no impact on their marks as it was added right at the end once all work had completed. From the averages it would appear that the two years in which the system was in place for the full year had better results than any of the previous years without the system in place, but in order to measure the actual impact of the system and whether it was statistically valid two techniques are used, Welch's t-statistic [140] and Cohen's d [141].

	Average	Median	Standard Deviation
2014	68.9%	69%	10.8%
2015	69%	68.9%	7.9%
2016	66.9%	67%	9.6%
2017	71.5%	67.5%	9.1%
2018	69.8%	68.5%	10%

Table 9.28: Descriptive statistics for passing students 2014-2018

Welch's t-statistic is an alternative to the student's t-test that tests two samples assuming unequal variances, where the sample size for the two groups can also differ. Using this technique the t-test is performed for each of the years in the control group compared to each of the years in the test group. For Welch's t statistic [140], the following equations are used:

m_A = Mean marks obtained by passing students in control year
m_B = Mean marks obtained by passing students in test year
SD_A = Standard deviation of marks in control year
SD_B = Standard deviation of marks in test year
n_A = number of students in control year
n_B = number of students in test year
df = degrees of freedom

$$t = \frac{m_A - m_B}{\sqrt{\frac{SD_A^2}{n_A} + \frac{SD_B^2}{n_B}}} \tag{9.8}$$

$$df = (\frac{SD_A^2}{n_A} + \frac{SD_B^2}{n_B})^2 / (\frac{SD_A^4}{n_A^2(n_A - 1)} + \frac{SD_B^4}{n_B^2(n_B - 1)}) \tag{9.9}$$

Interpreting Welch's t-statistic requires that the absolute calculated t value needs to be higher than a critical value that is taken from a t-table, but in this instance the

calculations were done using Excel 2016 with the Data Analysis Toolpak which calculates the critical value automatically. Welch's t-statistic calculates the statistical significance of the difference between the two groups being compared, but even if a difference is statistically significant, its effect may not be significant. To calculate the effect size Cohen's d is used. Cohen's d will measure the effect size comparing two groups in terms of the difference in their average value expressed as a multiple of the pooled standard deviation. The equation used for Cohen's d is [141]:

m_A = Mean marks obtained by passing students in control year
m_B = Mean marks obtained by passing students in test year
Var_A = Variance in the control year
Var_B = Variance in the test year

$$d = \frac{m_A - m_B}{SD_{pooled}} \tag{9.10}$$

$$SD_{pooled} = \sqrt{\frac{Var_A + Var_B}{2}} \tag{9.11}$$

To interpret Cohen's d, the following ranges of values are interpreted to indicate the level of impact of an intervention between the two groups:

- ≤ 0.2 - trivial effect (even if statistically significant)
- > 0.2 - small effect
- > 0.5 - moderate effect
- > 0.8 - large effect

These effect levels are merely guidelines however and although used widely, they are merely that, guidelines. Tables 9.29, 9.30 and 9.31 present both the statistical significance, as well as the Cohen's d value for each of the years being compared.

	2014	2017	2014	2018
Mean	68.94	71.521	68.94	69.797
Variance	119.527	84.248	119.527	102.008
Observations	50	60	50	86
degrees of freedom	96		96	
t Critical one-tail	1.661		1.661	
t Stat	-1.325		-0.453	
P(T<=t) one-tail	0.094		0.325	
Cohen's d	0.256		0.081	

Table 9.29: Statistical significance and effect size 2014 vs 2017/2018

As can be seen from the results, the impact was always positive, but in some instances not statistically significantly so. Table 9.32 shows a summary of the results in Tables

	2015	2017	2015	2018
Mean	69.005	71.521	69.005	69.797
Variance	63.931	84.248	63.931	102.008
Observations	52	60	52	86
degrees of freedom	110		126	
t Critical one-tail	1.659		1.657	
t Stat	-1.551		-0.509	
P(T<=t) one-tail	0.062		0.306	
Cohen's d	0.292		0.087	

Table 9.30: Statistical significance and effect size 2015 vs 2017/2018

	2016	2017	2016	2018
Mean	66.936	71.521	66.936	69.797
Variance	94.754	84.248	94.754	102.008
Observations	54	60	54	86
degrees of freedom	109		116	
t Critical one-tail	1.659		1.658	
t Stat	-2.58		-1.668	
P(T<=t) one-tail	0.006		0.049	
Cohen's d	0.485		0.288	

Table 9.31: Statistical significance and effect size 2016 vs 2017/2018

9.29 to 9.31, and indicates in colour the level of statistical significance and Cohen's d for all of the compared years. Statistical significance is compared at 5% and 10% but anything more than 10% is considered not significant. From this it can be seen that the system's impact in 2017 was a statistically significant increase in results, as well as a definite small impact measured against all years. 2018 was not as convincing a result however, as it is only when compared to 2016 that a statistically significant result and a small effect is measured. This however is explainable by the fact that in the middle of the 2018 academic year three study leaders resigned within a single month, leaving a number of students stranded. New study leaders were elected for the students, but as this was a significant disruption it can be expected that there would be an impact on the results as well.

Taking into account the event described above, it was still very encouraging to see that the marks were still better than in previous years, and with the analysis done it is proposed that the system did indeed leave a positive impression on students and lead to a higher level of success. This can only be improved however and there are definitely opportunities through refinement of the challenge system and more opportunities to encourage engagement, motivation and interaction to further increase these gains. This is also however where there is a benefit in using the DSR methodology, as there is always the opportunity for another iteration of the work.

p	2017	2018
2014	0.094	0.325
2015	0.062	0.306
2016	0.006	0.049

Cohen's d	2017	2018
2014	0.256	0.081
2015	0.292	0.087
2016	0.485	0.288

p >(a = 0.1)
p <(a = 0.1)
p <(a = 0.05)

<0.2 (trivial)
>0.2 (small)
>0.5 (medium)
>0.8 (large)

Table 9.32: Summary of statistical significance and effect size

9.2.6 Research Question 2

> *"The student project allocation problem is a known problem faced in capstone modules. In using an algorithmic approach to solving the problem, how much data is actually required to reach a suitable assignment given a number of students?."*

This research question actually appeared only after the first version of the tender game simply because I was not certain how many tenders were actually required to ensure a good chance for a stable match to occur between students and projects. The simulation was set up to place students within their first 4 choices where preferences were randomly assigned for students and projects. It is worth noting though that this is a random situation where each project and student is deemed equally desirable, as opposed to the real life situation where it is possible and even likely that certain projects and students would be more desirable. As such the simulated values are used as a baseline, rather than a guaranteed match value.

To calculate this baseline value for student matches, Equations 6.1 and 6.2 are used, duplicated here as Equations 9.12 and 9.13. This gives the number of tenders or applications students all need to present for there to be a good chance of a stable match. Exploring this area was an invaluable experience and actually finding that there was in fact a simple formula that could be used was a highlight in this project for me personally. The graphs obtained from the simulations are presented in Figure 6.4 in Chapter 6.

N = Number of elements in each set
$M_{\mu r}$ = Average ranking that will match for students
$W_{\mu r}$ = Average ranking that will match for projects

$$M_{\mu r} = log_{2.55} N - 1 \tag{9.12}$$

$$W_{\mu r} = \frac{N}{5.75} + 1.5 \tag{9.13}$$

The calculated baseline situation was taken into account in the second iteration of the tender game by allocating to each study leader 8 slots that could be filled by students,

instead of individual projects. This meant that for every application a student made to a study leader they would in effect be making 8 applications simultaneously. This lead to a much more effective allocation in the first round, but by giving study leaders the opportunity to reject applications, this did extend the process slightly. In the end there was only a need to run the allocation algorithm three times in 2018 to reach a point of stability. In the end there were still some students left that did not get allocated automatically, but that was because they repeatedly submitted either no documentation or very weak documentation and had to be guided and supported more directly by the course coordinator.

Although the formulas proved useful, it would in the future be useful to explore the concept put forward in one of the expert review sessions that a neural network could be a suitable solution to the problem as well. Although there was not enough real world data to train a neural network, a similar simulation experiment could be set up which could also include situations where certain projects are more desirable than others by creating a custom probability density function. With a sufficient number of training examples a neural network could possibly be created to perform the matching and a comparison to known algorithms for stable matching would make for a valuable addition to the literature on matching algorithms.

9.2.7 Research Goals

Implementing the system using the DSR approach that was followed allowed for all of the goals set out at the start of the project to be achieved. All of the subsystems put in place attempted to address directly the need to increase student engagement as highlighted by study leaders through the use of gamification, authentic learning design and a focus on self determination theory. Additionally, the design of the tender game in both of its versions addressed the needs of students for a fair and transparent allocation system that takes into account their preferences, as well as the preferences of study leaders. By giving students a voice in the allocation process and increasing their autonomy the system designed directly addressed student motivation and also highlighted this concept as an important factor that faculty members should consider during the capstone project module process.

The system that was created fostered interaction between all stakeholders in all phases of the academic year, admittedly with variable success. I still believe that with a larger catalogue of challenges that the challenge system has a lot more potential that can be realised, but the results obtained from the tender game and the location based game were very satisfactory. The system as a whole also served as a good platform for students and faculty members to share their profiles and the projects that they were working on fostering a greater sense of community and purpose. By highlighting the study areas that were represented by all projects it also showed the scope of work that is undertaken in the department.

The DSR process that was used was an effective research approach, but in using it through the course of the project I learned a lot about what can be done better. In the Section 9.3 the lessons learned as well as suggested changes that can be incorporated

into future projects will be discussed in depth and it is hoped that this work will also be published separately to contribute to the knowledge base.

9.2.8 Research Activities

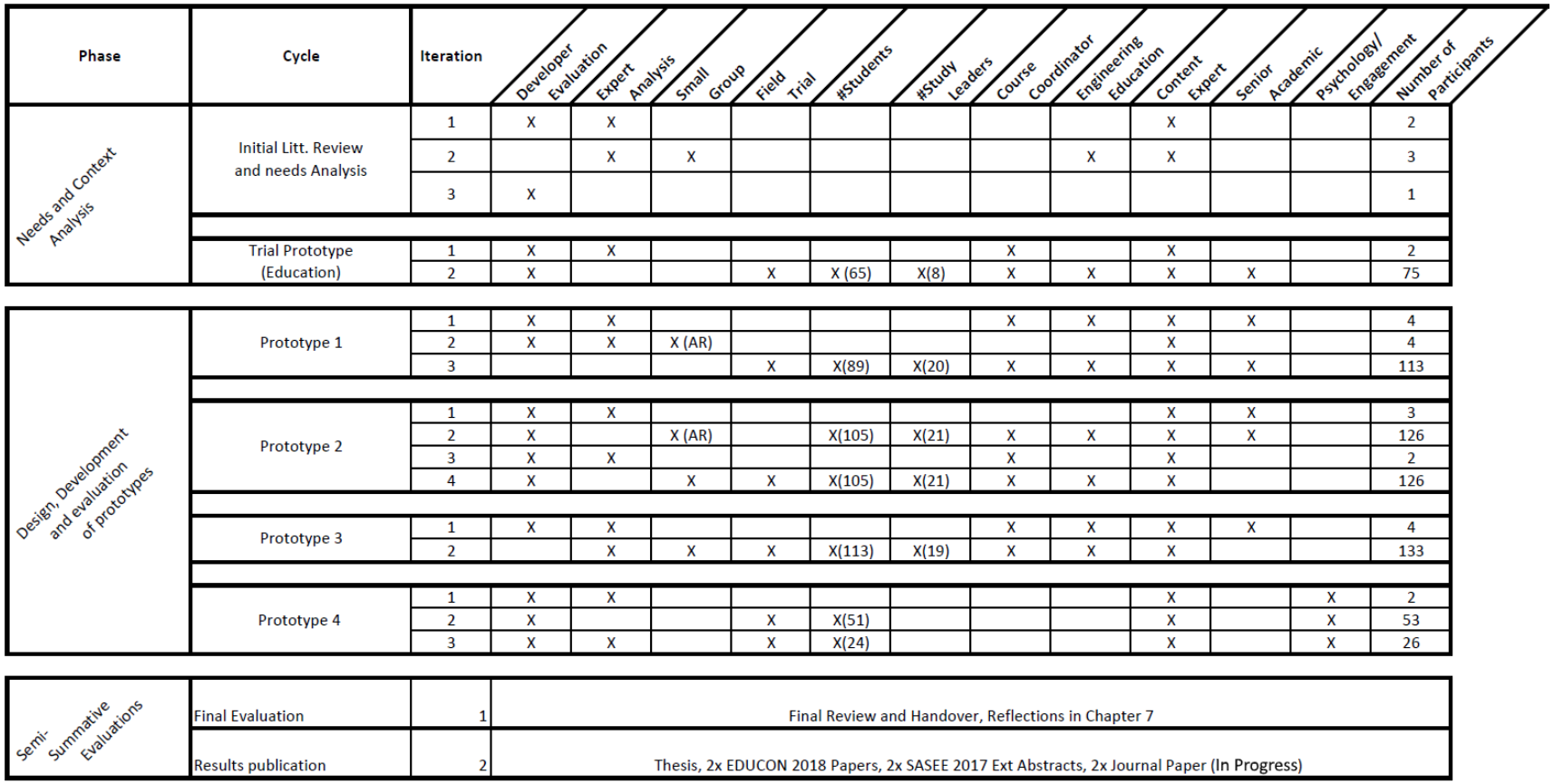
As described in Chapter 3, Nieveen's approach to quality measurement was employed. There were 14 data collection events that happened as described in Table 9.33. Expert analysis was done in between each of these points as well with the author being the main developer and the main team of experts being consulted being his three supervisors, and in seeing if the system can be generalised an expert in engagement from the Department of Psychology at the University of Twente. Research activities done on the project through the life cycle can be seen in Figure 9.2 with the prototype development timeline shown in Figure 9.3.

Table 9.33: Data Collection Points

Collection Date	Data Type	Description
Feb 2017	Quantitative	Results of Tender game V1 allocations
April 2017	Quantitative	Results of challenges V1
May 2017	Quantitative	Test of updated LBG
Nov 2017	Quan/Qual	Group interview, students / study leaders
Nov 2017	Qualitative	Group interview, study leaders only
Nov 2017	Quantitative	Results of LBG V3
Feb 2018	Quantitative	Results of Tender game V2 allocations
April 2018	Quantative	Results of Challenges V2
May 2018	Quan/Qual	Group interviews, students / questionaires
Jun 2018	Expert Review Only	Health By Tech 2018
Sep 2018	Expert Review Only	Narrative Matters 2018
Aug 2018	Quantitative	Final questionaire results

9.3 Reflections on Design Science

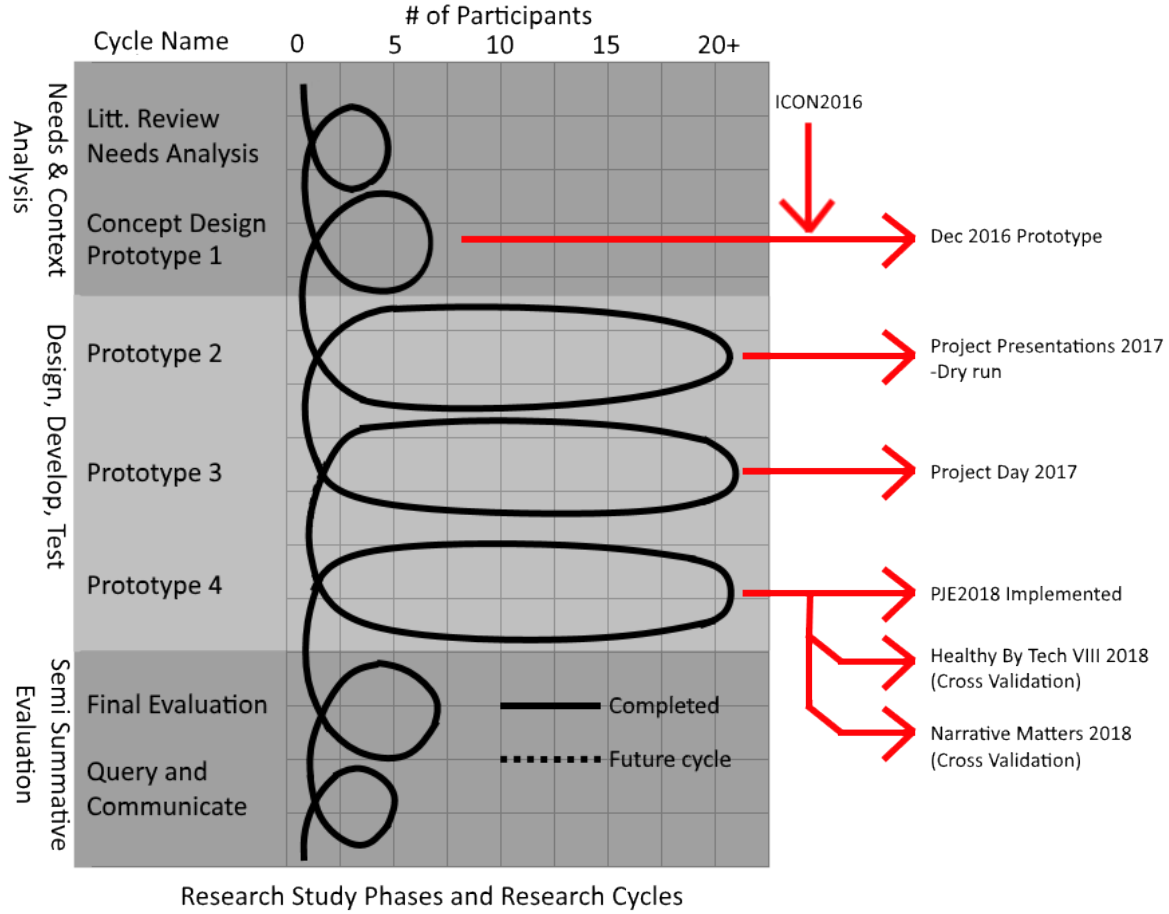
This project was not my first use of the techniques of DSR, but it was the first use for me in the higher education context. This brought about a number of unforeseen challenges that in many ways did make my practice stronger as I feel that some things would have been easier if I had all of the information I now have in hindsight. The two main areas that I think had the most impact are the ethical requirements for doing work in the educational space and the feedback and testing model used in this project. The two issues are quite intertwined and are discussed in the following two subsections.



Phase	Cycle	Iteration	Developer Evaluation	Expert Analysis	Small Group	Field Trial	#Students	#Study Leaders	Course Coordinator	Engineering Education	Content Expert	Senior Academic	Psychology/ Engagement	Number of Participants
Needs and Context Analysis	Initial Litt. Review and needs Analysis	1	X	X							X			2
		2		X	X					X	X			3
		3	X											1
	Trial Prototype (Education)	1	X	X					X		X			2
		2	X			X	X (65)	X(8)	X	X	X	X		75
Design, Development and evaluation of prototypes	Prototype 1	1	X	X					X	X	X	X		4
		2	X	X	X (AR)						X			4
		3				X	X(89)	X(20)	X	X	X	X		113
	Prototype 2	1	X	X							X	X		3
		2	X		X (AR)		X(105)	X(21)	X	X	X	X		126
		3	X	X					X		X			2
		4	X		X	X	X(105)	X(21)	X	X	X			126
	Prototype 3	1	X	X					X	X	X	X		4
		2		X	X	X	X(113)	X(19)	X	X	X			133
	Prototype 4	1	X	X							X		X	2
		2	X			X	X(51)				X		X	53
		3	X	X		X	X(24)				X		X	26
Semi-Summative Evaluations	Final Evaluation	1	Final Review and Handover, Reflections in Chapter 7											
	Results publication	2	Thesis, 2x EDUCON 2018 Papers, 2x SASEE 2017 Ext Abstracts, 2x Journal Paper (In Progress)											

Figure 9.2: Research Activities

Figure 9.3: DSR Study with the Prototype Releases Highlighted



9.3.1 Reflections on Ethics

Design Science Research is at its core concerned with the concept of "emancipation". What it means in this context is elevating one out of a position of lesser ability, access, skill or knowledge to one of higher ability, access, skill or knowledge. When this is the focus, it would be difficult to see any kind of ethical dilemma in employing such a methodology on a population. However, when conducting research with a focus on ethics, there is a need to ensure all interactions with the target population are first scrutinized and evaluated before employed. When used outside of the education sphere much less focus is placed on restricting communication between developers and users which does simplify the process greatly. This is where I feel a better technique needs to be employed in identifying what interactions will be required.

The reason this became apparent, is that I used psychometric instruments, specifically the Intrinsic Motivation Inventory (IMI) and Situational Motivation Scale (SIMS) to gauge the motivation of participants in certain parts of the study to great effect, but I feel that a wider array of testing would have been more beneficial, not only to the project, but also to the participants of the study. I feel it would be useful to map out

the process from start to finish in an idealized way in the hopes that it will help future researchers. The project flow will help an ethics board more easily understand the reason a large number of tests and interactions is requested.

In saying this, whenever there is a combination of social science and technical work, there will always be ethical questions, and in the last year or two this has become a very relevant question in the gamification space due to the sheer extent of it's implementation in places like the Chinese social credit system [142] as well as the work being done to map interactions on all levels of the social space [143]. It is deeply concerning because the lines between Gamification and blatant social control is becoming quite blurry.

9.3.2 A Model for Complete Testing

In order to achieve the goal of mapping up front all of the tests that are needed for a DSR study, a more complete model is required to allow for the test points to be identified. In this study I used the iterative looping approach that was proposed by Mckenny and Van den Akker [3] with the TOGAF approach [10] to create the DSR framework described in Section 3.3. This is a combination of different approaches, all of which are quite high level, specifically so that it may be employed in a variety of contexts. By going into a lower level of process abstraction however, it allows for the test points to be identified and the model can be adapted to more easily fit into the context of an educational study.

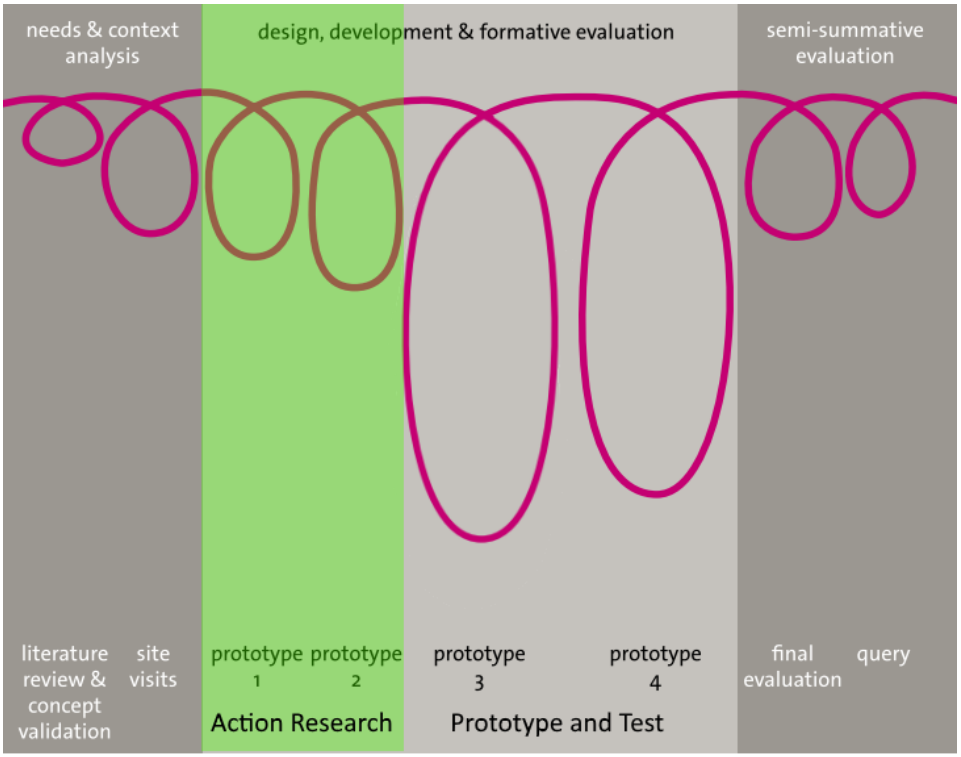


Figure 9.4: DSR Loops with Action Research

To do this, the Mckenny and Van den Akker loop model is flipped upside down as can

be seen in Figure 9.4 and space is identified for action research specifically. This is done so that a smaller number of participants can be identified which will need a higher level of ethical protection as during this phase of the project the researchers will be delving more intensely into their perspectives and problems in order to better inform the rest of the study. This is essential due to the fact that their is a gap between the start of the project where the researchers see what they consider to be a good idea, and what the participants may perceive to be a good idea. From here the TOGAF approach is mapped onto each loop individually as can be seen in Figure 9.5.

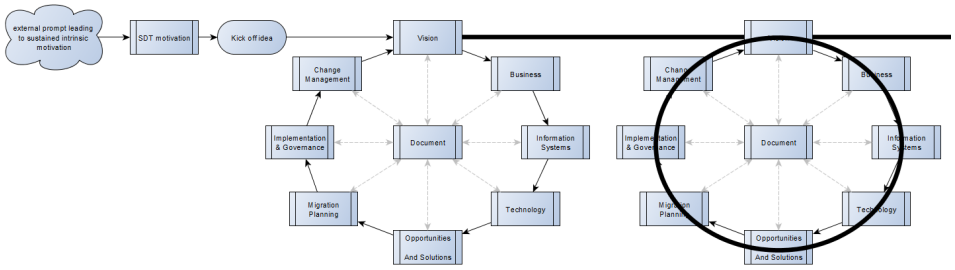


Figure 9.5: The TOGAF Approach in a DSR Loop

Each step in the TOGAF loop need not be followed every time the loop is repeated if it is not required, but when it is done, the step should be followed as an individual research and development cycle as can be seen in Figure 9.6. Depending on whether the step is part of the strategy, motivation and BDAT (Business, Data, Application and Technology) steps, or the implementation and migration steps the output of the research cycle may be part of the software artefact or of the documentation artefacts that go into making the artefact. Each research and development cycle in turn is composed of four steps that are iterated, namely:

1. Problem Analysis: Perform a gap analysis for artefact development, or create a requirements list that can be expanded on for documentation purposes.

2. Design and Prototype: Create the actual documentation or artefact components

3. Data collection and evaluation: Test the interim release of the artefact in question

4. Revision needed decision: If all tests pass then the interim release becomes the stable release

Testing happens predominantly in the design and prototype and data collection and evaluation steps. Figure 9.7 shows the research and development cycle and how it is decomposed into the Agile approach to software development as well as the detailed evaluation process. These are now considered separately.

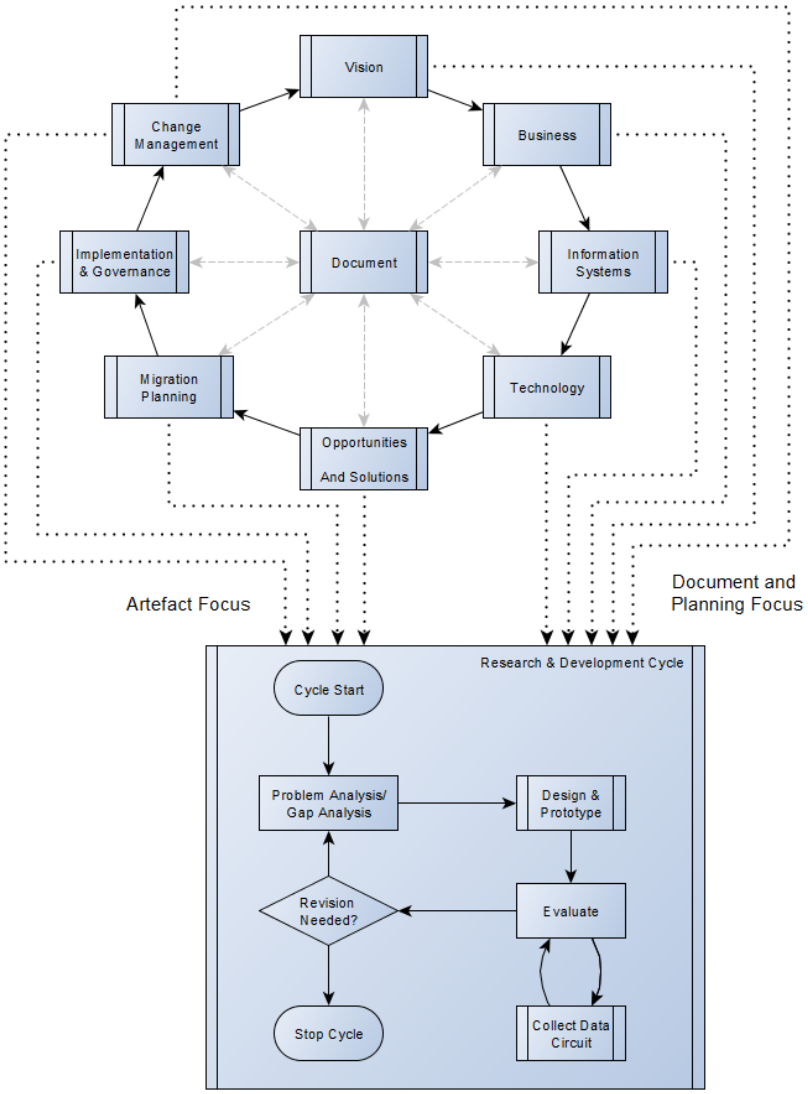


Figure 9.6: The TOGAF Steps as Research and Development Cycles

Testing in the Design and Prototype Step

Agile is a catch all term for a number of approaches that all subscribe to the agile manifesto's core principles of quality software over documentation. In the educational and academic context however, documentation does play a vital role in the overall process and as such the documentation that is created during the project is also seen as an artefact that is created in parallel. In the process being proposed here the Agile software development life cycle (ASDLC) with its sprint based strategy is used along with Kanban style task management. The sprints are also iteratively approached and as such should the required artefact not be completed in a planned sprint it can be rolled over to a following sprint. The four main steps in the ASDLC are:

1. Requirements gathering: break the gap analysis up into actionable tasks

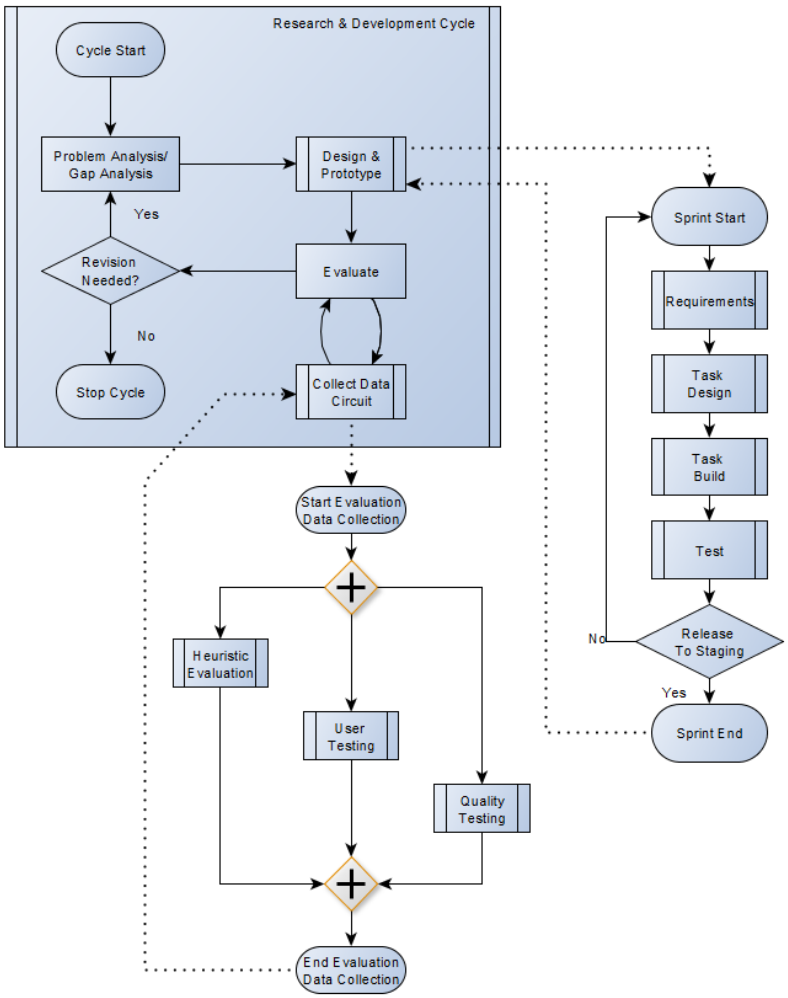


Figure 9.7: The Research and Development Cycle in Detail

2. Task Design: Taking each task in turn, plan out what will be done (this is generally not documented outside of the task list itself)

3. Task Build: Build the component/section specified in each task in turn

4. Test: Perform developer/writer testing on the candidate release

Figure 9.8 shows the first step in this process in detail and highlights the iterative nature of this step. Any tasks that could not be completed in the previous sprint are placed in a "parking lot" on the Kanban board if they had a prerequisite missing or were found to be unsuitable for some reason. At the start of the next sprint, this "parking lot" is evaluated along with the gap analysis to decide whether the feature or component is simply not necessary, or if it can be completed in the new sprint by first ensuring all of it's prerequisites are met. The combination of the parking lot analysis and gap analysis tasks make up the sprint "to do" list which is used in the next step in the sprint.

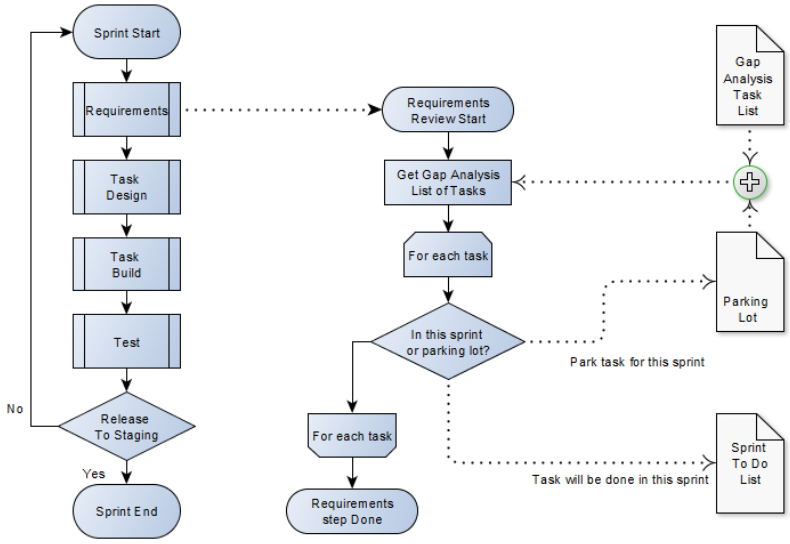


Figure 9.8: The Requirements Gathering Step in the ASDLC

Figure 9.9 shows the task planning step where the tasks on the "to do" list are evaluated and assigned a time and complexity value. This can be done in a variety of ways with the most common being to simply stack all of the tasks in a list from easiest to hardest and then assigning a time and complexity value to the easiest, hardest and median tasks and then splitting the tasks in three with those allocations. In a team based scenario the first two steps generally comprise the "kick off" session for the sprint.

Figure 9.10 shows the Task Build step where tasks are moved from the "to-do" list to the "In Progress" list while being worked on and finally to the "done" list when completed on the Kanban board. It is in this step that developer testing happens as each developer/writer takes the section of work that he has completed and performs their own quality testing on it. The type of testing done here will be ad-hoc as the type of testing that will be performed here is up to the developer/writer in question. As a rule of thumb however for software this will be indicated as passing all unit tests and for document artefacts will be a read through by the author.

Figure 9.11 shows the detailed testing step that takes place at the end of the sprint. This indicates a point where a section of work has been completed and a new version of the artefact or document can be reviewed by external parties. In the case of a software artefact this is achieved with a merge of all branches and a code review by all members of the team. In the case of a document artefact this is achieved with a full read through of the document by the author and then an external review by someone else. In the academic/educational context this will be achieved by a feedback session with academic supervisors or with a meeting with the content expert.

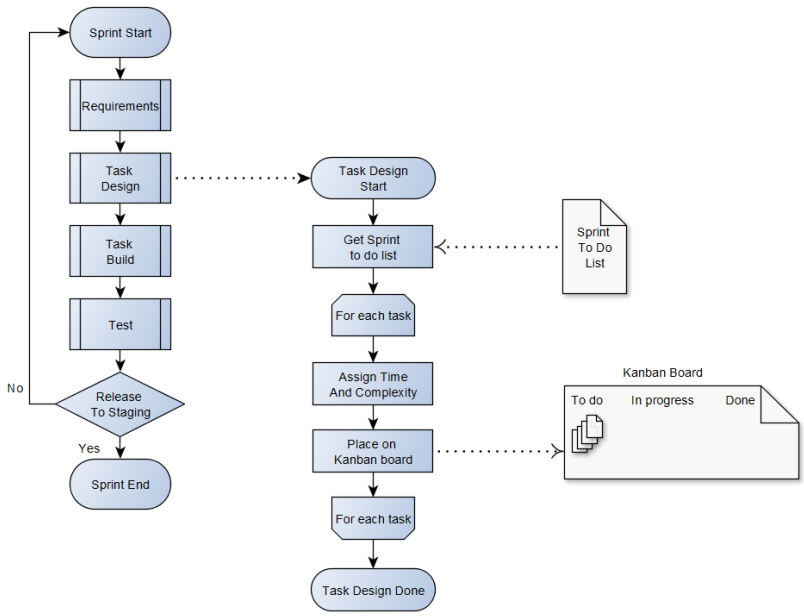


Figure 9.9: The Task Planning Step in the ASDLC

Testing in the Evaluation Step

Once the sprint has been completed, the released section of work can move to the evaluation and data collection part of the research and development cycle. This is where the artefact is evaluated by members external to the development team. Depending on the step in the TOGAF process, this will mean different things, but the four main ways in which this can be tested is through:

- Heuristic Evaluation
- User Testing and Psychometry
- Quality Testing
- Data Analysis

Data analysis will be dependant on the nature of the artefact being reviewed but will generally be done by the developers and researchers involved in the process. The nature of the data analysis that will be done needs to be detailed in the ethics application made at the start of the process. As an example of this the ethics application done for this study is attached in Appendix A. Of the four approaches highlighted, it would be a waste of time to perform each test at each step in the cycle, but they are all described here so that they may be performed at least once per loop.

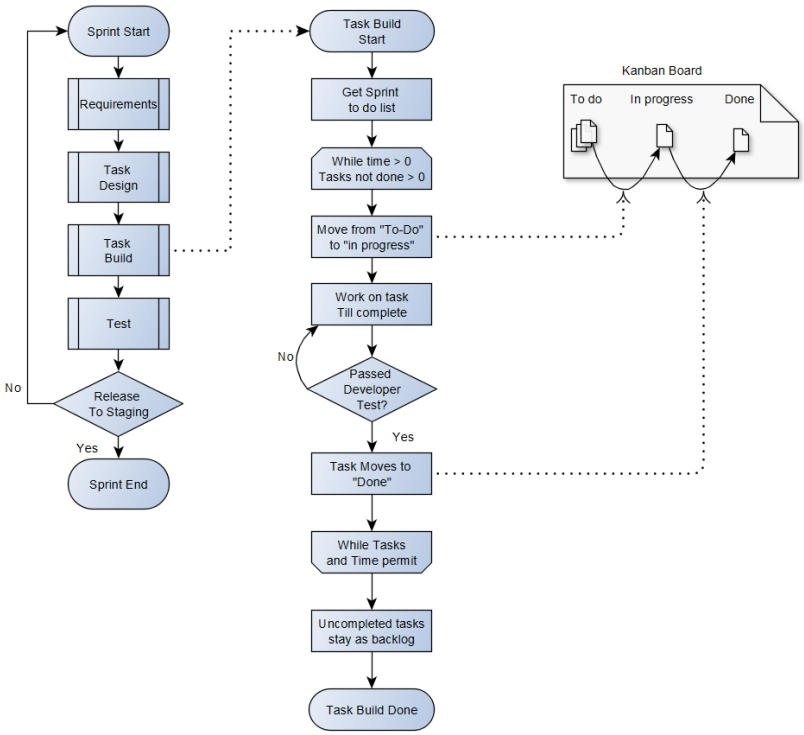


Figure 9.10: The Task Build Step in the ASDLC

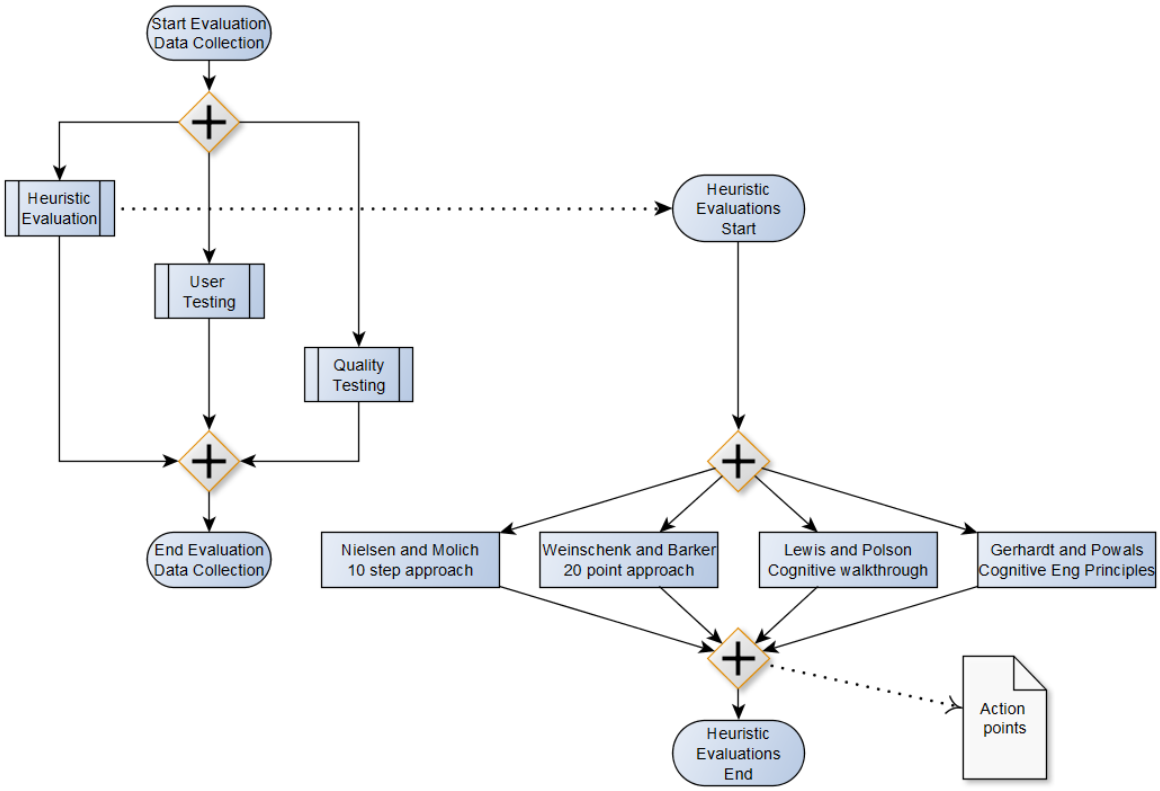


Figure 9.12: Heuristic Evaluation

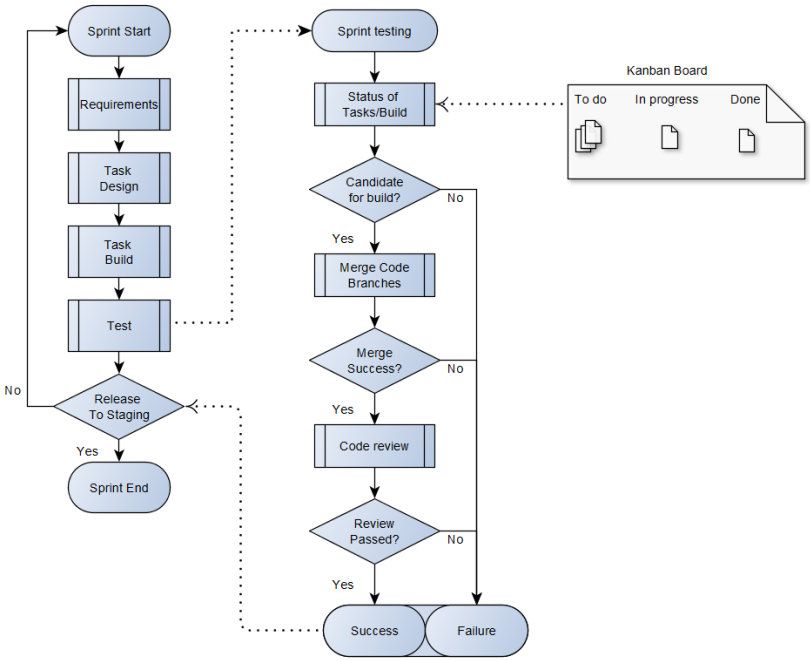


Figure 9.11: The Testing Step in the ASDLC

The first set of testing techniques shown in Figure 9.12 fall under the umbrella term of heuristic evaluation. In this study the techniques used were limited to the Nielsen and Molich approach [144] and the cognitive engineering principles by Gerhardt and Powals [145] simply because they are the check-lists most familiar to myself, but there are a number of other techniques that can also be used. If possible, these should be done by an external party, but it would be unlikely that this would be the case in an academic study and as such the developer should familiarise themselves with the chosen approach. Any problems highlighted should be listed as action points to be fixed during the following sprint. In this study a delta overlay approach was used as shown in Section 4.2.3 and I found it to be an effective method of performing this style of testing.

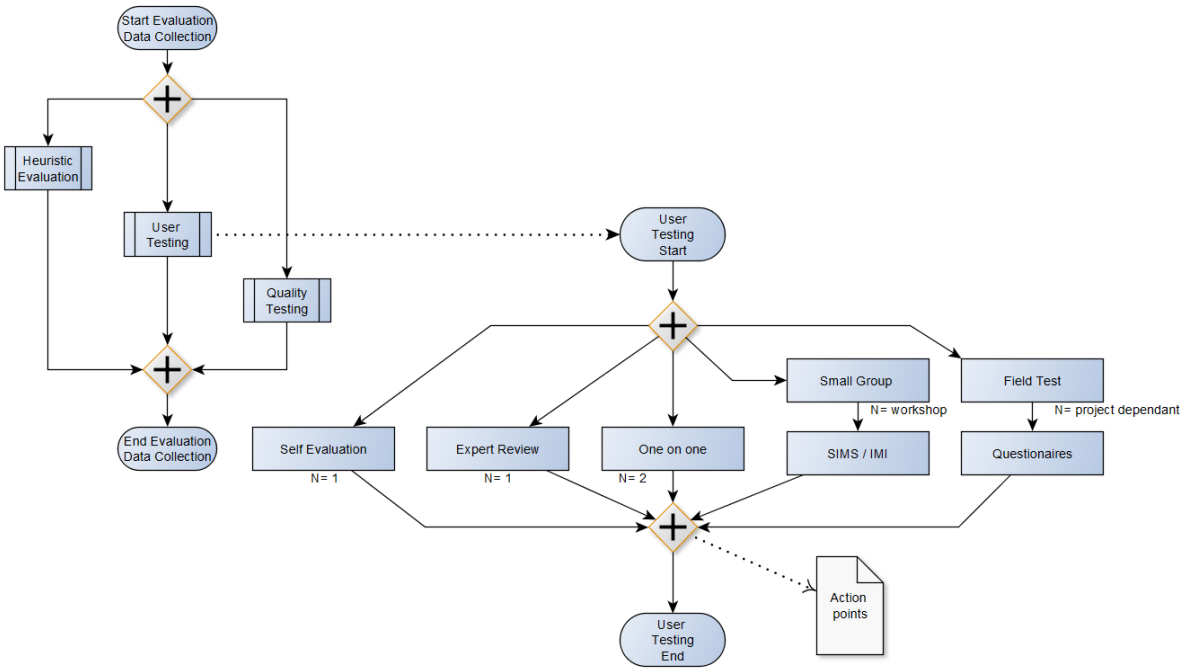


Figure 9.13: User Testing

Figure 9.13 shows the options for user testing and is the point where the most attention should be given to the testing techniques when making an ethics application. The approach taken in this study which I believe to be most applicable is the one put forward by Nieveen in [111]. All five of the testing techniques put forward are useful and were used throughout the project in conjunction with action research principles. Each loop beyond the first contained all five testing techniques, but it would have been useful to maintain the action research approach throughout all of the phases simply to have access to one or two students that could be used in the sprint testing as well.

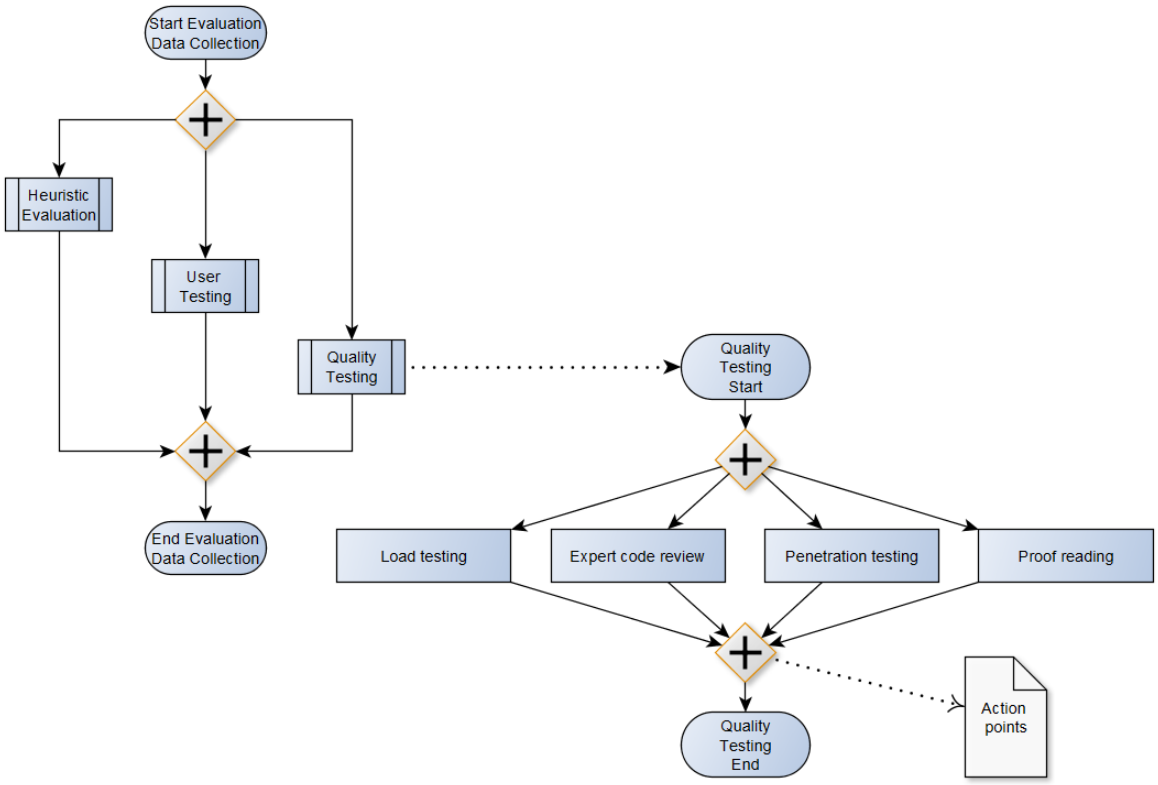


Figure 9.14: Quality Testing

The final testing approach shown in Figure 9.14 would be quality testing of the artefact. This will be the main style of testing for document artefacts as the proof reading and expert review of study leaders and editors is critical to the success of the work. For software however this will mean a slightly different set of tests as load testing, code review and penetration testing is simply good practice for software artefacts. It is unlikely that funding will be available for this in the academic context, and I am truly grateful to my colleagues and study leaders for helping out with these tests when I needed them.

The final step that is highly recommended is to find an early, easy context in which generalisation can be applied. The creating of the two conference web applications built on the base that was built in this project is what finally crystallised many of the concepts discussed in this reflection as it was difficult to see them when only applying it to one specific context. It may not always be possible, but I believe this may be the key to final success.

Testing Plan and Summary

For future studies, the testing plan can be put in place up front in the ethics application where the context is described as well as the nature of the participants and ethical clearance needs to be obtained up front for:

- Access to the data for the full development team and expert review team to do

task, unit and read through testing.

- Psychometric testing apparatus that will be used if applicable
- Defintion of the database and data collection strategy for analysis application
- The heuristic evaluation approach that will be taken and level of user interaction required
- The user testing strategy using all five testing types set out by Nieveen
- Clear identification of a subgroup of participants that can be used for small scale testing along with action research principles
- An up front identified generalisation plan
- Clear sprint timelines to correspond to academic mentorship meeting schedule

I believe it would have made the project a lot simpler had I gone through the process in this way, as well as tying the steps to the commit log in the version control system would have made tracking progress significantly simpler. The general six month loop length was used and was found to be appropriate, but in future projects I would rather attempt to have the full test cycle implemented twice per loop rather than once per loop.

9.4 Conclusions

The data collected during the various processes of the DSR approach taken greatly helped the author to iteratively improve the system and to finally put together the full system students experienced in the 2018 academic year. It is difficult to compare pre- and post- test scores on a system of this nature as there is no control group as such, but based on feedback from participants, the data obtained, expert review and comparison to previous years it was deemed a success. It is the author's hope that some of the work done here did have a very positive impact on the student experience as a whole.

The main take away from the project for the author is that autonomy really is key to good experiences in capstone projects, not just for the students doing the module but also for the study leaders presenting. Initially the hypothesis was that engaged students will achieve greater success in their capstone projects, but after going through the project from end to end it would appear that a greater focus on engagement needs to be had across the board.

In terms of gameful design and Gamification it would appear that students are indeed receptive to the interventions made, but they have a very short life span. Shorter interventions that are gamified appear to work better but there is a need for a serious game that adresses the coursework students experience as difficult. Although it wasn't part of the initial investigation at all, it would appear that there is a very real appetite for a sports themed serious game that adresses power electronics.

The approach of doing the external assesment in questionaires, interviews and data analysis after the action research approach of becoming part of the system worked very successfully and allowed the author to gain a very good insight into the needs of the users of the system. It is worth noting however that there is very little literature surrounding just how much and how many tests need to be done with a participatory design approach as doing too much of it distracts away from the design vision put in place initially (this would colloquially be called "design by committee"), but too little makes it easy to miss really good ideas that can come from the system users themselves. There is a need for more research in this area.

9.5 A Summary of Contributions

In this work I would like to believe that the following blocks of work represent a contribution made to the larger corpus of engineering education.

- I believe that my estimation function for the stable marriage (and specifically the student allocation problem) is a valuable contribution to the body of knowledge.
- I believe that testing and rejecting the Jen Ratio (in it's current simple form) was a valuable contribution because it proved to only be useful as an instantaneous measure and not as a measure of the social health of a space over time.
- I believe that the focus on educators as well as students in the creation of interventions is critical to having long term effectiveness of those interventions. Autonomy is key in this regard.
- I believe the process outlined for studies of this nature will be valuable to the practical body of knowledge as well as hopefully being useful to students.
- I believe that in future shifting the focus in gameful design to the loss mechanics rather than the "epic win" described by McGonigal will lead to a much longer period of engagement.

Sections of this work were presented at:

- The Ninth IEEE Global Engineering Education Conference in 2018
- The Fourth Biennial Conference of the South African Society for Engineering Education in 2017
- Elearning Update 2017

9.6 Recommendations for Future Work

The project overall was considered a success and future work is already continuing on both the generalised version as well as the implementation at the University of Johannesburg. The following are opportunities for future work that would yield useful results in my opinion:

- At the University of Johannesburg the same system could be implemented at the mechanical engineering department which would give an interesting opportunity for correlating results across two separate populations.
- Extending the Location Based Game to use Bluetooth based indoor location beacons could yield interesting results in human movement based studies.
- Using the data obtained it would be interesting to compare the SAP algorithm with a neural network based implementation once a sufficient amount of training data has been collected.
- Extending the study to explore the amount of time students and study leaders spend together after allocation and how this can be maximised.
- The full benefit of the Challenge Based System will only be achieved in time once a sufficient number of challenges are built up over multiple years. At that point it would be interesting to explore whether a community of practice of students can be built around it to further the community aspect of the capstone project experience.

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UNIVERSITY OF JOHANNESBURG

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

SUBMISSION TO ETHICS COMMITTEE

APPLICATION TYPE: REQUEST FOR ETHICAL CLEARANCE FOR RESEARCH SURVEY			
NAME	Jacob	SURNAME	Greef
SUPERVISOR	Prof Andre Nel		
Co-Supervisor			
SUBJECT	Exploring the viability of supporting engineering students through gameful academic interventions		
BRIEF EXPLANATION	This ethics approval application is for research to be carried out during the capstone project investigation done by BEng: Electrical and Electronic engineering students at the university of Johannesburg. The Researcher hopes to show that through a gamified approach that the experience of students and study leaders can be made more positive through positive social interaction. This multi-year study concerns the creation of a number of game and web based artefacts that will be implemented to assist students during their final year of studies, and the researchers aim is to measure the effectiveness of these interventions. During this study, only registered students at the University of Johannesburg will be part of the sample population, and all interactions will be voluntary.		

SUBMITTED BY	Mr Jacob Greef
Signature	
Date	25 July 2017

ETHICS COMMITTEE					
ESCALATED			~~RESOLVED~~		
COMMENTS	The Committee approved the study.				
CHAIRPERSON	Dr M.E Makhatha	Signature		Date	04 October 2017

JUDICIAL SERVICES APK					
DELIVERED BY				Date	
RECEIVED BY		Signature		Date	

OUTCOME:

APPROVED.

Ethics Approval Application

This ethics approval application is for research to be carried out during the capstone project investigation done by BEng: Electrical and Electronic engineering students at the university of Johannesburg. The Researcher hopes to show that through a gamified approach that the experience of students and study leaders can be made more positive through positive social interaction. This multi year study concerns the creation of a number of game and web based artifacts that will be implemented to assist students during their final year of studies, and the researchers aim is to measure the effectiveness of these interventions. During this study, only registered students at the University of Johannesburg will be part of the sample population, and all interactions will be voluntary.

Name of Researcher:	**Mr. Jacob Jacobus Greeff**
Name of Organisation:	**University of Johannesburg**
Name of Faculty:	**Faculty of Engineering and the Built Environment**
Name of Principal Investigator:	**Prof. Andre Nel**
Name of the Research Project:	**Exploring the viability of supporting engineering students through gameful academic interventions**

I, **Jacob Jacobus Greeff** (the researcher) hereby confirm that:

1. The information provided in this ethics approval application to undertake research with human participants is accurate to the best of my knowledge;
2. I understand the principles of conducting ethical research;
3. I will endeavor to conduct all the research in an ethical manner as prescribed by Faculty and University rules;
4. I will inform the Faculty of Engineering and the Built Environment Research Ethics Committee (REC) of any substantive changes to the project that might impact on the ethical clearance of the project.
5. This project has not been submitted to another REC or Review Board for review

Signature Date

Part I: Research Information

Research Context

For students registered for the Bsc.Eng degree, UJ requires the student to complete a 1 year capstone project to show that they can integrate the knowledge they have gained through their studies into a cohesive whole. The current process requires the creation of suitable project outlines by study leaders, and the manual assignment of those projects to students by the course coordinator.

On interaction with the Department and students the following issues were raised:

i) a lack of transparency,
ii) lack of student involvement,
iii) less than optimal manual process.

and based on an initial analysis a gamified approach to solving the problem was proposed. As the goal of the study is both to validate further the use of gamified academic interventions in the engineering education context, as well as to create an applicable artefact for solving the problem, an educational design research approach is followed. The potential impact of games and gamification has been an exciting development in recent years, and although it went through an initial phase of over-excitement where unsubstantiated claims were made, it is the author's belief that the field has reached a point of maturity where real world value can be obtained.

Through this study the team hopes to have an impact on:

- The current social climate of university campuses.
- The field of game development, specifically games for change and socially conscious games.
- Democratising engineering education by increasing student access to faculty decisions.
- The field of engineering education.

As one of the author's personal inspirations put forward in a recent TED Talk:

"*Gaming can make a better world*" - Jane McGonigal.

Through reflection on this context though, the author started thinking a little more deeply about the transformation that happens to the engineering student as they are completing their capstone project, and how this directly impacts their identity as they move through the process of becoming an Engineer where they were once a student. In this study, this process of identity formation will also be interrogated to find ways in which the students can be supported and guided in becoming more ethically and professionally aware early on in their development in order to strengthen the engineering fraternity as a whole.

Objectives

The creation of an artifact to solve the stated research problem is at the heart of an Educational Research Design (EDR) study. With this in mind, the following problems have been identified in the context:

Research Problem 1: Students perceive the assignment of final year projects as problematic due to

- A lack of input taken from students on the project allocation process
- A lack of transparency on how project assignment was arrived at
- A less than optimal final assignment due to the largely manual process used.

With this sub problems in mind, can gamification and an automated assignment process contribute positively to the problems experienced?

Research Problem 2: Gamification in other contexts have shown promise in addressing the problems of student motivation and engagement. Will a combination of a serious game, gamification and authentic learning academic intervention create a more positive, engaging and motivating experience for students completing their capstone project?

Research Problem 3: Does conceptualising the student as a traveler along the path towards gaining their professional identity bring to light any new knowledge when presented in a gameful way?

On reflection on the above 3 problems, the researcher identified that they fill in 3 distinct flavors namely:

1. A physical and procedural problem - The selection and assignment process that students form part of can be optimized
2. A ludic problem – the question of whether games and gamification can positively impact specifically the lives of engineering students can be seen through the light of game development techniques and measurements of quality
3. An ethical and social problem – the formation of identity and ethical practice speaks to deeper questions that may fall outside of the scope of the project to solve, but should still be interrogated nonetheless to attempt to address societal needs directly.

It is in this context now, that the objectives of the project are laid out.

Objective 1: Create a system that will support the students in the completion of the physical and procedural requirements put in place by the University of Johannesburg for the completion of the course.

Objective 2: Gamify the system, and validate whether this gamified approach actually benefits the students directly by increasing engagement, intrinsic motivation and social cohesion.

Objective 3: Optimise the project allocation process and give students a substantial input into the assignment of projects.

Objective 4: Address the questions of ethical awareness and professional directly, and sufficiently early in the students process to make them aware of the responsibilities they will take on when they enter the profession.

With the overarching objective stated, the proposed design is described next.

Design

Design of the system will take place iteratively in keeping with the tenets of EDR, and student participation in the design process may mean that the initial design choices will be changed in later prototypes of the system. This however is seen as a good thing as it can only be participative if the student's needs and requirements are sufficiently taken into account. The system will be predominantly web based, and access is predominantly browser based to take advantage of the cross-platform nature of HTML 5 design.

The system will comprise of the following sub systems:

Web based portal: The portal allows students to register their projects and any additional information they choose to, as well as being the central point where information is distributed to them. At the final phase of the project, this web portal will be federated with the UJ Blackboard system (LMS) to allow for single sign-on by students. Access is strictly controlled as registration of students needs to be whitelisted by the site administrator or course coordinator.

Domain specific challenges: Students can take on challenges in the different study areas that are participated in during the capstone projects to test their knowledge and to earn points and badges. This is done in keeping with the design principles put down in the Superbetter system of personal growth. Challenges are set by study leaders, approved and uploaded by the course coordinator and students are free to participate or not in the challenges.

Location based game: To foster social interaction, a location based game is available to students, study leaders and the public during the project presentation day at the end of the year. The goal here is to allow students to not only show off their project and network with other people, but also to allow them to mentor the following round of capstone project students as 3rd year students are encouraged to participate in project days. Again, this process is entirely voluntary and students that don't participate will not be negatively impacted by the choice.

The Tender game: This game is built on the authentic learning approach, and allows students to act in the capacity of engineers should they choose to. Instead of the course coordinator manually assigning projects to students, students are given access to all of the possible projects put forth by study leaders up front at the start of the year. They then have the opportunity to tender for as many projects as they choose to and to rank their preferences. Once a tender period has passed, tenders are anonymized, and the students then have the opportunity with faculty members to vote on which tenders are most appropriate to the projects in question. The balance of votes is controllable by the course coordinator, but the initial model is built on the principle that the student population and faculty will have equal vote as groups (so 50% of the preference is chosen by the students as a whole, and the remaining 50% by the faculty as a whole).

The preference of each individual student, as well as the preference of the projects (determined by the voting process above), is then used as the input into Gayle Shapley stable matching algorithm to propose an optimal match of students to projects. This is only a recommendation however and the course coordinator has the ability to override

the assignments as well as to double up projects if there is a particularly high number of students that tender for them.

This process is entirely voluntary however, and students are not forced to vote, choose preferences or even do one of the predetermined projects. Should a student wish to propose their own project or do one in collaboration with a specific study leader this is taken into account, and students that don't participate at all also will have a project assigned to them manually in the traditional way.

Research Question Battle: one of the challenges specifically highlighted as one of the things students struggle with the most is the stating of their research question. The research question battle will be a game designed specifically with the aim of supporting students in this process both by peer review and guidance in a collaborative writing style intervention, as well as to reward students who do take the time to help out their peers. This work will also be done in collaboration with members of faculty, and hopefully their input will allow for the creation of an effective solution to the problems faced by the students.

Each of the subsections of the system will be available to the students throughout the year at different times, depending on the problems present as the course progresses as follows:

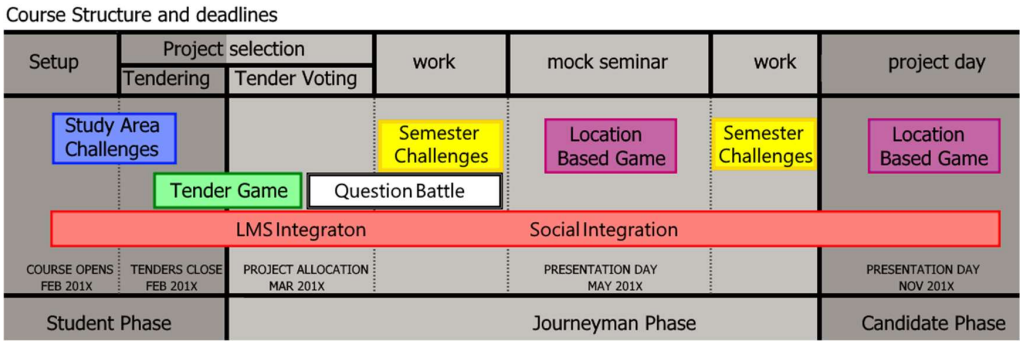


Figure 1: Envisioned final system access schedule

Look and feel of the system is done taking into account the colours and corporate identity of the University of Johannesburg both for brand purposes as well as to make students feel more at home and comfortable. For positive and negative ratings of projects and interactions, a very simple form has been created to allow for simple interactions to be measured. This is used particularly during the location based game where the participants in the study can anonymously rate interactions with fellow students and projects.

The look and feel, responsive design of the website and form design is available in Appendix A.

Data storage, access and security

The design of the web based system is done using the .net framework, and security has been heavily emphasized. Data for use by researchers is anonymized very simply as the user information is all contained in a single table specifically so that it can be purged

without influencing the data itself, but removing all personally identifiable information before the data is archived so that it can be accessed by other researchers in the future (for further study or validation purposes).

Appendix B shows the full entity relationship diagram of the database with the table holding all personally identifiable information highlighted in red. When archived, this table has all information except for foreign keys purged to ensure information is truly anonymous. During operation, all lookup actions reference this table when they are displaying user information to enable this process.

Data is stored in a password protected SQL database during development with backups taken weekly. Once completed, the artifact should be moved to a dedicated server on site at UJ so that it may be managed by the same team that manages the current learning management system.

Anonymized data can be made freely available should anyone wish to continue or validate the research being done.

The web server uses Razor markup language to structure the pages, rather than relying on front end DOM modification to hide and show information based on access levels of users. This means that confidential/user information is never served to the client's browser, rather than sending and then hiding it. There may be a slight impact to the load on the server as it does require the page to be made when it is requested rather than sending the same page to every kind of user, but this is far outweighed by the benefits in security.

Questionnaire design and instruments

The questionnaires to be used in this study are as follows:

General Questionnaire: A general questionnaire posted on the web system that any user can fill out at any point in time. The questionnaire will be done completely online and is available in Appendix C. Although anonymous, an email address is captured to ensure that should a participant feel later that their responses should be removed that it can be found. Participants are free to use a dummy email address, as it is only used in this instance for the de-enrollment process.

The Intrinsic Motivation Inventory: This instrument has been validated more than once, and is used to assess the subjective experience of activities of participants. The validation studies of the IMI and the instrument in its entirety is open and freely available at (R.M & Deci, undated): http://selfdeterminationtheory.org/intrinsic-motivation-inventory/

Situational Motivation Scale: This instrument is used to gauge the intrinsic and extrinsic motivation levels of participants in an activity. Design and validation of this instrument is available in (Guay, Vallerand, & Blanchard, 2000).

Part II: Research Design Overview

Please select one: ☒

☐ This *student research project (up to Masters level)* and associated ethics application have both been approved by the relevant FHDC prior to submission to the Ethic Committee.

☒ This *student research project (PhD)* and associated ethics application have both been approved by the relevant FHDC prior to submission to the Ethic Committee.

☐ This *staff research project* and associated ethics application have both been approved by the relevant FHDC prior to submission to the Ethic Committee.

☐ This *student group research project* and associated ethics application have both been approved by the relevant FHDC prior to submission to the Ethic Committee. This application covers the broad ethical issues pertaining to the group project as a whole.

☐ This *external research project proposal* and associated ethics application have both been approved by the Executive Dean or Vice-Dean (Research) prior to submission to the Ethic Committee.

Signature (Supervisor / Staff Researcher / External Researcher) Date

Research Design

(Use the ☒ to indicate selection)

Please supply the relevant information.

1. Data Collection Types
   - ☐ Qualitative
   - ☐ Quantitative
   - ☒ Mixed Methods

2. Research Methodologies/Approaches
   - ☐ Biographical
   - ☐ Phenomenological
   - ☐ Grounded Theory
   - ☐ Ethnographical
   - ☒ Case Study
   - ☐ Design Experiment
   - ☒ Action Research
   - ☒ Survey or other quantitative strategy (please provide details below)
   - ☒ Other (please provide details)

   An Educational Design Research (EDR) approach is taken so that an actual artifact is created that will address directly the needs of the students as they become clear over time. An initial needs analysis has been done, but the researcher feels that some information will only become clear over time as not all students are aware in the initial phases of their capstone project what stumbling blocks they will experience. The separate parts of the system being developed will be evaluated as separate case studies as well as through the summative evaluation at the conclusion of the study.

   To gain a deeper insight, the researcher will also take into account the problems faced specifically by students that are being supervised by them in the implementation of their capstone project by following the Action Research approach.

---

3. Research Instruments/Methods
   - ☐ Document analyses
   - ☒ Questionnaires
   - ☐ Surveys
   - ☒ Individual interviews
   - ☐ Group interviews
   - ☒ Observations
   - ☒ Other (please provide details)

   In addition to a general questionnaire that will be circulated to participants and interviews that will be conducted on students who chose to participate and highlight their needs and concerns around the structural gamification being employed, for the game based interactions the following instruments will be used to gauge the effectiveness of the system:

   Experience Sampling Method (for use during location based game interactions)
   Intrinsic Motivation Inventory (for use during Research question battle and Tender game)
   Situational Motivation Scale (for use with all game based interactions)

---

4. Sampling
   - ☒ Random
   - ☐ Targeted
   - ☒ Purposeful
   - ☐ Snow balling
   - ☐ Other (please provide details)

   During game based interactions, random sampling will be used to get as unbiased a response as possible from the ESM, IMI and SIMS instruments on the effectiveness of the game based interactions.

   To measure the effectiveness of the structural gamification put in place, a more purposeful sampling

method will be chosen, and specifically students that have elected to have the researcher and their co-researchers will be interviewed to attempt to gain a much more in depth understanding of weaknesses in the system over the longer term. It is envisioned that short term responses will be positive, but it is unclear whether the responses will remain positive and for these measurements a more purposeful selection of students would be more beneficial.

5. Sample size
   ☒ < 11
   ☐ 11- 50
   ☒ > 50
   ☐ Other (please provide details)
   As stated in the Sampling section, both purposeful and random sampling will be employed. Currently there are just over 100 students active in PJE2017 (project investigation IV), and as large as possible a group of these students will be used as the sample size. As participation is completely voluntary, it cannot be guaranteed that all students will participate but a large sample size is envisioned for the participation in the questionnaires, ESM, IMI and SIMS studies.

   For the purposeful sampling, this is a different situation however as the students that have specifically chosen to work with the researcher will be interviewed and their personal opinions will be taken into account. This is in keeping with the principles of EDR where members of the targeted population will be allowed to directly influence the creation of the artifacts that will benefit them and representatives of their groups.

   Two separate data sets are being collected, one through questionnaires collected from the participants online (which should have a sample size of larger than 50 questionnaires), and the other data set will be comprised of face to face interview transcriptions with individual students (< 11 interviews will be done). Currently, through the course of the study, it is expected that 10 interviews will be performed with individual students.

   Another factor to take into account during the sampling is the de-enrollment of students, and as such, the above numbers have been slightly underestimated, as a slightly larger set of students will be approached so that the data remains valid should they choose to de-enroll from the project.

6. Age of participants
   ☐ < 14
   ☐ 14-17
   ☒ >= 18

   All students that will be given the opportunity to participate will be in their final year of the BEng degree and no students are foreseen to be younger than 18. Should a unique case occur however, this will be brought to the attention of the ethics committee for further consideration.

Part II: Participant Related Statement

The research study being undertaken takes as one of its guiding principles the three human needs identified in Self Determination theory namely:

1. Autonomy
2. Social interaction
3. Mastery

Autonomy and intrinsic motivation in the students is not only required for this ethical clearance, but in fact for the entire project to be viable. Additionally, the concept of a game is summarized perfectly by Suits as follows:

"*Playing a game is the voluntary attempt to overcome unnecessary obstacles*." (Suits, 1978)

If Autonomy is not a part of this project, then it will not succeed.

With this in mind, the following areas are considered.

Autonomy

Participation in any of the subsections of the project is completely voluntary on the part of the students. Study leaders also have the option to not participate in the study and to also send their projects to the course coordinator directly if they choose never to interact with the system.

The course coordinator is part of the research team, so as the final stakeholder their autonomy is in that they are guiding this research effort, but in future situations if the artifact is to be re-deployed the course coordinator's participation should be sought separately.

In order for students to gain access to the system, they are told about it through the Learning management system that is already in place (this interaction is not voluntary, as the LMS is already in place at the university and without access to it students will not be able to complete their studies) and they are presented with the link to the system. In order for them to register, they do need to have their student numbers added to the white list controlled by the course coordinator so that they can be a part of the system.

Participation is also opt-in in that students not wishing to participate should simply take no action. They will not be added if they don't actively pursue joining the study.

For those that chose to participate in the study as a whole, they will also have to option to not partake in any of the sub systems. Students need not partake in the social aspects, location based game, tender game or research question battle, and if they do choose not to they will still be assigned a project manually or they have the option to also propose their own study should they choose to.

Beneficence

It is the hope of the researcher that this project will not only benefit students as whole, but also specifically the students that choose to partake in the study. The goal is to increase their positive experiences through the course, expose them to ethical problems they will face later on in life as well as to attempt to offer a peer-assistance route so that students can also help each other.

Additionally, the reason for attempting to gain insight into student problems through

interactions with students and study leaders is to ensure those problems are taken into account and addressed directly.

It is hoped that by allowing students a greater voice in the selection process of projects that they will feel more empowered as engineers and feel that their opinions and thoughts are respected very directly by the faculty in a tangible way.

Non-Maleficence

There does not appear to be from the researcher's point of view any risk to participants in the study. There will also be special care taken however that should something be presented that will do any harm that the participant(s) in question can be removed from the study immediately with no adverse effect on them.

Since Razor markup is used as opposed to front end DOM manipulation, this means that screen readers will work as the final page sent to the client's browser will be fully HTML5 compliant. Images that are not added by the researchers (for example by students) may not have the correct tags however but the structure of the site and all text information will be available to visually impaired students should they choose to partake in the study. Although no disabled students are currently foreseen by the researchers due to the nature of the course, this will be taken into account through the process should this become relevant later. Where this may become relevant is in the research question battle as it will be partially graphically driven. Should it be the case however, this can be mitigated completely by paying personal attention to students with visual impairments to ensure they get the same level of input and guidance on their research questions.

Audio will be used in game design, but predominantly the information conveyed will be visual so no disadvantage is foreseen to students with auditory impairments.

The system will be served to students through a browser, which naturally does mean that a certain level of computer literacy and general literacy is in place for participants to use the system. As the students in question are final year electronic/electrical engineering students however that in earlier levels of their studies are required to take programming courses it is assumed that they will all have the requisite skill level. Should the artifact be repurposed later however this will need to be taken into account. As the system is linked from the LMS at the university there is already a need for the student to have internet access. All parts of the system will be available freely to students that are registered however through library computers as there is no requirement for the student to download information to their machine – it is all available online. As the interventions will be used predominantly during the semester, it is not foreseen that students that come from difficult financial backgrounds and don't have access to internet at home will experience any difficulties, but should this be the case the ethical committee will be made aware of this.

Justice

Although not in the general sense of the word justice, it is the belief of the author that the study is just simply because it aims to advantage the same group of students that form part of the sample group, as well as the students that are to follow them in the future. Furthermore, it is hoped that the study will address problems generally experienced by all students in the course, as opposed to just those that partake in the study and that the intervention will in fact positively impact the student's lives and hopefully the lives of others. It is part of the code of conduct for

members of the engineering profession to act ethically and the researcher hopes to bring about awareness of this through the study.

Additionally, the ability for students to have a say in the way their research projects are chosen is in the opinion of the researcher one of the steps to take in the advancement of the democratization of the syllabus. Although there will always be a need for the faculty to hold a high level of knowledge (as this is partially why students are paying to be at university – to gain that knowledge), there is a need for student's voices to be heard and their autonomy and partial mastery of the subject matter to be respected.

Participant selection

Students who will have the opportunity to participate in the study will all be part of the capstone project group in each of the years that the study will run. There will be no discrimination based on race, gender, age or political affiliation. The only prerequisite to participation will be registration to the course.

Students that will be interviewed and work more closely with the research team on the design of the system will be chosen from the group of students that get chosen to work with the researchers already through the project tendering process. This is not done to discriminate on the students that are not supervised by the researchers, but rather as an admission that the students that will participate in design and give input may have some impact on their time, and this will allow the researchers to ensure that they are not negatively impacted by this in any way. Their participation however will also be completely voluntary.

Conclusion

Hopefully the goals and underlying motivations for the commencement of this study are clearly described by this document, but should there be any additional questions, please do not hesitate to contact any of the members of the research team.

Applicants requesting approval

Researcher	Mr. Jacob Jacobus Greeff	**Principal Investigator**	Prof. Andre Nel
Student #	217073650	**Staff #**	
Department	Electrical and Electronic Engineering	**Department**	Mechanical Engineering
Phone	072 403 1221	**Phone**	011 559 4667
Email	japieg@gmail.com	**Email**	andren@uj.ac.za
Address	46 Jacaranda Lane Panther Road Boskruin 2188	**Address**	

Appendix A: Web Design/look and feel

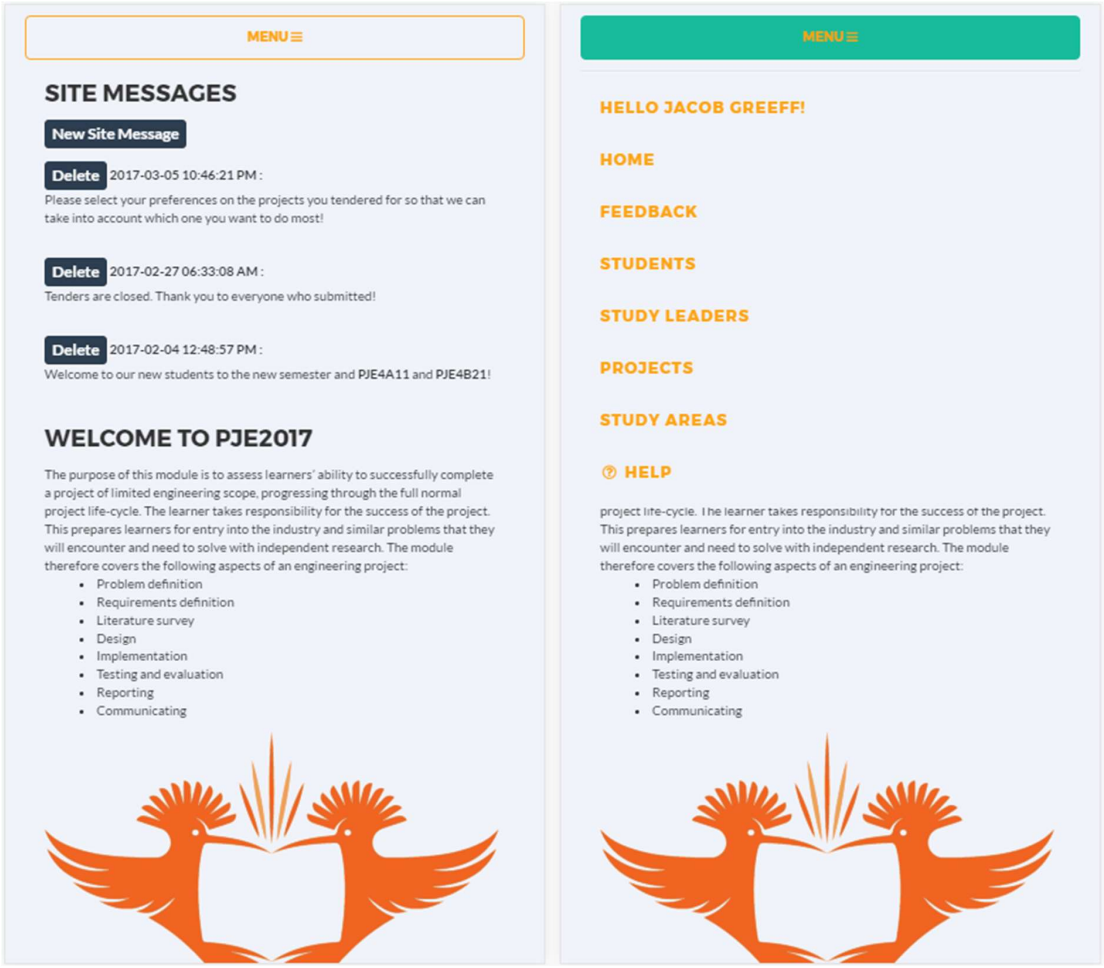


Figure 2: Web design - mobile layout

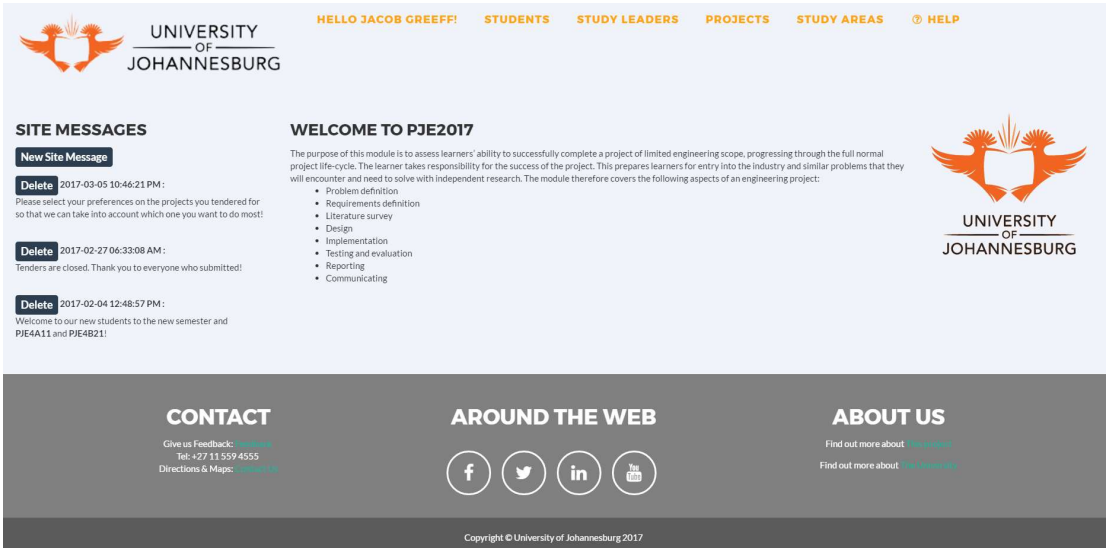


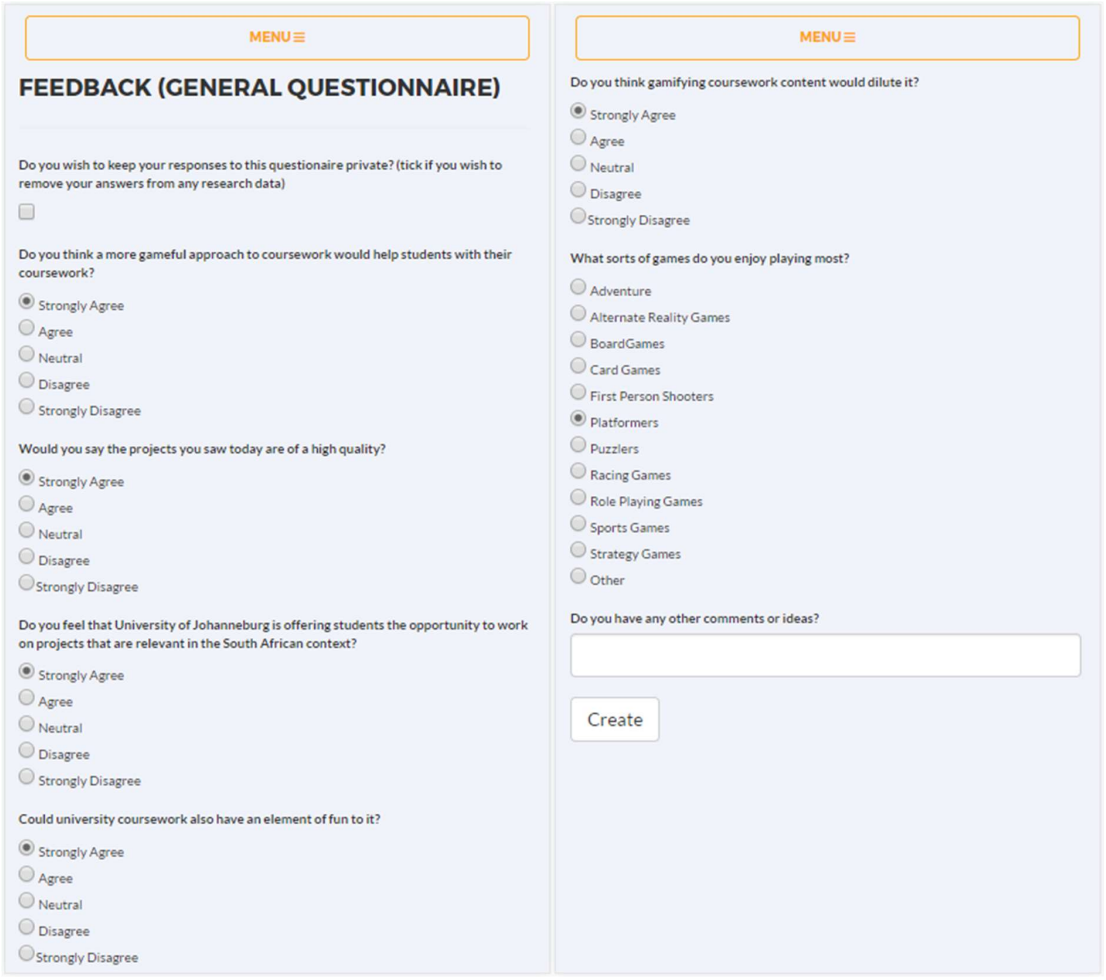
Figure 3: Web design - desktop browser layout

Figure 4: Simple social interaction form

Appendix B: Entity Relationship Diagram

Figure 5: Entity Relationship diagram

Appendix C: General Questionnaire



MENU ≡

FEEDBACK (GENERAL QUESTIONNAIRE)

Do you wish to keep your responses to this questionaire private? (tick if you wish to remove your answers from any research data)

☐

Do you think a more gameful approach to coursework would help students with their coursework?

- ◉ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree

Would you say the projects you saw today are of a high quality?

- ◉ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree

Do you feel that University of Johanneburg is offering students the opportunity to work on projects that are relevant in the South African context?

- ◉ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree

Could university coursework also have an element of fun to it?

- ◉ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree

MENU ≡

Do you think gamifying coursework content would dilute it?

- ◉ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree

What sorts of games do you enjoy playing most?

- ○ Adventure
- ○ Alternate Reality Games
- ○ BoardGames
- ○ Card Games
- ○ First Person Shooters
- ◉ Platformers
- ○ Puzzlers
- ○ Racing Games
- ○ Role Playing Games
- ○ Sports Games
- ○ Strategy Games
- ○ Other

Do you have any other comments or ideas?

Create

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Informed Consent Form for Exploring the viability of supporting engineering students through gameful academic interventions

This informed consent form is for students at the University of Johannesburg currently enrolled in the module "PJE201X" and will in 2017 be working on their capstone project for the degree "BEng (Electrical Engineering)" or "BEng (Electrical and Electronical Engineering with IT)". We are inviting students to participate in this research project entitled "Exploring the viability of supporting engineering students through gameful academic interventions".

Principal Investigator:	Prof. Andre Nel
Researcher:	Mr. Jacob Jacobus Greeff
Organisation:	University of Johannesburg

This Informed Consent Form has two parts:

- **Information Sheet (to share information about the study with you)**
- **Certificate of Consent (for signatures if you choose to participate)**

Part I: Information Sheet

My name is Japie Greeff and I am currently in the process of working on my doctoral studies through the University of Johannesburg. In partial fulfillment for the requirements of this degree, I am studying the viability of using gameful interventions to make the lives of final year engineering students better. I aim to give you some more information around the work I am doing and to invite you to be a part of the work I am doing. You do not need to decide on whether you wish to participate now and you can speak to anyone you feel comfortable about this work. This consent form may contain words that you do not understand, and if so please feel free to stop me and ask for clarification at any point in time. If you have any questions later, you can ask them of either myself or any of the other researchers.

Purpose of the research

BEng students are required by the University of Johannesburg to complete in their final year of study a capstone project. This project shows that that have managed to master the coursework given to them and that they can demonstrate their mastery by applying engineering knowledge in the solving of a sufficiently complex problem. Students may find this project stressful as it will require them to employ all of their skills in solving the problem. Currently, the projects that are offered to students are chosen by the faculty and assigned based on their experience and knowledge having taught the course many times in the past. On interaction with the Department and students the following issues were raised:

i) there is a lack of transparency in how projects are assigned,
ii) there is a lack of student involvement,
iii) there is a less than optimal manual process.

In other places, there has been a very positive experience found when students have had the opportunity to interact in their studies through games and gamified systems as they feel it puts them more at ease and that they feel more engaged with their coursework and the challenges they experience therein.

The goal of this research project is to address both of these things at the same time. On the one hand to give students a voice in the assignment of their projects so that faculty might also take into account their opinions when assigning projects, but to also hopefully make the life of students a little bit easier by providing them with games and game like tools to help them through their capstone projects. We hope to learn from this what the students wants and needs are so that we can address those directly in future.

Type of Research Intervention
For you to participate you may be asked to log onto the website and interact with other students, and also to fill in from time to time a questionnaire about your experiences of the parts of the project being tested. Questionnaires will be kept short and should take no more than 10 minutes of your time should you participate. If you wish to be more involved in the research and want to give your input on the design of the interventions you would be more than welcome to do so and can contact any of the researchers involved and we will take your input in the form of an interview or as part of a collaborative design session. In this case, the interaction will be a little bit longer, but should take no more than an hour of your time.

Participant Selection
You are being invited to take part in this research as you are one of the students that is going to be working on their capstone project in this year and we would like to understand the needs and problems you face in the completion of your studies and how we can help you.

Voluntary Participation
Your participation in this study is entirely voluntary and should you choose not to participate you will still be able to do your project and nothing will change. Your choice to participate in this study will have no direct influence on your marks and you will not be expected to perform any actions should you choose not to participate. You may also choose to participate initially and then change your mind later and withdraw and there will be no consequences for doing so.

Procedures
Most of the study will be done from data obtained by using the project investigation website. There are 5 parts to the system, and you can choose to participate in all, part or none of them.

A. The PJE website
B. The tender game
C. Social interaction
D. Research question battle
E. Location based game

During your use of any of the above parts of the system the researchers may approach you to fill out a short questionnaire about your experiences of it. The questions will be short and will mostly consist of a multiple-choice style question where you can choose to agree or disagree to varying levels on the questions asked. For example:

Q: *Why are you currently engaged in this activity?*
A: *Because I think that this activity is interesting*
1 2 3 4 5 6 7

Key: 1: not at all
2: very little
3: a little
4: moderately
5: significantly
6: a great deal
7: exactly

To answer the question, you need only circle the choice that most accurately represents your feelings. These questionnaires may also be presented to you online through the website should you choose to use that in which case the same kinds of questions will be asked, you merely have to answer them online by selecting the radio button the same way as you would have circled the answer.

Duration
This research will take place from now until 2019 and multiple classes of students will be asked if they wish to participate in the study over the years. There will be no expectation that you will do any additional work outside of filling in questionnaires or submitting documents as you would have done normally, only if you do participate the documents will be uploaded to the website rather than mailing them directly to the course coordinator. There may be time involved in playing various games throughout the course of the study or time involved in interacting with your peers, but the amount of time you choose to do this will not be mandated by the research at all. Feel free to spend as much or as little time participating as you choose.

Risks
There are no risks foreseen for you in participating in this research, but should any question asked by the researchers or any interaction make you feel uncomfortable in any way feel free to simply not answer. You will not need to give a reason for not sharing information, and should you feel pressured at all please feel free to speak to the course coordinator at any time.

Benefits
It is hoped that this study will not only benefit you directly in giving you the ability to have a greater say in the way in which your course is run, but that your input will also benefit future students that will be in the same position as you in later years. If you feel there is a way that you can benefit more by changing the way the interventions are created, please feel free to also contact the researchers outside of the questionnaires if you feel there is any information they are missing that you would benefit from them knowing.

Reimbursements
You will not be provided any incentive to take part in this research.

Confidentiality
Your participation in this study will allow the research team to gain insight into the problems experienced by you and your fellow students. This information will be available to researchers in the team as well as the course coordinator. All of your personal information will be kept private in a password protected cloud based database, and once the year is completed any personally identifiable information will be purged from the database so that only data remains. No personal information is required in order for the research to be successful and due to that it will be cleared before it is shared with anyone else. During your participation, if you do interact with other students please also respect their right to privacy and do not share their information anywhere else either, as the research team cannot keep confidential information that is shared by other people. Wherever possible however, the team will do their utmost to keep your information safe.

Nothing you share with the research team will be shared with anyone else, but once anonymised everyone that participates will be entitled to a summary of the results obtained and should you wish any additional information (outside of personal information) simply ask one of the members of the research team. More broadly, the results obtained from the data will be shared with the university and the research community as a whole through publications and conference presentations where applicable.

Right to Refuse or Withdraw
You do not have to partake in this research if you do not want to and choosing not to participate will carry no negative consequences. At the end of this interview I will discuss with you any notes that I have made and you will the opportunity to modify or remove any of the portions I have written down.

Who to Contact
If you have any questions you can ask them to me now, or later. If you want to speak to someone else, you are also welcome to contact:

Dr. Johnson Carroll	(jcarroll@uj.ac.za)
Dr. Reolyn Heymann	(rheymann@uj.ac.za) or
Prof. Andre Nel	(andren@uj.ac.za)

As they will all have the ability to either answer your questions directly or refer you to someone else who

can if they do not have the information. The faculty of Engineering and the Built environment also has a research ethics committee that ensures that participants in research are shielded from harm and should you feel any of the researchers or affiliated researchers have acted incorrectly please reach out to your departmental secretary who can put you in contact with the independent body who will investigate any problems that arise.

Part II: Certificate of Consent

<u>If you do feel you wish to participate, please sign the below declaration</u>

I have been invited to take part in a study of the viability of using gameful interventions to make the lives of final year engineering students better. I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study

Print Name of Participant_____

Signature of Participant _____

Date _____
Day/month/year

<u>Statement by the researcher/person taking consent</u>

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands the scope of the research, the types of interventions being built and the way in which data will be collected and kept confidential.
I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this ICF has been provided to the participant.

Print Name of Researcher/person taking the consent_____

Signature of Researcher /person taking the consent_____

Date _____
Day/month/year