STUDENT CENTRED DIGITAL GAME-BASED LEARNING

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ABSTRACT

Background: Modernisation of education encompasses the integration of technological advances, and more active participation of students in their learning through recognised, effective techniques such as Student Centred Learning (SCL). To increase active participation of students with their learning within a classroom environment, significant effort has focused on the integration of digital games into education. These techniques, known collectively as Digital Game-Based Learning (DGBL), show strong potential as a vehicle to deliver SCL, a method termed Student Centred Digital Game-Based Learning (SCDGBL). However, SCDGBL offerings have so far not been focused on the delivery of a fully student centred experience through a comprehensive integration of all seven tenets that comprise SCL.

Aim: To design, develop and evaluate a novel DGBL experience that fully realises all seven tenets of SCL in delivering an engaging and effective educational experience.

Methods: A design science research approach was used: A systematic literature review assessed state of the art, creating a conceptual framework for SCDGBL literature evaluation. A game design framework, the Student Centred Experience framework, was developed using design thinking and utilised to design a game-based educational artefact: the LogicGate System. It was deployed in a classroom environment to create a SCDGBL experience, with mixed methods evaluation blending user surveys and qualitative focus groups. The revised system, LogicGate-R, was evaluated against a traditional student-centred learning task for delivery of SCL tenets and learning outcomes producing knowledge improvement, by randomised cross-over trial design using a knowledge test, user surveys and qualitative focus group data on student experience.

Results: The literature review demonstrated SCDGBL offerings do not currently deliver all seven SCL tenets, particularly the social aspects. In Experiment 1, students responded positively to the LogicGate System, feeling it was an engaging and effective way to learn, and made recommendations for improvements to immersion and feedback which were integrated into developing the high fidelity LogicGate-R System. A randomised cross-over trial, evaluating the Logic-Gate-R system, found that all SCL tenets were delivered while providing equivalent knowledge improvement to a traditional student-centred task. It was rated highly over the traditional task by students in feedback, joint productive activity and autonomy areas.

Conclusions: The key contributions of this work include a conceptual framework to evaluate SCDGBL research, identifying gaps for redress. A highly customisable game design framework facilitates full delivery of SCL tenets and desired learning outcomes within a high quality game design. A game designed using this framework was demonstrated to deliver on all SCL tenets, including social aspects neglected in previous offerings. This enabled development of implications and recommendations for future design, usage and evaluation of SCDGBL offerings in educational settings.

DEDICATION

I would like to dedicate this thesis to my wife, Marianne, who has given me solid ground throughout these years and without whose love and unwavering support I could never have accomplished this, and to my parents, Ian and Gillian, to whom I owe so much.

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PUBLICATIONS AND CONFERENCE PAPERS

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LIST OF ACRONYMS AND ABBREVIATIONS

AL – Active Learning

DGBL – Digital Game-Based Learning

DL – Deep Learning

DSR – Design Science Research

DT – Design Thinking

GE – Game Element

ID – Teacher and Learner Interdependence

IR – Increased Responsibility and Accountability

MDA – Mechanics, Dynamics, Aesthetics

MR – Mutual Respect

P1 – Principle 1: Co Design

P2 – Principle 2: Customisation

P3 – Principle 3: Player Identity

P4 – Principle 4: Manipulation

P5 – Principle 5: Ordered Problems

P6 – Principle 6: Pleasantly Frustrating

P7 – Principle 7: Cycles of Expertise

P8 – Principle 8: Information Provision

P9 – Principle 9: Fish Tank Learning

P10 – Principle 10: Sandbox Learning

P11 – Principle 11: Skills as Strategies

P12 – Principle 12: Systems Thinking

P13 – Principle 13: Meaning from Experience

RA – Reflexive Approach to Teaching and Learning

SA – Sense of Autonomy

SCDGBL – Student Centred Digital Game-Based Learning

SCL – Student Centred Learning

Chapter 1. Groundwork and Research Overview

1.1 Introduction

This chapter introduces and explores the groundwork for the research presented throughout this thesis. The thesis covers an exploration of the benefits of a fully realised Student Centred Digital Game-Based Learning (SCDGBL) system which delivers across all aspects of student centred learning including those often neglected in educational game design. Following a discussion of the real world context into which this research fits, introducing the concepts of Student Centred Learning and Digital Game-Based Learning, the Research Problem is presented (Section 1.2). This Research Problem is framed by issues such as pressure from governments and families to modernise education, a need to deliver curriculum content in a more engaging way, and a drive towards engaging students as active participants in their education. To address the research problem, it is proposed that lessons learned in delivering education through Student Centred Learning techniques be more directly applied to game design from an early stage, to combine the benefits of these techniques with those offered by modern Digital Game-Based Learning solutions. The aims and objectives of the research are then presented (Section 1.3), addressing the need to incorporate not just the learning techniques but also the social aspects of Student Centred Learning into the design of a SCDGBL system. A brief description of the approaches employed to realise these goals is also provided, following a Design Science Research paradigm (Section 1.4). Following this the research contributions are explored (Section 1.5), these being:

1. A conceptual framework to guide the evaluation of the Student Centred Digital Game-Based Learning research domain, based upon a literature survey on the area.
2. A framework for the design of Student Centred Digital Game-Based Learning experiences to guide and enable their development and use.
3. An artefact, being a novel implementation of a SCDGBL system that delivers on all seven tenets of Student Centred Learning.
4. A set of implications and recommendations for research and practise based upon the research undertaken.

This chapter concludes with a guide to the thesis structure and a brief synopsis of later chapter contents (Section 1.6).

1.2 Research Problem

The challenge of developing and supporting a modern education system is one faced by all developed and many developing countries, with aspects of that challenge in part handed down to local authorities, schools and individual teachers. The exact definition of what it means to

modernise an education system is one that eludes researchers, politicians and educators alike, with approaches including the removal of exams for ongoing assessment and later removal of ongoing assessment in favour of exams both being described in these terms (Department for Education, 2013). In some areas there appears to be some consensus however, these areas include the integration of modern technological advances and the more active participation of students in their learning (Prince, 2004, Freeman et al., 2014). This is reflected in government initiatives which stress the need for increased digital skills and capability (James, 2017, Intel, 2018). Concepts of active participation, drawing from constructivist educational theories, have given rise to concepts such as Student Centred Learning (Hannafin and Land, 1997), which stresses the importance of designing a classroom around how the learner best learns, rather than around how a teacher prefers to deliver (Rogers, 1983).

The seven tenets of SCL may be summarised as follows (Lea et al., 2003):

- *Active Learning*, as contrasted with passive learning is students learning through active involvement and experimentation rather than passive absorption of facts.
- *Deep Learning and Understanding* involves the building in of learning on a deeper level, giving students reasons to understand or care by relating or integrating learning to the student's own life or experiences.
- *Increased Responsibility and Accountability* means giving students a measure of control over their own learning, allowing them to take responsibility for actions or situations and giving the corresponding safety net to help deal with success or failure.
- A *Sense of Autonomy* means allowing students to engage with work without feeling they are being watched at every stage and they are allowed to make choices themselves that are or appear meaningful.
- *Teacher and Learner Interdependence* conveys that the relationship between students and teachers is important and flows both ways; students should feel they are learning from the teacher while also directing their experience while a teacher should look to students for guidance as to the speed of progression and level of understanding as well as nature of tasks.
- *Mutual Respect* covers the importance of students respecting each other as co-workers as this provides a grounding for collaboration and for students to learn from and assist one another.
- Finally, a *Reflexive Approach to Teaching and Learning* represents the ability for students and teachers to look back on work completed, evaluating not just how they achieved but the lessons to be learned from their approach and how to improve this in future.

To increase the active participation of students with their learning within a classroom environment, there has been significant effort focused on the integration of digital games into education which, while already delivering benefits, holds promise in areas such as student engagement, allowing students to personalise their experience and making the overall learning experience a more rich and involving process for students and teachers (Connolly et al., 2012, Gee, 2005). These techniques, known collectively as Digital Game-Based Learning, are summarised into 13 principles as follows (Gee, 2003):

- *Co Design*, giving players the feeling that their choices are the primary driving force behind the experience they are having.
- *Customisation,* players being able to make decisions about the way in which they play the game.
- *Player Identity*, through embodying someone in a situation, the lessons from that situation become personally relevant.
- *Manipulation*, taking actions that affect the world offers opportunities to bring the player closer to the experiences the game is mirroring.
- *Ordered Problems*, the idea that people lose interest if faced with something too far beyond their ability to solve through complexity or lack of understanding.
- *Pleasantly Frustrating,* ideal problems for both players and learners are those that are just towards the limits of where they are comfortable.
- *Cycles of Expertise*, the cycle of a learner picking up a new skill, practising until the skill becomes second nature to them and then having a challenge that requires the skill to be adapted.
- *Information Provision*, information in games is often provided either just in time for the player to make use of it, or on demand so the player can draw upon it at need.
- *Fish Tank Learning*, a fish tank in games is used to allow experimentation with a concept or mechanic without the stresses that may impact the visibility of this effect.
- *Sandbox Learning*, a sandbox provides an area of the game for experimentation and learning, but where it is difficult for things to go very far wrong.
- *Skills as Strategies*, bringing skill practise in to the strategy of the game, such that a player or learner is able to feel they are gaining an edge and progressing through the game.
- *Systems Thinking*, fitting the skills and ideas the game conveys as meaningful elements of the game world.
- *Meaning From Experience,* learning occurs best as filtered through the experiences a learner has had.

The extent to which Digital Game-Based Learning techniques have focused on the delivery of a fully student centred experience, such as through the integration of the seven tenets of SCL is yet to be determined.

Having framed the two fields of SCL and DGBL, it is now important to briefly frame their position within the wider research landscape. The area of digital game-based learning forms a subset of game-based learning focusing specifically on the use of digital games. Game-based learning as a whole can be said to fit within the wider area of serious games, where educational benefit is simply one aim amongst others such as skills training or behaviour change (Connolly et al., 2012), and education comprises one area among many settings, including healthcare, business and marketing (Sawyer and Smith, 2008). Previous evaluations of serious games for educational purposes have criticised the majority of offerings for their lack of pedagogical foundation or didactic approach (Kebritchi, 2008, Law et al., 2008). This work focuses specifically on the deployment of DGBL blended with SCL within a formal educational context. This focus distinguishes this work from the larger body of serious games research. For this reason, an in-depth focus and consideration of serious games is not within scope for this work.

Taking into account the current real-world context of modern education, the explored benefits of SCL and current research on the effectiveness of digital games within education, the problem statement will now be defined.

1.2.1 Problem Statement

The UK government, along with many others, recognises that in order for a country to deliver an education system that equips students to compete in an increasingly global market it is vital to continually modernise and improve the quality of curriculum delivery on offer through schools and universities (Directorate-General for Education and Culture, 2017). It is apparent from the existing DGBL experiences reviewed (see Chapter 2 for full literature review) that there is significant research effort drawing from Student Centred Learning principles in this area.

A majority of such DGBL experiences examined in the literature review focus on a subset of the goals of Student Centred Learning, addressing aspects such as *Deep Learning and Understanding*, *Sense of Autonomy* and particularly *Active Learning* (Lea et al., 2003). The survey raises questions over the degree to which the social aspects of Student Centred Learning are being addressed in Digital Game-Based Learning, and what benefits could be realised from embracing these aspects in game design. Within existing DGBL experiences there appears to be little evidence that SCL concepts were considered core to the design of the games presented, with SCL elements often missing entirely. While Student Centred

Learning provides a guideline and is not an entirely proscriptive design methodology for learning experiences**, the absence of such elements from a number of DGBL experiences across the landscape implies the benefits from these elements may not be fully realised**. In this case, particularly notable is developing students *Mutual Respect*, *Teacher and Learner Interdependence* and a *Reflexive Approach to Teaching and Learning* (Lea et al., 2003).

These social aspects may prepare students for working in teams and with peers in work or at university, as well as offering benefits such as stronger and more productive relationships with teachers and a healthy attitude towards making and learning from mistakes and improving (Schulz, 2008). With this in mind it is felt the **integration of Student Centred Learning tenets from the earliest stages of design with particular focus on the neglected social elements** offers an opportunity to better deliver curriculum content and to do so in an engaging and rewarding way, in alignment with government policies on this topic (Directorate-General for Education and Culture, 2017).

To address this problem, this research therefore explores the use of Student Centred Learning from the games design stage onwards, through to the deployment of a fully realised Student Centred Digital Game-Based Learning experience. This exploration allows the identification of the potential SCDGBL offers to deliver a modern education system that both academically and socially engages and motivates students.

1.3 Aim and Objectives

Given the above problem statement, this research therefore explored the potential benefits that a SCDGBL experience may offer to students and through them to the education system. Most importantly this research explored the ground-up integration of all tenets, but in particular the social aspects of Student Centred Learning into the experience and the effects this had on students' perceptions of the experience and of others involved in their learning alongside their ability to achieve the intended learning outcomes. The primary aim of this research therefore was:

> **To develop and evaluate a novel game-based educational artefact, that fully integrates the seven tenets of Student Centred Learning and principles of Digital Game Based Learning, to deliver an engaging and effective educational experience.**

This overall research aim was delivered through the following research objectives which guide the design and deployment of the artefact and its evolution through the studies undertaken.

RO1. Identify gaps in the state of the art through a survey of the literature in this domain and develop a conceptual model of that domain from which aspects of those systems can be classified and explored.

RO2. Design and develop a conceptual approach to delivering the gaps in Student Centred Digital Game-Based Learning identified above and explore the practicality of applying this approach.

RO3. Develop a framework to enable and assist with the design of Student Centred Digital Game-Based Learning experiences.

RO4. Develop an artefact based upon the above conceptual design that implements the identified aspects of Student Centred Learning.

RO5. Evaluate the developed artefact through appropriate means to assess both the educational effectiveness as a tool for learning alongside the acceptability and usability for users.

1.4 Research Approach

While research approaches were selected for individual studies as appropriate, overall it was decided to follow the Design Science Research (DSR) paradigm to provide guidance as to the direction of this work. The nature of this work aligns well with the DSR as core to the research is the design, development and assessment of an game-based educational artefact, in this case the LogicGate System designed to fulfil the research aim and objectives presented above (Hevner, 2007, Peffers et al., 2007). DSR presents an approach to identifying a potential for improvement and a rationale for the need to do such, with a focus on the development of a technology based solution that provides or improves upon existing tools to solve the identified issues and the evaluation of this solution in practical deployment (Dresch et al., 2015). Figure 1 summarises the activities undertaken in a DSR project, alongside the studies completed and their role in the activity, and the corresponding chapters in which this work is detailed. A full exploration of the research methods employed and a more in-depth mapping of DSR activities to work undertaken may be found in Chapter 3.

The artefacts presented here are designed according to the values expressed through the project's aim and objectives. In terms of DSR an artefact is considered a contribution in its own right, being a technological innovation that addresses a specific problem be it to improve upon solutions or to present an entirely novel solution to a hitherto unexplored problem (March and Smith, 1995). In this context it is important to note that the artefact itself is the focus and contribution, and not the software development project that lead to its creation, which may be considered a means to an end.

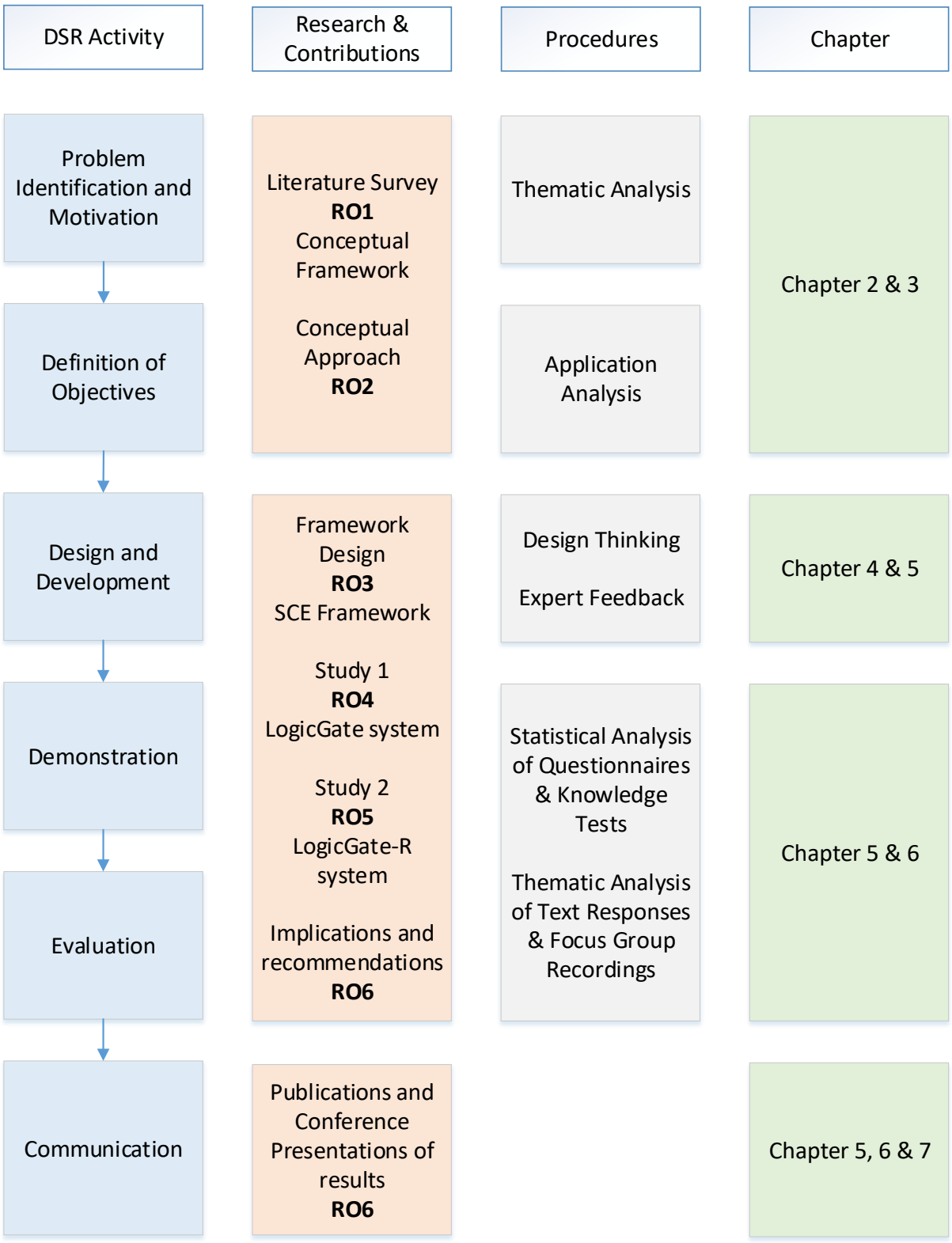

Figure 1: Research Process Overview

Both studies in this research project took the form of user-based trials of the game-based educational artefact, simulating a laboratory setting such as participants would experience in

their normal learning process to compare their responses to the produced artefact alongside that of more traditional teaching methods. These studies utilised a mixed methods approach, collecting both qualitative and quantitative data to assess effectiveness in achieving learning outcomes alongside capturing students' experiences and feelings on the SCDGBL experience created by deploying the artefact. This user experience evaluation provides a depth of understanding and insight that is less commonly available within educational games research (Slavin, 2003, Olson, 2004). This feedback formed an iterative loop to enable the further development of the artefacts to achieve the goals laid out. The contributions to knowledge from these studies are presented in brief in the following section, while the full detail on the studies may be found in Chapters 4 & 5 respectively.

1.5 Research Contributions

The research covered in subsequent chapters of this thesis makes the following contributions to the fields of Student Centred Learning and Digital Game-Based Learning, and to the wider area of games for education, which in turn comprises one aspect of serious games.

- A conceptual framework for the Student Centred Digital Game-Based Learning research domain.

  This contribution is based upon the structured literature review of the Student Centred Digital Game-Based Learning domain presented in chapter 2. The studies within this review were systematically reviewed and categorised to create a conceptual framework that describes the domain as a whole and provides a guide for evaluation of this domain. This framework was utilised to survey the research literature and identify gaps as well as other trends which were presented. This forms a meaningful contribution as the lens of Student Centred Learning provides a fresh viewpoint through which to explore the Digital Game-Based Learning landscape, which was not developed previously to the researcher's knowledge and has already been published in a peer-reviewed journal as original research. This literature review identifies some challenges addressed within this research as well as a number of other challenges which may be taken forward in future work to advance the field.

- A SCDGBL game design framework, developed utilising established education and games design theory, which guides the design of SCDGBL experiences.

  This artefact, developed utilising the Design Thinking approach, forms a guide to practitioners of both education and games design to assist in the design of games that create SCDGBL experiences. The framework provides a novel work that enables practitioners to integrate all tenets of Student Centred Learning while retaining the

flexibility to create games with any genre or educational goals. It may be utilised in future to design games intending to deliver on all opportunities within SCDGBL.

- An artefact, being a novel implementation of an educational game that delivers on all aspects of Student Centred Learning.

  This contribution, presented as according to the DSR methodology followed through this work, is designed from the ground up to follow and embrace all aspects of student centred learning, delivering a fully student centred experience when deployed. This educational game-based artefact, named the LogicGate System, presents a functional learning experience that could be easily adapted by practitioners without programming knowledge to address different student levels, and forms a basis for further development of systems targeting other subjects or subject areas.

- A set of implications and recommendations for research and practice

  This contribution, based upon the experiences and outcomes throughout the project, forms a series of implications and recommendations which can inform the design and deployment in practice of future SCDGBL experiences. These recommendations present actionable guidance that should assist in the successful use of the LogicGate System, and other educational games that create SCDGBL experiences, by practising teachers within the education system, and the design and improvement of such games by designers.

1.6 Thesis Roadmap

The following chapters present the work described here in greater detail. The chapter contents are explained in brief here.

1.6.1 Chapter 2

Chapter 2 presents the systematic literature review of the Student Centred Digital Game-Based Learning domain, addressing **RO1** of identifying gaps in the state of the art systems. It includes the conceptual framework of the domain developed through the review process as well as the themes that arise from that framework. Thematic analysis techniques were used to identify the themes which are explored within the chapter. The chapter sums up a number of gaps in the literature, making recommendations for work in these areas; particular gaps in the research on the social aspects of Student Centred Learning arising from this review form the focus of this work.

1.6.2 Chapter 3

Chapter 3 describes the research approach utilised within this work, speaking to **RO2** through a conceptual approach to delivering the gaps identified in Chapter 2 and exploring practical deployment of any solutions. It includes a description of the Design Science Research paradigm which informed and directed the nature of this work and explores how this was applied to the research undertaken including its integration with the Design Thinking approach to problem solving in design. The nature of data collection and design work undertaken is explored and justified including the mixed methods approach that determined the design of both experiments. The ethical considerations are explained along with steps taken to address these considerations while the role of software development and theory under which this work was undertaken are presented.

1.6.3 Chapter 4

Chapter 4 presents the Student Centred Experience (SCE) framework, a game design framework which was developed to guide the design of an SCDGBL game which fully integrates the tenets of SCL. This chapter meets RO3 by documenting the design process of the SCE Framework, identifying first the need for a framework in educational games design that has a focus on SCL. The Design Thinking process is then stepped through as it guided the Empathising, Defining, Ideation, Prototyping and Testing of the framework, including the existing source material that informed and contributed to the design. The completed framework is then presented and stepped through to explain its utilisation within the process of games design, leading to a need to test the designed artefact.

1.6.4 Chapter 5

Chapter 5 presents Experiment 1, a mixed methods study using the initial version of the LogicGate System, a game delivering learning outcomes related to Boolean logic designed under guidance from the SCE framework, undertaken with university students in a simulated laboratory environment. The chapter presents the design process for the LogicGate System, highlighting the educational links presented and how they address each of the Student Centred Learning aspects, thereby meeting RO4 which calls for an artefact that achieves this. The LogicGate System layout is then presented and the technical implementation explored. A walkthrough of the LogicGate System is presented, along with the study procedure, data collection and data analysis methods utilised, which combine quantitative analysis of survey data on learning experience and game experience with thematic analysis of open text survey responses, in-game chat data and focus groups. The results of this study are then presented and discussed, demonstrating students held positive views about the LogicGate System, believing it to be engaging and effective in delivering the content they sought to learn. Lessons

learned from the prototype are then presented with a view towards further improvement and evaluation. Finally the conclusions from this study are presented.

1.6.5 Chapter 6

Chapter 6 presents Experiment 2, which deploys the LogicGate-R System, a revised version of the LogicGate System above based on findings from the Experiment 1. This study, undertaken with university students in a simulated laboratory environment, presents and evaluates the LogicGate-R System in comparison to a traditional student-centred task. It uses a randomised cross-over trial design that takes into account lessons learned through the first study, with learning and game experience survey data as quantitative outcome measures, accompanied by thematic analysis of focus group, in-game chat and open-ended survey data. An overview of the study is presented with a rationale for the changes employed in both the study process and system design. The LogicGate-R System architecture and game-flow are presented along with a walkthrough of the revised system. The protocol and data collection/analysis techniques are presented and justified, followed by the results from the study. The key findings from this study were that the LogicGate-R System was able to deliver all aspects of SCL while providing an engaging gameplay and learning experience in comparison to the traditional task, without compromising on delivery of learning outcomes. These findings are presented and related to the Research Questions, Aim and Objectives presented. Finally conclusions are drawn and presented from this study, satisfying RO5 through appropriate evaluation of the LogicGate-R System artefact to assess educational effectiveness as a learning tool, acceptability and usability

1.6.6 Chapter 7

Chapter 7 provides a summary of the thesis and discussed the findings in relation to the initial Aim and Objectives outlined, and existing literature within this area. The research contributions are presented along with the value those contributions hold to the field. Limitations encountered through the research process are acknowledged along with the impact of these limitations on issues such as research generalisability. Finally future research directions that address and overcome these limitations are proposed.

Chapter 2. Literature Review

2.1 Introduction

Student Centred Digital Game Based Learning (SCDGBL) is the name given to the crossover of Student Centred Learning techniques, practiced through primary to tertiary education (Wright, 2011, Rohrbeck et al., 2003), with the use of digital video games as a vehicle for learning instead of more traditional techniques. A consensus definition (Attard et al., 2010) for Student Centred Learning (SCL) identifies it as a learning approach broadly related to, and supported by, constructivist theories of learning. This approach is characterised by innovative teaching methods aiming to promote learning in communication with teachers and other learners, taking students seriously as active participants in their own learning, and fostering transferable skills such as problem-solving and critical/reflective thinking (Attard et al., 2010). Greater integration of the Student Centred Learning approach with Digital Game-Based Learning (DGBL) may provide opportunities to both further improve learning and build upon students' Information and Communications Technology (ICT) skills (Samaniego Erazo et al., 2015, Del Blanco et al., 2010). Arising from early pioneers such as Baltra (Baltra, 1990), the use of digital video games may offer an effective method to deliver SCL techniques through the connections between DGBL principles such as *Player Identity* and SCL tenets such as *Deep Learning and Understanding* inside and outside the classroom (Gee, 2005, Lea et al., 2003).

In his work on DGBL, Gee establishes that good games, by their very nature, deliver high quality learning, teaching players through gameplay the skills they need to complete the game, although not necessarily traditional educational content (Gee, 2003). His works, alongside those of other researchers, identify that high quality games are able to use a variety of techniques, such as building *Cycles of Expertise* and *Sandbox Learning*, to teach players the knowledge and skills they require in order to succeed at and eventually complete the game (Hamari et al., 2016, Gee, 2005). Gee suggests that good quality digital video games deliver a high quality learning experience, thereby maximising the quality of learning outcomes (Gee, 2005).

Many attempts have been made to harness the learning potential of games to deliver educational content in areas such as Mathematics and Language and Sciences (Abdul Jabbar and Felicia, 2015). However, as with traditional teaching techniques, there is a need for a pedagogical underpinning upon which to base the design and utilisation of educational games (Tang et al., 2009). The use of SCL, as an effective group of teaching techniques, provides one such potential underpinning that has become increasingly a part of the delivery of teaching and learning within institutions (Krahenbuhl, 2016). SCL has been shown to benefit student

motivation (Nichols and Miller, 1994, Urdan and Schoenfelder, 2006), independence (The Scottish Government, 2009, Motschnig-Pitrik and Holzinger, 2002, Bonk and Cunningham, 1998, Clements and Battista, 1990), responsibility (Corno, 1992) and flexibility (Gabel and Bunce, 1994, Ward-Penny, 2010, Taber, 2009). The use of SCL to provide this pedagogical underpinning to DGBL, comprising SCDGBL, could therefore facilitate effective delivery of educational content through the medium of digital video games.

As with many services, the education sector faces increasing pressure to perform at an ever-higher level. Increasing student numbers at university and global competition encourages the delivery of higher trained, more well equipped students (Marginson, 2006). Meanwhile, societal pressures push teaching towards developing social skills alongside their learning through greater peer interaction, and understanding the real-world applications of their learning. Alongside this are increasing calls for an ever higher degree of ICT literacy in students (Samaniego Erazo et al., 2015), needed to participate and compete in the workplace. SCDGBL could provide an important vehicle to address this, and reviews have been conducted on SCL (Rocca, 2010, Din and Wheatley, 2007) and DGBL (Abdul Jabbar and Felicia, 2015) as separate entities. However, it is difficult to assess how well existing Digital Game-Based Learning delivers key tenets of SCL due to the absence of reviews covering SCDGBL as an entity in its own right. Subsequently, a state of the art review on this would be timely and valuable to the SCDGBL research domain.

The remainder of this chapter is organised as follows, in section 2.2, the role of games as a vehicle for SCL will be explored, and the key concepts of DGBL and SCL broken down for presentation and conceptually linked, providing a starting point for conceptual framework that guides the analysis of papers identified in the literature review. In section 2.3, the literature identification, retrieval and thematic analysis process leading to the development of the conceptual framework is detailed. Section 2.4 follows on from this, wherein the conceptual framework is presented as developed from identified themes and scaffolded by the key concepts of SCDGBL. Conceptual frameworks aim to structure a presentation, in this case papers from a literature search, based upon a set of broad ideas and principles taken from relevant fields of enquiry (Reichel and Ramey, 1987). For this chapter, the two relevant fields are SCL and DGBL, in order to frame papers that combine both fields with equal weighting to form SCDGBL. In section 2.5, the use of this framework to systematically organise and present findings from the literature review will identify more clearly both areas of strength, and areas where interventions or game design can be adapted to better integrate both fields and deliver more effective and engaging learning. Section 2.6 delivers insights and reflections on the state-of-the-art in SCDGBL literature based upon the findings from section 2.5, culminating in a series of recommendations for future work in the area of SCDGBL, presented in section

2.6.4. Section 2.7 then provides a summary of the work done within the chapter, findings and suggestions.

2.2 Background: Key Concepts of Student Centred Digital Game Based Learning.

This section presents the concepts that make up Student Centred Digital Game-Based Learning, exploring first Digital Game-Based Learning and the principles behind it. This is followed by an exploration of Student Centred Learning and the tenets and techniques within it, leading to a presentation of the links between Student Centred and Digital Game-Based Learning.

2.2.1 Digital Game Based Learning

In examining the use of digital video games in DGBL, Gee broke down his ideas on aspects of gaming that deliver effective learning into thirteen principles, encompassed by three areas: *Learner Empowerment*, *Problem Solving* and *Understanding* (Gee, 2003). These are described in Table 1 and are referred to as DGBL principles throughout this work.

Table 1: Gee's thirteen design principles for Digital Game Based Learning.

	Principle
Learner Empowerment	P1: Co Design
	P2: Customisation
	P3: Player Identity
	P4: Manipulation
Problem Solving	P5: Ordered Problems
	P6: Pleasantly Frustrating
	P7: Cycles of Expertise
	P8: Information Provision
	P9: Fish Tank Learning
	P10: Sandbox Learning
	P11: Skills as Strategies
Understanding	P12: Systems Thinking
	P13: Meaning from Experience

With regards to ***Learner Empowerment***, the first principle, *Co-design*, relates to giving players the feeling that their choices are the primary driving force behind the experience they are having. *Customisation* is the principle of players being able to make decisions about the way in which they play the game. *Player Identity* is established through embodying someone in a situation, thus the lessons from that situation become personally relevant. *Manipulation* represents taking actions that affect the world, offering opportunities to bring the player closer to the experiences the game is mirroring. The DGBL principle of *Co-design* merits further clarification. This principle refers to giving players of a game the feeling that the choices they

make during gameplay are the primary definer of the experience they have within the game (Gee, 2003). This principle refers specifically to self-determination within the game and is not directly connected to the definition of co-design from a software development perspective which involves incorporating students during the design of the game itself. Within this work, the definition of co-design as presented by Gee and related to students in-game experience only will be utilised.

Within ***Problem Solving***, the principle of *Ordered Problems* relates to the idea that people lose interest if faced with something too far beyond their ability to solve, through complexity or lack of understanding. Ideal problems for both players and learners are those that are just towards the limits of where they are comfortable, conceptualised as *Pleasantly Frustrating*. *Cycles of Expertise* describes the cycle of a learner picking up a new skill, practising until the skill becomes second nature to them and then having a challenge that requires the skill to be adapted. *Information Provision* represents the idea that information in games is often provided either just in time for the player to make use of it, or on demand so the player can draw upon it at need. *Fish Tank Learning* is the principle used to allow experimentation with a concept or mechanic in games, without the stresses that may impact the visibility of this effect. *Sandbox Learning* provides an area of the game for experimentation and learning, but where it is difficult for things to go very far wrong. The final principle is that of *Skills as Strategies*, which brings skill practice into the strategy of the game, such that a player or learner is able to feel they are gaining an edge and progressing through the game.

Lastly, ***Understanding*** embodies two principles: *Systems Thinking*, which relates to fitting the skills and ideas the game conveys as meaningful elements of the game world; and *Meaning From Experience*, which considers that learning occurs best when filtered through the experiences a learner has had.

It can be clearly seen that the overarching areas of *Learner Empowerment*, *Problem Solving* and *Understanding* have a strong link to SCL as based on the consensus definition (Attard et al., 2010) given above. However, the aim of this chapter is to evaluate SCDGBL literature, through giving both concepts equal weighting. In order to organise concepts relating to SCL and map their connections to DGBL, it is important to break down the broad consensus definition (Attard et al., 2010), which contains multiple facets and methods of delivery, into key elements.

2.2.2 Student Centred Learning

Lea et al. (Lea et al., 2003) identified seven key tenets of SCL that comprehensively represent the student-centred experience:

- *Active Learning (AL)* - Active learning utilises techniques that involve learners engaging and interacting with material on a level beyond simply cognitive processing.
- *Deep Learning and Understanding (DL)* - The concept of deep learning and understanding offers opportunities for students to better internalise learning and connect it to concepts, characters and experiences, rather than isolating a learning experience from its context and presenting it for its own sake.
- *Increased Responsibility and Accountability (IR)* – A responsible student may be described as one who understands and accepts their role as an independent learner (Corno, 1992), thereby becoming accountable within this role. Such students are more able to engage in an active learning partnership with the teacher, as both understand the learning goals and can seek ways to achieve those goals (Corno, 1992).
- *Sense of Autonomy (SA)* – Student independence and autonomy are two major goals of the constructivist philosophy SCL is derived from (Clements and Battista, 1990). An independent student has the ability to seek out further knowledge and develop their skills on their own. Providing students with a sense of autonomy shifts the roles of teachers and lecturers towards facilitating the activity of the learner (Motschnig-Pitrik and Holzinger, 2002, Bonk and Cunningham, 1998).
- *Teacher and Learner Interdependence (ID)* - A teacher may provide a human face to the learning that occurs in a classroom, being someone students can seek assistance from and who can answer questions or solve problems, and student centred strategies can draw from this strength.
- *Mutual Respect (MR)* – The respect built allows students to learn from each other, and helps a teacher gain an accurate understanding of their student's ability while encouraging students to seek help and assistance, or share success
- *Reflexive Approach to Teaching and Learning (RA)* – Teachers and learners look back over work undertaken with a view to the efficiency of that learning and the reasons behind it. It enables the student to consider the processes behind their own best learning experiences, in order to answer the question 'How do I learn?', and teachers to iterate upon these processes in response to the student's needs.

These tenets of SCL, represented by the above acronyms in tables throughout this work, provide a suitable structure for conceptual linkage into areas of videogame design as explored by Gee (Table 1). Table 2 provides the linkage between these DGBL principles and the tenets of SCL defined by Lea et al. (Lea et al., 2003), along with the rationale for such linkage. An important consideration alongside this table is that the tenet of *Active Learning* in particular has received further research attention since Lea et al.'s work (Lea et al., 2003). As such, this area merits additional focus to ensure adequate exploration within this review.

Table 2: Links between Digital Game-Based Learning Principles and Student Centred Learning tenets.

Principle	**SCL Relationships**	**Rationale for Linkage**
P1: Co Design	SA, AL	This principle requires students to have a degree of autonomy necessary to make the choices that drive their in-game experience. Decision-making and the implementation of decisions within the game world are by nature active processes.
P2: Customisation	SA, RA, MR	That a player may make decisions about the way they play the game necessitates the player having the autonomy to make those decisions. A student making such decisions is encouraged to reflect upon these decision points, with a view to improving their gameplay and the learning obtained through it. Further opportunities to approach challenges in different ways are gained from the interaction with other students and therefore the ability to explore multi-student approaches.
P3: Player Identity	DL	Through taking on a role within the game, a player's interactions and experiences become less distant and more personal. Learning gained through these interactions may feel more practical and experiential.
P4: Manipulation	AL, DL	Learning through actions taken speaks to the core concept of Active Learning. The information gained from such actions becomes less something the student was told and more something they have discovered, and are given the opportunity to internalise themselves.
P5: Ordered Problems	SA	Effective implementation of ordered problems allows the student to hone their skills, including knowledge and understanding as they practice and progress at their own pace. This individual progression indirectly provides learners a sense of control.
P6: Pleasantly Frustrating	SA, IR	Surmounting an objective at the limit of a student's skill-based comfort zone provides a student a recognition of this personal achievement, which promotes autonomy. Such a well-placed objective makes a student aware they are capable of achieving it should they stretch their skills, inherently placing the responsibility to do so upon that student.
P7: Cycles of Expertise	RA	In adapting to a new challenge, the student is prompted to reflect upon the skill they have learned and consider ways in which it may be adapted. When encountering a new skill, the student is then aware that the skill will be expanded upon and is encouraged to consider how best to approach it.
P8: Information Provision	SA, ID, RA	Having information provided as students are about to or wish to use it allows them to implement it without seeking further explanation, thereby appearing to students as if they have solved the problem without help. Bringing teachers into the game world may allow teachers to take an active part in a student's activities on a similar level, without breaking student concentration. The ability to look back upon information gained and use that as revision tool and a tool by which to gauge progress fosters reflection.
P9: Fish Tank Learning	AL	The experimentation with concepts and mechanics is a clear implementation of Active Learning.
P10: Sandbox Learning	IR	Within a sandbox, the responsibility to experiment and learn falls upon the student, in these areas, students receive little or no prompting and are able to adopt an exploratory role and set challenges or discover boundaries for themselves.
P11: Skills as Strategies	AL, DL, SA	Practicing skills and implementing strategies requires the student to take an active role. That the learning forms a part of the strategy and progression of the game means the student is internalising this towards an immediate purpose, rather than learning for its own sake. The student individually coming up with a strategy based upon their learning engenders a sense of personal control.
P12: Systems Thinking	AL (Problem-Based Learning), DL	The skills and ideas being meaningful elements of the game world gives them deeper meaning to the student than surface level facts. For the skills and ideas to be meaningful elements that are learned implies strongly that the challenges a student faces requires the application of these skills.
P13: Meaning from Experience	DL, IR, SA	Associating learning with experience speaks to the core principles of Deep Learning and Understanding. The personal nature of the experience gained gives students a level of accountability for the choices made within that experience. This accountability prompts students to consider how they may have made alternative choices, promoting a sense of autonomy.

SCL tenet acronyms: Active Learning (AL), Deep Learning and Understanding (DL), Increased Responsibility and Accountability (IR), Sense of Autonomy (SA), Teacher and Learner Interdependence (ID), Mutual Respect (MR), Reflexive Approach to Teaching and Learning (RA)

Later work on the concept of *Active Learning* has broken this tenet down further, highlighting a number of nested techniques that deliver the concept; techniques include Problem-Based Learning and Peer-Assisted Learning approaches such as Peer Tutoring, Collaborative Learning and Cooperative Learning, which are briefly defined and their benefits stated in Table 3. The interlocking and nested nature of these techniques is demonstrated in Figure 1 (Bishop and Verleger, 2013), for example, Problem-Based Learning is frequently achieved through group work utilising Peer-Assisted Learning approaches (Bishop and Verleger, 2013). In Figure 2, Cooperative Learning is nested within Collaborative Learning as a more structured approach with defined roles (Bishop and Verleger, 2013), although still distinct in identity (Bruffee, 1995).

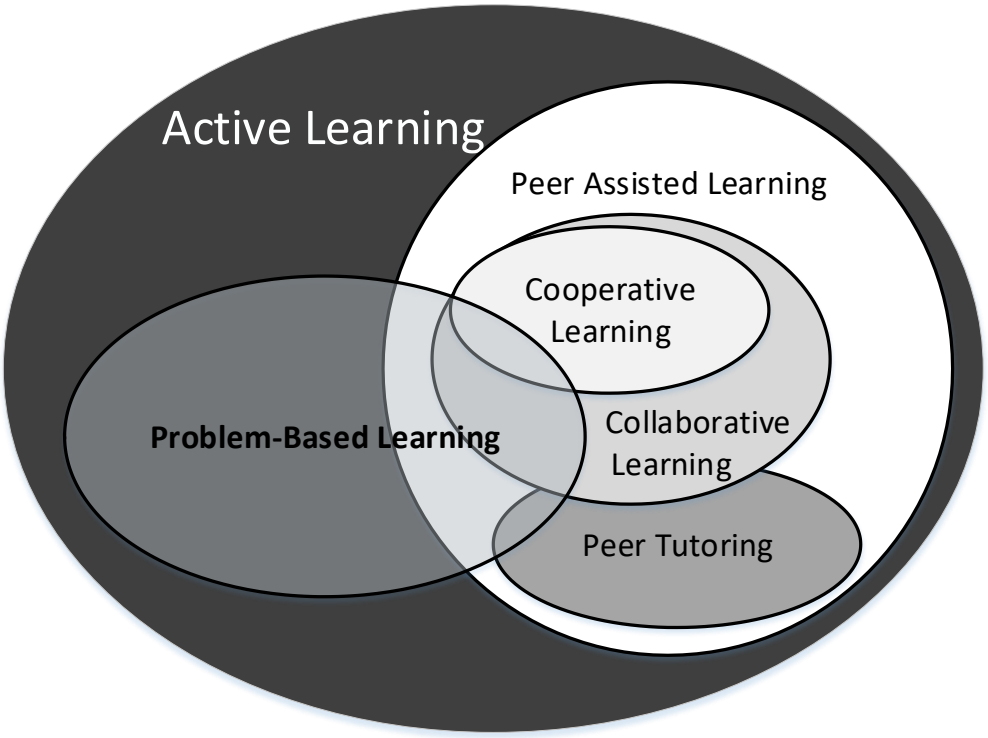

Figure 2: Relationships between SCL Theories and Methods, adapted from Bishop and Verleger (Bishop and Verleger, 2013).

Having presented the key tenets of SCL and conceptually linked them with the design principles for DGBL, this formulates the lens through which to assess the literature in the area of SCDGBL. The strategy and analysis for this literature review will now be presented, leading to the conceptual framework developed from the thematic analysis.

Table 3: Definitions and benefits of Active Learning techniques.

Active Learning Technique	Definition	Student benefits
Problem Based Learning	Providing a problem or challenge to the learner that becomes the stimulus for them to learn or implement new skills. New information is gathered through an element of self-directed learning while the role of the teacher is that of a facilitator or guide (Barrows, 1996).	*Motivation:* Giving students a reason to complete work as they relate the problem and solution to a real world context (Ames, 1992, Sungur and Tekkaya, 2006) (Wijnia et al., 2011) *Responsibility:* Allowing students to understand what could go wrong in a real situation if done incorrectly *Independence and Flexibility:* Allowing students enough space to find their own way to an answer.
Peer-Assisted Learning	An umbrella term for all learning involving peers. It represents a base level of learning in which participants of similar status (identifying as learners rather than teachers, albeit different levels or ages) help and support one another in their learning. This encompasses peer tutoring, collaborative learning and cooperative learning.	*Flexibility:* Students learn to deal with each other in a work capacity *Independence:* Students learn their personal strengths and how they can contribute.
Peer Tutoring	Students work in pairs or groups, with one (often older) student taking on an element of a teaching role to explain concepts or demonstrate techniques to the more inexperienced students within the group. It is in place as an educational technique in a large number of institutions worldwide with strong results (Topping, 1996)	*Responsibility:* Tutoring students appreciate the role they have to the learners *Flexibility:* Students come to appreciate different ways of teaching and learning
Collaborative Learning	Makes use of individual accountability within a group situation to promote interdependence within the group (Doolittle, 1995). Implementations may seek to promote group and self-evaluation through social discourse with a goal of allowing student to understand their areas of strength and weakness by examining the world, including themselves, from the perspective of others (Udvani-Solner, 2011).	*Responsibility:* Students take a role within a group and have peers relying on them to complete work. Students learn to self-evaluate from different perspectives. *Flexibility:* Students come to appreciate different ways of teaching and learning *Motivation:* Peer expectations push students forwards
Cooperative Learning	Seeks to develop further a student's help-seeking behaviour, inviting students to consider who or where they may get help from and if there is help they may offer (Bruffee, 1995), it may be promoted through methods such as enforced group roles to encourage students to reach out to others when at the limits of the area their role includes (Bishop and Verleger, 2013).	*Responsibility:* Students take on the role of identifying where and how to ask for assistance and have peers relying on them to complete work. *Independence:* Students seek ways to get and offer help.

2.3 Determining the State of the Art within Student Centred Digital Game Based Learning Literature

This section covers the exploration and literature collection process used to identify and analyse the state of the art in SCDGBL literature, from which to develop the framework. The search terms and inclusion criteria are presented, followed by an explanation of the analysis process.

2.3.1 Identification of Papers

A systematic literature search was carried out in the area of Digital Game Based Learning and Student Centred Learning. The paper selection process for this literature search is presented in Figure 3.

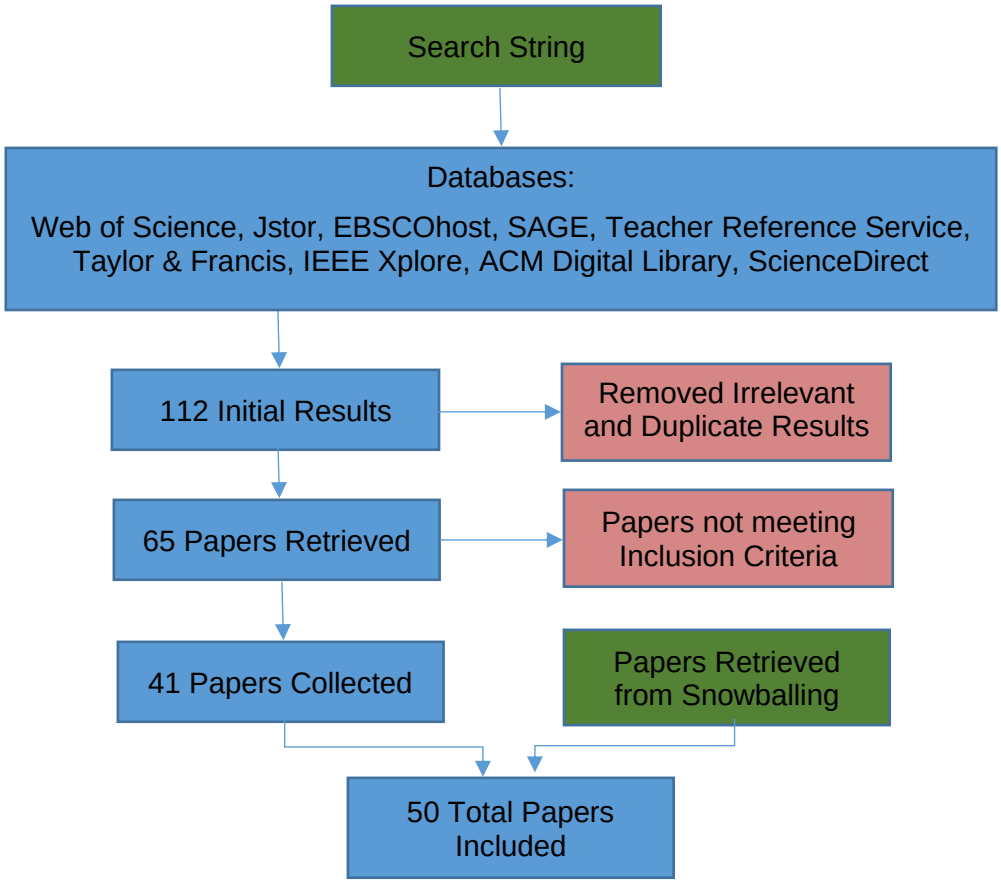

Figure 3: Paper selection process for the systematic literature review

The following databases were searched: Web of Science, Jstor, EBSCOhost, SAGE, Teacher Reference Service, Taylor & Francis, IEEE Xplore, ACM Digital Library and ScienceDirect. The list of databases was drawn up through an examination of previous literature reviews within this and related fields to locate the databases deemed relevant to those aspects and an examination of popular published papers to identify key journals where databases were sought that included those publications. The database list includes databases that focus on

both the technical and computing aspects, such as IEEE Xplore, and those that focused on the education and social science aspects, to ensure both approaches to this inter-disciplinary field were taken into account.

2.3.2 Development of a search string

While the term Digital Game Based Learning has achieved some recognition in recent years, it is far from being a ubiquitous term within the field. In particular, given the pace of research within education, a number of relevant papers were written before this term came to prominence and to exclude these papers through key wording was felt not to do justice to the state of research within the field. For this reason a number of key phrases and words believed to be representative of Digital Game Based Learning were used in order to draw out the scope of the literature. Results were limited to those that made some mention of a student centred approach to avoid comparing papers seeking wildly differing things, such as those that may be based on alternative educational theories and that may look for a different definition of success. A number of terms were considered but not included as they yield results that may be misleading, this includes permutations of the term “Serious Games” which while including many digital games also includes traditional board games. Papers which included the term serious games were not excluded from the results but the term itself was not a part of the search string. Search terms are presented in US English as it is the most commonly used however expanders were used to identify permutations such as plurals or British spellings within the literature.

With these factors in mind, the search string applied was:

("game based" OR “game-based”) AND ("student centred" OR "student-centred") AND ("computer game" OR "video game" OR "online game")

The abstracts of papers located were examined, and those that were found to be obviously unrelated were discarded. The remaining papers were then downloaded and examined. Papers that dealt with non-digital interventions were excluded following this examination, similarly previous literature reviews were removed from the pool of papers to be categorised but retained for further information. Finally a snowballing process was undertaken to find further papers referenced or referencing those located, that met the inclusion criteria.

2.3.2.1 Inclusion Criteria

Papers included within the final literature sample met a number of criteria:

The paper must reference or demonstrate the utilisation of SCL concepts. The focus of this review on SCL as a pedagogical grounding for DGBL mandated an exploration of such within the papers addressed.

The paper must be based around or include Game-Based Learning, and the games addressed must be digital in nature. While a variety of different games on different platforms were considered it was felt inappropriate to use or compare non-digital games.

The paper must have been published since 2007. Within the last ten years significant changes to both the education and computing fields have occurred, and it was felt that the current landscape, in terms of technology available within a modern-day school, made comparisons before this date of rapidly less relevance to games used today. The initial search was conducted in October 2017 including papers published up to September of that year. The literature search was updated in July 2018 prior to submission for publication including papers published up to June 2018.

2.3.3 Analysis Strategy

Following the identification of a dataset above, a thematic analysis was carried out to draw out the common themes arising within the papers. This technique involves the categorisation of common ideas and discussion points within papers to identify and categorise areas of similarity (Crabtree and Miller, 1992). Papers were analysed and sections relating to a particular topic were given a code.

Themes were derived based upon the codes using a hybrid approach of both inductive and deductive analysis. This approach provides an initial framework for the coding process while allowing for the development of themes through an iterative process while reflecting upon the identified common elements (Fereday and Muir-Cochrane, 2006). The initial themes were drawn from the design principles of DGBL (Gee, 2003) and the tenets of SCL (Lea et al., 2003), allowing both techniques in game design and in teaching to be considered with equal weighting, and categorised under one or more of these deductive themes. This hybrid approach allows exploration of the extent to which current SCDGBL literature delivers on the tenets of SCL and the DGBL principles by which this delivery is achieved, while also allowing consideration of other common game design and educational themes as inductively derived from the literature crossing both fields.

The codes were examined and links between them identified, assisted by the conceptual linkage between DGBL and SCL as formulated in Table 2. These links allowed the transition from codes identifying a certain aspect, to themes exploring a similar idea within the literature. Some codes were applied directly into the pre-existing themes while in other cases new themes were created on an inductive basis. Through an iterative process codes were transitioned into themes directly, or combined as subthemes within a larger theme. During this period both deductive and emerging themes were considered in the broader viewpoints of

Student Centred Learning and Game Based Learning to tie them to existing literature where appropriate.

The results of this were considered alongside existing literature reviews on related areas and the conceptual framework presented below drawn up from the results. This framework organises and displays the Student Centred Digital Game-Based Learning landscape as it currently exists, represented by the current literature in the field. The conceptual framework will now be presented, along with an explanation of how it was derived from the thematic analysis.

2.4 Conceptual Framework for Student Centred Digital Game-Based Learning

The overall framework structure is presented in Figure 4, with further detail explained below.

Firstly, SCDGBL interventions described in the literature can be stratified using the conceptual framework according to the *Player Engagement*, *Intervention Type* and *Game Design* categories. These categories represent common themes inductively derived from the SCDGBL literature review.

Player Engagement describes the number of players engaged in a single game world, which was a strong emerging theme and was considered particularly important due to the strong role of Peer-Assisted Learning within SCL.

Intervention Type covers the description of papers by the design of the intervention undertaken. It includes a number of elements found to be common delineators between types of research undertaken. *Study Setting* includes the elements of education *Level* (Primary, 4-11 years, Secondary, 11-18 years, Tertiary, 19+ years) which was prominent within the literature due to foreseeable impacts on game content and complexity. *Situation* describes the physical setting of the intervention, inside/outside the classroom required consideration for practical application/deployment of interventions (Kern and Carpenter, 1986). *Study Type* was incorporated to assess validity and generalisability, comprising the Data Type collected (Qualitative, Quantitative or Mixed Methods) while *Study Design* describes the approach taken to participants (Cohort Study, Focus Group or Case Study).

Game Design addresses aspects of game design not covered by the 13 principles that emerged as themes. This grouping includes the *Platform* the intervention was designed for, which has relevance to the practical application/deployment as well as the use of emerging technologies such as virtual or augmented reality. *Development Style* denotes the source of the game, split between those that used games designed solely for an educational purpose, those that used games designed primarily as commercial/entertainment software and those

studies that utilised both typed. This delineation may be relevant as education-led developments are likely to have differing goals vs commercial-led.

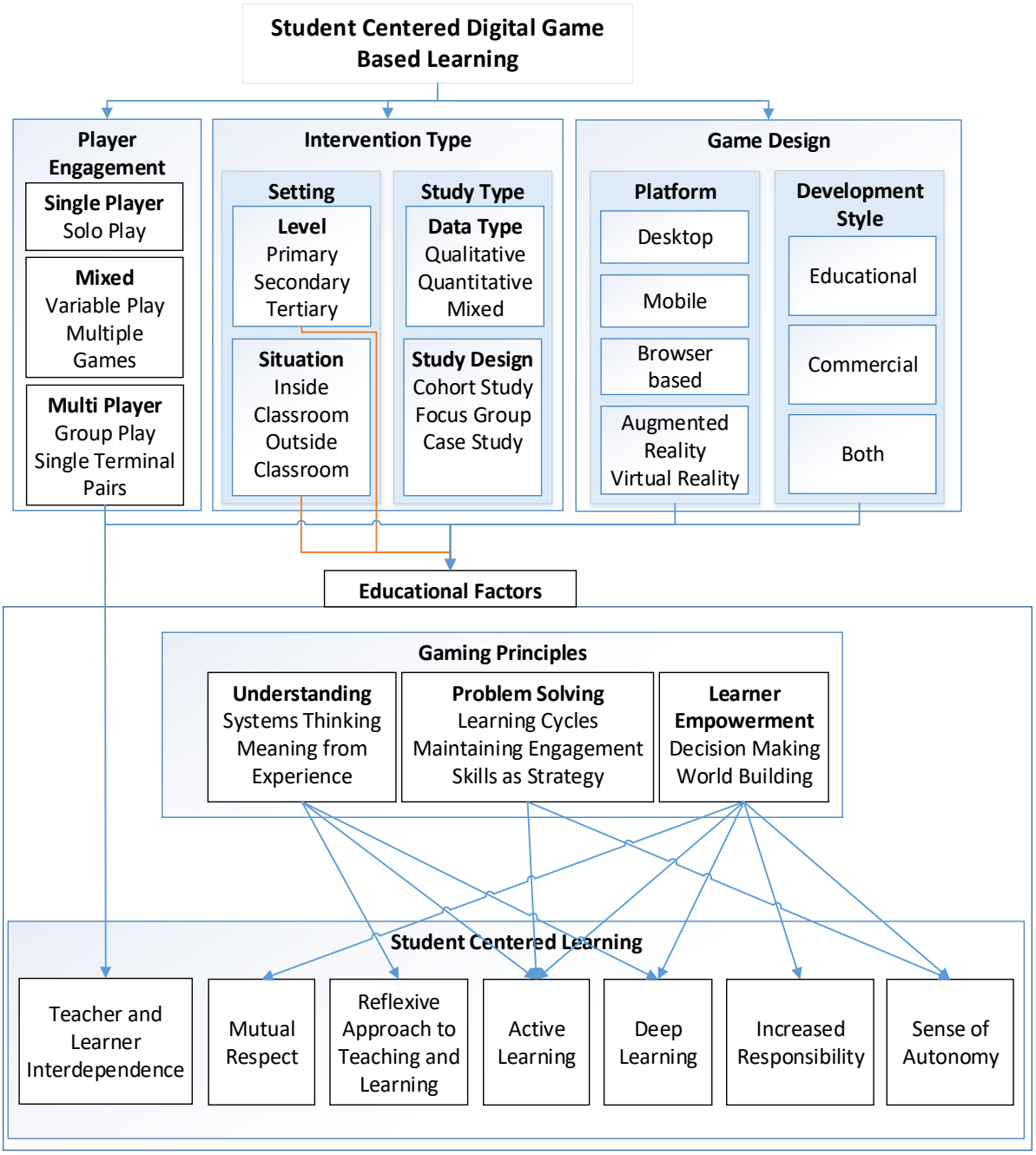

Figure 4: Conceptual Framework for Student Centred Digital Game Based Learning

These additional layers of stratification for SCDGBL interventions feed directly into the level of integration of both concepts, and therefore the conceptual framework presents these first. The interventions can subsequently be evaluated according to the second part of the conceptual framework: *Educational Factors*.

Educational Factors encompass deductive themes informed by Gee's design principles for DGBL, and Lea et al.'s SCL tenets, while considering the key relationships between the two

concepts. Organising the literature by these inductive and deductive themes as presented within the conceptual framework enables consideration of the extent to which SCDGBL interventions deliver on these key components.

Gaming Principles recategorizes the design principles for DGBL as explored by Gee for easier display within the framework and resulting tables: The *Understanding* sub-category remains as originally presented. Within the *Problem Solving* sub-category, *Learning Cycles* combines the principles of *Ordered Problems* and *Cycles of Expertise*, as both principles describe ways to encourage continued learning and game participation by providing students with cycles of learning. *Maintaining Engagement* combines the principles of *Pleasant Frustration*, *Fish Tank Learning*, *Information Provision* and *Sandbox Learning*. These are all intended to alleviate frustration in players/students to maintain long-term engagement, ensuring deeper learning. Within the *Learner Empowerment* sub-category, *Co-Design* and *Customisability* are grouped under *Decision Making*, as both relate to encouraging and allowing students to make decisions before and during the game. *Player Identity* and *Manipulation* were grouped together as *World Building*, as they relate to ways players are made to feel closer and more involved with the game, and the deeper embedded learning to be gained from doing so.

Each of these sub categories is linked to the SCL tenets they were found to most closely connect to. While it is acknowledged that it is possible to find further links between principles and tenets, these are the primary links which emerged from the literature and have been identified within *Table 2*. This allows for the identification of these tenets as having been addressed and integrated within the literature.

Having presented the conceptual framework, it will now be used to systematically organise and present the findings from the literature review for subsequent synthesis and discussion.

2.5 Results

These papers were examined and categorised as explored in Figure 3. Results are tabulated according to Player Engagement category, and then stratified within each table according to the first level of the Game Type (Group), Study Type (Data Type) and Setting (Level) categories, denoted in italics. This enables easy recognition of qualitative, quantitative, mixed method and theoretical studies (separated by thicker borders), and then identification of relevant studies within primary, secondary and tertiary academic levels through shading (primary and tertiary level studies are shaded). This demonstrates how the conceptual framework can be used to organise and present the literature for ease of evaluation. For each Player Engagement category, results will now be presented according to the above categories, and the level of representation of the DGBL principles by overarching area as detailed in section 2.2.1, and SCL tenets detailed in section 2.2.2.

2.5.1 Single Player

Table 4 presents studies (n = 26) that discussed or utilised exclusively single player games with a Student Centred Learning basis. The remainder of this section explores the key characteristics of these studies.

2.5.1.1 Game Type

This category includes a variety of different types of games, ranging from simulation for use in medical training (Monteiro et al., 2011) and collections of mini-games designed to teach a specific element (Garcia and Pacheco, 2013) to exploration games where the player is offered a world to explore (Diah et al., 2012).

The majority of papers within this table dealt with educational games (E) (So, 2012, Neville et al., 2009, Kiger et al., 2012, Baytak and Land, 2011, Annetta et al., 2013, Monteiro et al., 2011, ter Vrugte et al., 2017, Seng and Yatim, 2014, Hwang et al., 2015, Hwang et al., 2013, Peng et al., 2017, Bowen et al., 2014, Su and Cheng, 2013, Liu and Chu, 2010, Diah et al., 2012, Shafie and Ahmad, 2010, Yang et al., 2010, Garcia and Pacheco, 2013, Norton et al., 2008, Wang et al., 2018, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018). Many appear to have been designed exclusively for the research study, e.g. 'MathQuest' (Shafie and Ahmad, 2010) which targeted 10-11 year old students to provide mathematics education blended with an immersive roleplaying experience. Others utilised pre-existing educational games, e.g. mobile learning applications (Kiger et al., 2012). However, some commercial games (C) were used to achieve research aims (Shahriarpour, 2014, Lin and Lin, 2014, Boutsika, 2014), either adapted using packaged tools to better fit the needs of the classroom, or presented as is, e.g. use of SimCity (Lin and Lin, 2014) to investigate which elements of the game were stimulating learning and understanding in university students. The remaining paper used both (B) educational and commercial games in discussion on the effect of increased gaming within classrooms and schools (Bate et al., 2014), focusing on the broader effect of accessible gaming in a school environment (Bate et al., 2014).

Table 4: Single Player Games

Author(s) n = 26	Game Type			Study type		Setting		Student Centred Learning							Digital Game-based Learning						
															Learner Emp		Problem Solving			Understanding	
	Group	Development	Games Platform	*Data Type*	Study Design	*Level*	Situation	Active Learning	Deep Learning and Understanding	Increased Responsibility and Accountability	Sense of Autonomy	Teacher and Learner Interdependence	Mutual Respect	Reflexive Approach to Teaching and Learning	Decision Making	World Building	Learning Cycles	Maintain Engagement	Skills as Strategy	Systems Thinking	Meaning From Experience
Baytak and Land (Baytak and Land,	S	E	D	L	A	P	-	P,A	√			√	√	√				P,F,S			
Shafie and Ahmad (Shafie and Ahmad,	S	E	D	L	A	P	O	√			√				√	√	√	P,F			√
So (So, 2012)	S	E	D	L	A	P	I	-	-	-	-	-	-	-				I,F,S			
Bate et al. (Bate et al., 2014)	S	B	D	L	O	S	I			√	√	√	√	√	√	√	√	I,F	√	√	√
Bowen et al. (Bowen et al., 2014)	S	E	B	L	F	S	I	P	√	√	√				√	√					√
Shahriarpour (Shahriarpour, 2014)	S	C	D	L	O	S	I	√	√						√	√	√	F			√
Lin and Lin (Lin and Lin, 2014)	S	C	D	L	A	T	I	√	√	√	√				√	√		F,S	√	√	√
Seng and Yatim (Seng and Yatim, 2014)	S	E	D	L	A	T	I	√		√	√					√	√	P,F			
Peng et al. (Peng et al., 2017)	S	E	D	L	A	T+	I	P	√		√				√	√		S		√	√
Garcia and Pacheco (Garcia and	S	E	D	M	O	P	I	P	√		√				√	√	√	P,I,F			
Hwang et al. (Hwang et al., 2013)	S	E	D	M	O	P	I	P		√	√			√	√	√	√	I,F			√
Hwang et al. (Hwang et al., 2015)	S	E	D	M	O	P	I	P		√	√				√	√	√	I,F			√
Khamparia & Pandey (Khamparia and	S	E	D	M	O	P	O	P		√	√				√			P,I,F			
Wang et al. (Wang et al., 2018)	S	E	D	M	O	P	I	P	√	√					√	√	√	P			√
Yang et al. (Yang et al., 2010)	S	E	V	M	O	P	I	P				√			√	√	√	F			√
Annetta et al. (Annetta et al., 2013)	S	E	D	M	O	S	I	√		√				√	√	√	√	I			
Liu and Chu (Liu and Chu, 2010)	S	E	D	M	O	S	I	P	√	√					√	√		I,S			√
Ameerbakhsha et al (Ameerbakhsh et	S	E	D	M	A	T	O	P	√	√	√				√	√		P,I	√	√	√
Neville et al. (Neville et al., 2009)	S	E	D	M	O	T	O	√	√		√				√	√	√	I			√
Kiger et al. (Kiger et al., 2012)	S	E	M	N	O	P	I	P				√			√	√	√	I	√	√	
Su and Cheng (Su and Cheng, 2013)	S	E	M	N	O	P	I	√	√	√	√				√	√		I,S			√
ter Vrugte et al. (ter Vrugte et al.,	S	E	D	N	O	S	O	√			√				√	√	√	P,F,S			√
Diah et al. (Diah et al., 2012)	S	E	D	T	-	P	-	P		√					√	√	√				
Boutsika (Boutsika, 2014)	S	C	A	T	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Monteiro et al. (Monteiro et al., 2011)	S	E	D	T	-	T	I	P	√	√	√					√	√	P			√
Norton et al. (Norton et al., 2008)	S	E	V	T	-	T+	-	P	√	√	√				√	√		I,S			√
Frequencies	26	E: 22 C: 3 B: 1	D: 20 B: 1 M: 2 V: 2 A: 1	L: 9 M: 10 N: 3 T: 4	A: 7 O: 14 F: 1 -: 4	P: 12 S: 6 T: 5 T+: 2 A: 1	O: 5 I: 17 -: 4	P: 15 A: 1 √: 8 -: 2	√: 13	√: 15	√: 16	√: 4	√: 2	√: 4	√: 21	√: 22	√: 15	P: 9 F: 13 S: 8 I: 13	√: 4	√: 5	√: 17

Key: Group - (S)ingle player; Development - (E)ducation, (C)ommercial, (B)oth; Platform - (D)esktop, (B)rowser-based, (A)ugmented Reality, (V)irtual Reality, (M)obile; Data Type - (M)ixed methods, Qua(L)itative, Qua(N)itative, (T)heoretical; Study Design - C(A)se study, (F)ocus group, C(O)hort; Level - (P)rimary, (S)econdary, (T)ertiary; Setting - (O)utside classroom, (I)nside classroom; Active Learning - (P)roblem based learning, Peer (A)ssisted learning; Maintain Engagement - (P)leasantly frustrating, (I)nformation provision, (F)ishtank Learning, (S)andbox Practice; √ = Exemplified; blank = not exemplified, - = not possible due to being a theoretical paper.

The majority of single-player games were Desktop (D) games (So, 2012, Neville et al., 2009, Bate et al., 2014, Baytak and Land, 2011, Annetta et al., 2013, Monteiro et al., 2011, ter Vrugte et al., 2017, Shahriarpour, 2014, Seng and Yatim, 2014, Hwang et al., 2015, Hwang et al., 2013, Peng et al., 2017, Liu and Chu, 2010, Diah et al., 2012, Lin and Lin, 2014, Shafie and Ahmad, 2010, Garcia and Pacheco, 2013, Wang et al., 2018, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018). Studies using these kind of games include an investigation into the effect of embedding concept maps which utilised desktop systems with 11 year old pupils (Hwang et al., 2013) and discussion on the development and deployment of a game to teach resuscitation as part of a university course (Monteiro et al., 2011). A single Browser-based (B) game, "Green Acres High" (Bowen et al., 2014) was separated out as it was possible to identify the game as such (Bowen et al., 2014). Mobile games (M) were also under-represented in the table (Kiger et al., 2012, Su and Cheng, 2013), with one study making use of a wide selection of maths based applications available on Apple devices (Kiger et al., 2012). A small number of games were using emerging technologies such as Augmented Reality (A) (Boutsika, 2014) and Virtual Reality (V) technology (Yang et al., 2010, Norton et al., 2008). These technologies may utilise desktop, console or mobile platforms in order deliver a different experience, e.g. utilising Microsoft's Kinect system to deliver interactive tailored learning to autism sufferers (Boutsika, 2014). This includes educational simulations, e.g. replicating a chemical plant within an education environment for both undergraduate university students and plant staff (Norton et al., 2008).

2.5.1.2 Study Type

Studies in this table collected primarily qualitative data (So, 2012, Bate et al., 2014, Baytak and Land, 2011, Shahriarpour, 2014, Seng and Yatim, 2014, Peng et al., 2017, Bowen et al., 2014, Lin and Lin, 2014, Shafie and Ahmad, 2010), such as interviews (Baytak and Land, 2011) or survey free-text responses (Bate et al., 2014). Mixed methods were also well represented (Neville et al., 2009, Annetta et al., 2013, Hwang et al., 2015, Hwang et al., 2013, Liu and Chu, 2010, Yang et al., 2010, Garcia and Pacheco, 2013, Wang et al., 2018, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018). A small number of studies (Kiger et al., 2012, Su and Cheng, 2013) collected primarily quantitative data, e.g. class test data to analyse the intervention effects (Su and Cheng, 2013) or questionnaire data (Kiger et al., 2012). The final category was a small number of purely theoretical papers (Monteiro et al., 2011, ter Vrugte et al., 2017, Diah et al., 2012, Boutsika, 2014, Norton et al., 2008), where no intervention was performed, however new ideas were proposed that may form a basis for future studies; e.g. one paper discussed creation of a recycling themed educational game, without data to demonstrate its effectiveness (Diah et al., 2012).

Cohort studies made up the largest group of study designs (Neville et al., 2009, Kiger et al., 2012, Bate et al., 2014, Annetta et al., 2013, ter Vrugte et al., 2017, Shahriarpour, 2014, Hwang et al., 2015, Hwang et al., 2013, Liu and Chu, 2010, Yang et al., 2010, Garcia and Pacheco, 2013, Wang et al., 2018, Khamparia and Pandey, 2018), with larger accompanying sample sizes (ranging from n = 120 (Bate et al., 2014) to n = 15 (Neville et al., 2009)). There were a smaller number of case studies (So, 2012, Baytak and Land, 2011, Seng and Yatim, 2014, Peng et al., 2017, Lin and Lin, 2014, Shafie and Ahmad, 2010, Ameerbakhsh et al., 2018) where assessment was limited to primarily a small group of individuals (So, 2012) or to a single class (Baytak and Land, 2011). A single study employed a focus group design (Bowen et al., 2014).

2.5.1.3 Setting

Many papers addressed Primary age (5-11) students (So, 2012, Kiger et al., 2012, Baytak and Land, 2011, Hwang et al., 2015, Hwang et al., 2013, Su and Cheng, 2013, Diah et al., 2012, Shafie and Ahmad, 2010, Yang et al., 2010, Garcia and Pacheco, 2013, Wang et al., 2018, Khamparia and Pandey, 2018), these included examples that may address the entire primary spectrum (So, 2012) or targeting a particular year group, e.g. aged 10-11 (Hwang et al., 2013). Secondary (11-18) was well represented (Bate et al., 2014, Annetta et al., 2013, ter Vrugte et al., 2017, Shahriarpour, 2014, Bowen et al., 2014, Liu and Chu, 2010), however only one paper attempted longitudinal study over a three year period (Bate et al., 2014), with most studies focusing on a particular class or group within an academic year. Tertiary age (17+) was the focus of another group of papers (Neville et al., 2009, Monteiro et al., 2011, Seng and Yatim, 2014, Peng et al., 2017, Lin and Lin, 2014, Norton et al., 2008, Ameerbakhsh et al., 2018), one of which investigated adult learning alongside university students (Norton et al., 2008).

A majority of studies were undertaken inside the classroom, with attempts made to place the learning within a normal school context (So, 2012, Kiger et al., 2012, Bate et al., 2014, Annetta et al., 2013, Monteiro et al., 2011, Shahriarpour, 2014, Seng and Yatim, 2014, Hwang et al., 2015, Hwang et al., 2013, Peng et al., 2017, Bowen et al., 2014, Su and Cheng, 2013, Liu and Chu, 2010, Lin and Lin, 2014, Yang et al., 2010, Garcia and Pacheco, 2013, Wang et al., 2018). Such studies typically looked to integrate classroom teachers and blend the intervention to preserve the normal school experience for participating students (Hwang et al., 2013, Baytak and Land, 2011). A small number of studies (Neville et al., 2009, ter Vrugte et al., 2017, Shafie and Ahmad, 2010, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018) were undertaken that took learning outside the usual school environment, e.g. as a focus on student engagement with games at home (Neville et al., 2009), or interventions where students were removed from regular lessons to play the game (Shafie and Ahmad, 2010).

2.5.1.4 Student Centred Learning

Active Learning was almost universally represented in the papers examined; only a few theoretical papers did not include some level of this. However, the delivery method for active learning was often not specified in many papers (Neville et al., 2009, Annetta et al., 2013, ter Vrugte et al., 2017, Shahriarpour, 2014, Seng and Yatim, 2014, Su and Cheng, 2013, Lin and Lin, 2014, Shafie and Ahmad, 2010), or the game was used as a catalyst to inspire learning rather than as a more direct vehicle for learning itself (Lin and Lin, 2014). A number of papers integrated elements of Problem-Based Learning into interventions or discussions (Kiger et al., 2012, Baytak and Land, 2011, Monteiro et al., 2011, Hwang et al., 2015, Hwang et al., 2013, Peng et al., 2017, Bowen et al., 2014, Liu and Chu, 2010, Diah et al., 2012, Yang et al., 2010, Garcia and Pacheco, 2013, Norton et al., 2008, Wang et al., 2018, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018), e.g. a game designed around money problems such as when to spend or save created learning experiences off these problems (Hwang et al., 2013). Only one paper included Peer-Assisted Learning elements, which, while using single player games developed by students, integrated peer discussion through a group based evaluation process students were able to take part in once the solo design and testing had been completed (Baytak and Land, 2011).

Deep Learning and Understanding was well represented (Neville et al., 2009, Baytak and Land, 2011, Monteiro et al., 2011, Shahriarpour, 2014, Peng et al., 2017, Bowen et al., 2014, Su and Cheng, 2013, Liu and Chu, 2010, Lin and Lin, 2014, Garcia and Pacheco, 2013, Norton et al., 2008, Wang et al., 2018, Ameerbakhsh et al., 2018), e.g. carrying over the consequences between dependent game components to reinforce intended learning outcomes, thereby tying them closely to the student experience throughout the game (Peng et al., 2017). *Increased Responsibility and Accountability* was another well-represented category (Bate et al., 2014, Annetta et al., 2013, Monteiro et al., 2011, Seng and Yatim, 2014, Hwang et al., 2015, Hwang et al., 2013, Bowen et al., 2014, Su and Cheng, 2013, Liu and Chu, 2010, Diah et al., 2012, Lin and Lin, 2014, Norton et al., 2008, Wang et al., 2018, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018), e.g. use of the freedom a sandbox game such as SimCity provides while learning concepts, with even failure conveying meaningful information and creating a discussion point (Lin and Lin, 2014). *Sense of Autonomy* was also addressed in a number of papers (Neville et al., 2009, Bate et al., 2014, Monteiro et al., 2011, ter Vrugte et al., 2017, Seng and Yatim, 2014, Hwang et al., 2015, Hwang et al., 2013, Peng et al., 2017, Bowen et al., 2014, Su and Cheng, 2013, Lin and Lin, 2014, Shafie and Ahmad, 2010, Garcia and Pacheco, 2013, Norton et al., 2008, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018), e.g. integrating faded worked examples into a game to give students needing help a feeling they have completed the work without teacher

input, building confidence in their ability to work autonomously (ter Vrugte et al., 2017). Although some game genres such as text-based adventures could be perceived as potentially limiting decision-making, another paper demonstrated that providing a carefully selected breadth of responses and providing similarities between the players and their avatar can still give the sense that a student can choose very different paths (Bowen et al., 2014).

Teacher and Learner Interdependence (Kiger et al., 2012, Bate et al., 2014, Baytak and Land, 2011, Yang et al., 2010), *Mutual Respect* (Bate et al., 2014, Baytak and Land, 2011) and *A Reflexive Approach to Teaching and Learning* (Bate et al., 2014, Baytak and Land, 2011, Annetta et al., 2013, Hwang et al., 2013) were least represented within single-player games, however some examples did exist to evidence that these can be integrated into Student Centred Digital Game Based Learning interventions, e.g. Kiger et al.'s mobile learning intervention was closely integrated within a standard classroom situation to preserve the Teacher-Learner relationship (Kiger et al., 2012). Integration of student/teacher involvement in the games design and testing process demonstrates a way to create and reinforce respect between peers and teachers as the games are evaluated and students may experience others creations (Baytak and Land, 2011). Finally, Hwang et al. utilised cycles of learning where students not demonstrating an appropriate level of understanding are encouraged to seek out more information and return, engendering a reflexive approach (Hwang et al., 2015).

2.5.1.5 Digital Game Based Learning Principles

2.5.1.5.1 Learner Empowerment

In terms of *Learner Empowerment*, the *Decision Making* principle was evident in a majority of studies (Neville et al., 2009, Kiger et al., 2012, Bate et al., 2014, Annetta et al., 2013, ter Vrugte et al., 2017, Shahriarpour, 2014, Hwang et al., 2015, Hwang et al., 2013, Peng et al., 2017, Bowen et al., 2014, Su and Cheng, 2013, Liu and Chu, 2010, Diah et al., 2012, Lin and Lin, 2014, Shafie and Ahmad, 2010, Yang et al., 2010, Garcia and Pacheco, 2013, Norton et al., 2008, Wang et al., 2018, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018). This principle was integrated through, for example, adventure games (Shafie and Ahmad, 2010) and visual novels, where such decisions are the main interaction players have (Bowen et al., 2014). *World Building* was a well-represented section, appearing in a number of studies (Neville et al., 2009, Kiger et al., 2012, Bate et al., 2014, Annetta et al., 2013, Monteiro et al., 2011, ter Vrugte et al., 2017, Shahriarpour, 2014, Seng and Yatim, 2014, Hwang et al., 2015, Hwang et al., 2013, Peng et al., 2017, Bowen et al., 2014, Su and Cheng, 2013, Liu and Chu, 2010, Diah et al., 2012, Lin and Lin, 2014, Shafie and Ahmad, 2010, Yang et al., 2010, Garcia and Pacheco, 2013, Norton et al., 2008, Wang et al., 2018, Ameerbakhsh et al., 2018). Commercial games such as Sim-City allowed players to learn while creating and developing their world during their integration of the game into the classroom (Lin and Lin, 2014). Hwang

et al. (Hwang et al., 2015) made use of these principles in their social-science based game, allowing students the ability to interact with and manipulate objects and non-player characters in the world as a part of their learning process.

2.5.1.5.2 Problem Solving

Use of *Learning Cycles* was observed in a number of papers (Neville et al., 2009, Kiger et al., 2012, Bate et al., 2014, Annetta et al., 2013, Monteiro et al., 2011, ter Vrugte et al., 2017, Shahriarpour, 2014, Seng and Yatim, 2014, Hwang et al., 2015, Hwang et al., 2013, Diah et al., 2012, Shafie and Ahmad, 2010, Yang et al., 2010, Garcia and Pacheco, 2013, Wang et al., 2018), e.g. providing feedback on mistakes and encouraging players to repeat and improve with each iteration to master resuscitation techniques (Monteiro et al., 2011), or task level progression to encourage understanding of one skill before progression to the next (Garcia and Pacheco, 2013).

Multiple methods of *Maintaining Engagement* were often used within papers. A number of papers sought to make their games *Pleasantly Frustrating* (Baytak and Land, 2011, Monteiro et al., 2011, ter Vrugte et al., 2017, Seng and Yatim, 2014, Shafie and Ahmad, 2010, Garcia and Pacheco, 2013, Wang et al., 2018, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018), e.g. multiple levels that increasingly stretch skill, with each new element becoming routine within the next level (Seng and Yatim, 2014), and or utilised *Information Provision* (So, 2012, Neville et al., 2009, Kiger et al., 2012, Bate et al., 2014, Annetta et al., 2013, Hwang et al., 2013, Hwang et al., 2015, Su and Cheng, 2013, Liu and Chu, 2010, Garcia and Pacheco, 2013, Norton et al., 2008, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018), e.g. prompts with commonly forgotten information and relevant instructions (Su and Cheng, 2013). *Fish Tank Learning* was featured in a number of games (So, 2012, Bate et al., 2014, Baytak and Land, 2011, ter Vrugte et al., 2017, Shahriarpour, 2014, Seng and Yatim, 2014, Hwang et al., 2013, Hwang et al., 2015, Lin and Lin, 2014, Shafie and Ahmad, 2010, Yang et al., 2010, Garcia and Pacheco, 2013, Khamparia and Pandey, 2018), e.g. allowing students to observe poor choices and then retake those decisions after seeing the outcome (Hwang et al., 2015). The final engagement-based principle is that of *Sandbox Learning* (So, 2012, Baytak and Land, 2011, ter Vrugte et al., 2017, Peng et al., 2017, Su and Cheng, 2013, Liu and Chu, 2010, Lin and Lin, 2014, Norton et al., 2008), e.g. allowing players to explore the results of their actions and how that affects a simulated cityscape (Lin and Lin, 2014).

Skills as Strategy was the least well represented category within *Problem Solving* (Kiger et al., 2012, Bate et al., 2014, Lin and Lin, 2014, Ameerbakhsh et al., 2018), although some papers used games that were able to tie a student's progression to their understanding, with greater understanding of the game mechanics allowing greater success (Lin and Lin, 2014).

2.5.1.5.3 Understanding

Systems Thinking was found within a small number of studies (Kiger et al., 2012, Bate et al., 2014, Lin and Lin, 2014, Peng et al., 2017, Ameerbakhsh et al., 2018), e.g. using simulation to develop an understanding of game concepts to progress clearly provides the real-world learning outcomes (Peng et al., 2017).

Meaning from Experience was better represented (Neville et al., 2009, Bate et al., 2014, Monteiro et al., 2011, ter Vrugte et al., 2017, Shahriarpour, 2014, Hwang et al., 2015, Hwang et al., 2013, Peng et al., 2017, Bowen et al., 2014, Su and Cheng, 2013, Liu and Chu, 2010, Lin and Lin, 2014, Shafie and Ahmad, 2010, Yang et al., 2010, Norton et al., 2008, Wang et al., 2018, Ameerbakhsh et al., 2018). This was particularly evident in commercial games utilised in language learning, where language skills developed as a natural part of the game are applicable in similar situations in life (Liu and Chu, 2010, Neville et al., 2009).

2.5.1.6 Reflective Summary

The Single Player category was dominated by educational games in desktop format, often designed exclusively for the study reported. Mobile and Virtual or Augmented Reality platforms were rarely utilised. Studies were primarily qualitative or mixed methods, accompanied by a small number of theoretical papers – few collected quantitative data on educational outcomes. Cohort studies were favoured in this category over other study designs but mainly focused on in-classroom deployment within-academic year groups/classes, with limited use of follow-up or longitudinal embedding of interventions. Year groups were often Primary level but implementation within Secondary and Tertiary levels was also demonstrated.

A cross-section of SCL tenets were implemented within interventions discussed or used, however, the tenets were not represented in a balanced fashion within individual papers. *Active Learning* and tenets speaking to the learner as an individual or involving internalisation were well represented (*Deep Learning and Understanding, Increased Responsibility and Accountability*, *A Sense of Autonomy*). However, the representation of other tenets was poor or only specified in a limited fashion, such as Peer-Assisted forms of *Active Learning,* and tenets that incorporate interaction with peers or teachers, such as *Teacher and Learner Interdependence, Mutual Respect*, or reflection on the part of both students and teachers, i.e. *A Reflexive Approach to Teaching and Learning*. In terms of design principles for DGBL, some principles were better represented than others. Learner Empowerment principles such as *Decision Making* and *World Building* were evidenced in many studies as key delivery mechanisms for SCL tenets, along with *Problem Solving* approaches that employed *Learning Cycles* and multiple methods of *Maintaining Engagement* (although Sandbox Practice was relatively less featured). However, *Skills as Strategy* was a *Problem Solving* design principle

with limited implementation, and *Systems Thinking* was rarely utilised as a design principle to facilitate Understanding, with many papers ascribing to *Meaning from Experience* instead.

2.5.2 Mixed and Variable Play

Table 5 presents studies (n = 12) that used or discussed a combination of single and multiplayer games (n = 7 (King, 2015, Kim and Yao, 2010, Owston, 2009, Ucus, 2015, Kennedy-Clark, 2011, Kebritchi, 2008, Barr, 2018)), and also includes studies where the number of players was varied or not specified, without a particular focus on the effects of such variation (n = 5 (Kikot et al., 2013, Cojocariu and Boghian, 2014, Ahmad et al., 2011, Ciampa, 2017, Abrams, 2009)).

2.5.2.1 Game Type

Similarly to the single-player category, the majority of studies made use of educational games (Kim and Yao, 2010, Owston, 2009, Kebritchi, 2008, Kikot et al., 2013, Cojocariu and Boghian, 2014, Ciampa, 2017), while commercial games were used less often (King, 2015, Ahmad et al., 2011, Abrams, 2009, Barr, 2018), e.g. investigating the effect online games such as World of Warcraft may have on learning after school (King, 2015).

Again, desktop systems were predominant (King, 2015, Ucus, 2015, Kennedy-Clark, 2011, Kebritchi, 2008, Kikot et al., 2013, Cojocariu and Boghian, 2014, Ahmad et al., 2011, Ciampa, 2017, Abrams, 2009, Barr, 2018), although more studies considered flexible browser-based games that can be utilised on a number of systems compared to the single-player category (Kim and Yao, 2010, Owston, 2009). No mobile games were identified.

2.5.2.2 Study Type

Data collection was primarily qualitative as per the single-player category (King, 2015, Ucus, 2015, Kennedy-Clark, 2011, Kikot et al., 2013, Ciampa, 2017, Abrams, 2009, Barr, 2018), or purely theoretical, presenting new ideas as yet untested or discussing primarily the development of a game or its pedagogical foundations without data on the implementation (Kim and Yao, 2010, Owston, 2009, Kebritchi, 2008, Cojocariu and Boghian, 2014, Ahmad et al., 2011). There were no quantitative studies conducted in this category.

Papers were primarily small sample case studies by design (Ucus, 2015, Kennedy-Clark, 2011, Kikot et al., 2013, Ciampa, 2017, Abrams, 2009, Barr, 2018), e.g. elementary school teachers views of game-based learning (Ucus, 2015). One study was a cohort study using a group of participants, in this case an after school programme put together for the purpose of another research study (King, 2015). Theoretical papers, as is their nature, did not collect data (Kim and Yao, 2010, Owston, 2009, Kebritchi, 2008, Cojocariu and Boghian, 2014, Ahmad et al., 2011). There were no focus group studies.

Table 5: Mixed and Variable Games

Author(s) (n = 12)	Game Type			Study type		Setting		SCL							Digital Game-based Learning						
															Learner Emp		Problem Solving			Understanding	
Author(s) n = 12	Group	Development	Games Platform	Data Type	Study Design	Level	Situation	Active Learning	Deep Learning and Understanding	Increased Responsibility and Accountability	Sense of Autonomy	Teacher and Learner Interdependence	Mutual Respect	Reflexive Approach to Teaching and Learning	Decision Making	World Building	Learning Cycles	Maintain Engagement	Skills as Strategy	Systems Thinking	Meaning From Experience
(Ucus, 2015)	M	-	D	L	A	P	I	-	-	-	-	-	-	-					-		
(Kennedy-Clark, 2011)	M	N/A	D	L	A	S	I	P,A			√				√	√		I,S			√
(King, 2015)	M	C	D	L	O	S	O	P,A		√		√									
(Barr, 2018)	M	C	D	L	A	T	O	A			√		√	√				F			√
(Kim and Yao, 2010)	M	E	B	T	-	-	-	P,A		√	√				√	√	√	P	√	√	√
(Kebritchi, 2008)	M	E	D	T	-	A	-	√	√		√				√	√		I			√
(Owston, 2009)	M	E	D,B	T	-	P	O	√													
(Ciampa, 2017)	N	E	D	L	A	P	I	P		√				√							
(Abrams, 2009)	N	C	D	L	A	S	O	P	√		√				√	√		P			
(Kikot et al., 2013)	N	E	D	L	A	T	I	P	√	√	√			√	√	√	√	P,F	√	√	√
(Cojocariu and Boghian, 2014)	N	E	D	T	-	P	-	-	-	-	-	-	-	-					-		
(Ahmad et al., 2011)	N	C	D	T	-	T	-	P,C			√				√	√		S			
Frequencies	12	E: 6 C: 4 -: 1	D: 11 B: 2	L: 7 T: 5	A: 6 O:1 -: 5	P: 4 S: 3 T: 3 A: 1 -: 1	O: 4 I: 4 -: 4	P: 7 A: 3 C: 1 √: 2 -: 2	√: 3	√: 4	√: 7	√: 1	√: 1	√: 3	√: 6	√: 6	√: 2	P: 3 F: 2 S: 2 I: 2	√: 2	√: 2	√: 5

Key: Group - (N)ot specified, (M)ixed single and multiplayer; Development - (E)ducation, (C)ommercial, (B)oth; Platform - (D)esktop, (B)rowser-based, (A)ugmented Reality, (V)irtual Reality, (M)obile; Data Type - (M)ixed methods, Qua(L)itative, Qua(N)itative, (T)heoretical; Study Design - C(A)se study, (F)ocus group, C(O)hort; Level - (P)rimary, (S)econdary, (T)ertiary, (A)ll; Setting - (O)utside classroom, (I)nside classroom; Active Learning - (P)roblem based learning, Peer (A)ssisted learning, (C)ollaborative; Maintain Engagement - (P)leasantly frustrating, (I)nformation provision, (F)ishtank Learning, (S)andbox Practice; √ = Exemplified; blank = not exemplified, - = not possible due to being a theoretical paper.

2.5.2.3 Setting

Primary education was the principal area studied (Owston, 2009, Ucus, 2015, Cojocariu and Boghian, 2014, Ciampa, 2017), including teachers (Cojocariu and Boghian, 2014) (Ciampa, 2017) as well as pupils. Few papers looked at Secondary level (11-18 years) (King, 2015, Kennedy-Clark, 2011, Abrams, 2009), and focus on narrower age bands within this group, e.g. boys aged 13-16 (King, 2015). Similarly there was limited focus on Tertiary level education (Kikot et al., 2013, Ahmad et al., 2011, Barr, 2018). One paper dealt with all age groups (A), categorising pedagogical foundations of a number of educational games without focusing on a particular age-group or educational level (Kebritchi, 2008). A final paper did not specify the age group addressed and has not been assigned to any of the above categories (Kim and Yao, 2010).

Papers mostly utilised settings inside a traditional classroom, per the single-player category (Ucus, 2015, Kennedy-Clark, 2011, Kikot et al., 2013, Ciampa, 2017), including integration of games into an existing university module (Kikot et al., 2013). A small number of studies (Abrams, 2009, King, 2015, Barr, 2018) took place outside of a school environment, e.g. after school club (King, 2015). A final group of papers could not be categorised (Kim and Yao, 2010, Kebritchi, 2008, Cojocariu and Boghian, 2014, Ahmad et al., 2011), e.g. single game studies not specifying where/when the developed world was accessed (Ahmad et al., 2011), or studies evaluating multiple games without addressing the intended situation of use (Kebritchi, 2008).

2.5.2.4 Student Centred Learning

A small group of papers (Owston, 2009, Kebritchi, 2008) demonstrate *Active Learning* but do not clearly show the usage of any particular sub-techniques – in one instance this was due to the large volume of games discussed without sufficient detail to identify these (Kebritchi, 2008). Problem-Based Learning was identified in most papers (King, 2015, Kim and Yao, 2010, Kennedy-Clark, 2011, Kikot et al., 2013, Ahmad et al., 2011, Ciampa, 2017, Abrams, 2009), e.g. investigation of a pre-designed area and its issues within Second Life (Ahmad et al., 2011). Peer-Assisted Learning was shown or addressed in some papers, more so than in the single-player category but still only representing a third of studies in this current category (King, 2015, Kim and Yao, 2010, Kennedy-Clark, 2011, Barr, 2018). The sole example of Collaborative Learning within this category invites students to engage, explore and solve the problems presented as a group within a massively multiplayer online setting (Ahmad et al., 2011).

Compared to the single-player category, a relatively small number of papers demonstrated *Deep Learning and Understanding* (Kebritchi, 2008, Kikot et al., 2013, Abrams, 2009). More commonly observed within papers were the principles of *Increased Responsibility and*

Accountability (King, 2015, Kim and Yao, 2010, Kikot et al., 2013, Ciampa, 2017), and promoting a *Sense of Autonomy* within learners (Kim and Yao, 2010, Kennedy-Clark, 2011, Kebritchi, 2008, Ahmad et al., 2011, Abrams, 2009, Barr, 2018). However, few papers encompassed *Teacher and Learner Interdependence* (King, 2015), *Mutual Respect* (Barr, 2018) and A *Reflexive Approach to Teaching and Learning* (Kikot et al., 2013, Ciampa, 2017, Barr, 2018), echoing the distribution of coverage identified within the single-player category. Again, strong examples existed to evidence the possibilities for integration, such as including opportunities for a teacher to take part in a guiding and participatory role within the game (King, 2015), learning communication skills through working together in-game (Barr, 2018), and teacher reflection on revisions and improvements to games within special education classrooms.

2.5.2.5 Digital Game Based Learning Principles

2.5.2.5.1 Learner Empowerment

Decision Making (Kim and Yao, 2010, Kennedy-Clark, 2011, Kebritchi, 2008, Kikot et al., 2013, Ahmad et al., 2011, Abrams, 2009) and *World Building* (Kim and Yao, 2010, Kennedy-Clark, 2011, Kebritchi, 2008, Kikot et al., 2013, Ahmad et al., 2011, Abrams, 2009) were observed within a number of studies. In a study on teacher perspectives on games, location/task choice and multiple paths to success were seen as a positive way to provide the same learning outcomes in different ways (Kennedy-Clark, 2011). Virtual worlds were seen as a way to allow a high level of interaction in and between created objects and players inside the game world (Ahmad et al., 2011).

2.5.2.5.2 Problem Solving

Learning Cycles were demonstrated within a small number of papers compared to the single-player category (Kim and Yao, 2010, Kikot et al., 2013), with simulation games providing the main example of this, as players are able to observe the unfolding effects of decisions use the information they get 'on the fly' to avoid repeating or compounding mistakes and enable success (Kikot et al., 2013).

As per the single-player category, many studies included at least one method of *Maintaining Engagement*, often multiple: *Pleasantly Frustrating* (Kim and Yao, 2010, Kikot et al., 2013, Abrams, 2009), *Information Provision* (Kennedy-Clark, 2011, Kebritchi, 2008), *Fish Tank Learning* (Barr, 2018, Kikot et al., 2013) and *Sandbox Learning* (Kennedy-Clark, 2011, Ahmad et al., 2011). Utilisations varied across papers, e.g. limiting consequences to just a time delay as players realise what was and was not effective (Ahmad et al., 2011), or release students from negative consequences early on while they come to understand the basics of managing the virtual business (Kikot et al., 2013).

Skills as Strategy was only utilised within a small number of papers, as in the single-player category (Kim and Yao, 2010, Kikot et al., 2013). However, a strong example of this is presented through treasure hunt derived games directly making searching and identification skills a key part of the strategy for winning (Kim and Yao, 2010).

2.5.2.5.3 Understanding

Systems Thinking was under-represented (Kim and Yao, 2010, Kikot et al., 2013). Simulation games were one example, where players immediately put theory into practice through the game and routes to success and game rules are based on understanding of the educational content (Ahmad et al., 2011). *Meaning From Experience* was the better represented category (Kim and Yao, 2010, Kennedy-Clark, 2011, Kebritchi, 2008, Kikot et al., 2013, Barr, 2018). Virtual learning, explored by Kennedy-Clark addresses this principle, as skills closely linked to in-game experiences enable users to gain a deeper understanding to take beyond the confines of the game (Kennedy-Clark, 2011).

2.5.2.6 Reflective Summary

Findings pertaining to Game Type were similar to the Single Player category, but with regard to Study Type, no quantitative studies were identified with all papers being either qualitative or theoretical with no data presented. Small sample case study designs were frequently used with only a single cohort study identified, and studies at secondary level were limited. Similar findings were identified with regard to the unequally weighted implementation of SCL tenets and DGBL design principles, although Peer-Assisted forms of *Active Learning* was relatively better represented here in comparison to the Single Player category, and use of the DGBL design principle of *Learning Cycles* was very limited within this category.

2.5.3 Multiplayer

Table 6 presents studies that involved exclusively multiplayer games, these games include those with a true multiplayer focus (G, n = 7) (Dickey, 2007, Liu et al., 2011, Yang et al., 2015, Baydas et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007, Hung et al., 2018), one played in pairs (P) (Hatton et al., 2008) and those played by multiple players using a single shared terminal (L, n = 4) (Watson et al., 2011, Sung and Hwang, 2013, Margino, 2013, Yang, 2015).

Table 6: Multiplayer Games

Author(s) (n = 12)	Game Type			Study type		Setting		SCL							Digital Game-based Learning						
															Learner Emp		Problem Solving			Understanding	
Author(s) n = 12	Group	Development	Games Platform	Data Type	Study Design	Level	Situation	Active Learning	Deep Learning and Understanding	Increased Responsibility and Accountability	Sense of Autonomy	Teacher and Learner Interdependence	Mutual Respect	Reflexive Approach to Teaching and Learning	Decision Making	World Building	Learning Cycles	Maintain Engagement	Skills as Strategy	Systems Thinking	Meaning From Experience
Squire and Klopfer (Squire and Klopfer, 2007)	G	E	A	L	A	S	I	P,C	√		√				√	√	√	P,I,F	√	√	√
Stanley and Latimer (Stanley and Latimer, 2011)	G	E	D	L	F	T	I	P,A	√	√	√				√	√	√		√		√
Liu et al. (Liu et al., 2011)	G	E	D	M	O	S	I	P,A	√	√	√				√	√	√	P,I,F			√
Yang et al. (Yang et al., 2015)	G	E	M	M	O	S	I	P,C	√	√	√			√	√		√	I	√		√
Baydas et al. (Baydas et al., 2015)	G	C	D	M	O	T	I	√			√	√	√		√	√		S			
Hung et al. (Hung et al., 2018)	G	E	D	N	O	S	I	P,A					√		√		√		√		√
Dickey (Dickey, 2007)	G	E	D	T	-	-	-	A		√	√				√	√	√	F			√
Watson et al. (Watson et al., 2011)	L	C	D	L	A	S	I	√			√				√	√			√		√
Sung and Hwang (Sung and Hwang, 2013)	L	E	D	M	O	P	I	P,C		√	√				√	√	√	P,I,F	√		√
Yang (Yang, 2015)	L	E	D	N	O	S	I	P,A			√	√			√	√	√	P,I	√		√
Margino (Margino, 2013)	L	E	D	T	-	T	I	√	√		√								-		
Hatton et al. (Hatton et al., 2008)	P	E	A	L	O	S	O	C			√	√			√	√	√	F			√
Frequencies	12	E: 10 C: 2	D: 9 M: 1 A: 2	L: 4 N: 2 M: 4 T: 2	A: 2 F: 1 O: 7 -: 2	P: 1 S: 7 T: 3 -: 1	I: 10 O: 1 -: 1	P: 7 A: 5 C: 4 √: 3	√: 5	√: 5	√: 11	√: 3	√: 2	√: 1	√: 11	√: 9	√: 9	P: 4 F: 5 S: 1 I: 5	√: 7	√: 1	√: 10

Key: Group - (G)roup, (P)airs, (L)imited Multiplayer; Development - (E)ducation, (C)ommercial, (B)oth; Platform - (D)esktop, (A)ugmented Reality, (V)irtual Reality, (M)obile; Data Type - (M)ixed methods, Qua(L)itative, Qua(N)itative, (T)heoretical; Study Design - C(A)se study, (F)ocus group, C(O)hort; Level - (P)rimary, (S)econdary, (T)ertiary; Setting - (O)utside classroom, (I)nside classroom; Active Learning - (P)roblem based learning, Peer (A)ssisted learning, (C)ollaborative; Maintain Engagement - (P)leasantly frustrating, (I)nformation provision, (F)ishtank Learning, (S)andbox Practice; √ = Exemplified; blank = not exemplified, - = not possible due to being a theoretical paper.

2.5.3.1 Game Type

As per the other categories, a small number of studies used commercial games as a basis (Watson et al., 2011, Baydas et al., 2015), such as popular massively multiplayer online (MMO) game Second Life (Baydas et al., 2015). The remainder used games primarily designed with educational purposes in mind (Hatton et al., 2008, Sung and Hwang, 2013, Margino, 2013, Yang, 2015, Dickey, 2007, Liu et al., 2011, Yang et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007, Hung et al., 2018), e.g. 2D educational role-playing game within a science context (Sung and Hwang, 2013). Again, the majority (Watson et al., 2011, Sung and Hwang, 2013, Margino, 2013, Yang, 2015, Dickey, 2007, Liu et al., 2011, Baydas et al., 2015, Stanley and Latimer, 2011, Hung et al., 2018) ran on desktop systems, with one paper suggesting the power afforded by a desktop system is an important factor in this choice for multiplayer games such as MMOs (Dickey, 2007). A small number of studies utilised Augmented Reality to engage students (Hatton et al., 2008, Squire and Klopfer, 2007), such as handheld devices for educating students on environmental sciences out in the field (Squire and Klopfer, 2007). Like the other categories, only a single study utilised mobile devices and this was primarily for data access across locations (Yang et al., 2015). There were no browser-based games in this category.

2.5.3.2 Study Type

Distribution of data types was more mixed for this category, including qualitative data (Hatton et al., 2008, Watson et al., 2011, Stanley and Latimer, 2011, Squire and Klopfer, 2007) (e.g. observations, interviews, documentary analysis), mixed methods (Sung and Hwang, 2013, Liu et al., 2011, Yang et al., 2015, Baydas et al., 2015) and to a more limited extent quantitative data (Yang et al., 2015, Hung et al., 2018). There were fewer entirely theoretical papers compared to the other categories (Margino, 2013, Dickey, 2007). Study designs also varied. A number of cohort studies were performed (Hatton et al., 2008, Sung and Hwang, 2013, Yang, 2015, Liu et al., 2011, Yang et al., 2015, Baydas et al., 2015, Hung et al., 2018), with less usage of case studies (Watson et al., 2011, Squire and Klopfer, 2007). Like the other categories focus group studies were very limited (Stanley and Latimer, 2011).

2.5.3.3 Setting

In contrast to other categories which focused usually on Primary education, a single study in the Multiplayer category targeted students at the Primary level (Sung and Hwang, 2013). Instead most were aimed at Secondary (Hatton et al., 2008, Watson et al., 2011, Yang, 2015, Liu et al., 2011, Yang et al., 2015, Squire and Klopfer, 2007, Hung et al., 2018), typically targeting a subgroup e.g. US middle school students (aged 11-14) (Liu et al., 2011). In contrast

to other categories, Tertiary students were the focus of a small number of papers (Margino, 2013, Baydas et al., 2015, Stanley and Latimer, 2011).

Like the other categories, the majority of the studies looked at the use of games inside a traditional classroom (Watson et al., 2011, Sung and Hwang, 2013, Margino, 2013, Yang, 2015, Liu et al., 2011, Yang et al., 2015, Baydas et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007, Hung et al., 2018). One study took place outside the normal school environment, using a specially designed facility for augmented reality based learning to which students were invited from school to take part (Hatton et al., 2008). A final theoretical paper did not specifically cover the location the learning was to take place within (Dickey, 2007).

2.5.3.4 Student Centred Learning

Active Learning was represented to some degree in all papers, however the subcategories included within each paper differ. Fewer papers did not specify the delivery method for active learning, compared to other categories (Watson et al., 2011, Margino, 2013, Baydas et al., 2015). One such example addresses the potential of digital video games within an area, but does not identify in any game a significant lean towards problem based learning nor realise peer-based learning beyond the presence of multiple players (Margino, 2013).

Many included Problem-Based Learning (Sung and Hwang, 2013, Yang, 2015, Liu et al., 2011, Yang et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007, Hung et al., 2018), with one applying this within an augmented reality platform for both long and short term problems (Squire and Klopfer, 2007). A small number of papers included peer-assisted learning aspects (Yang, 2015, Dickey, 2007, Liu et al., 2011, Stanley and Latimer, 2011, Hung et al., 2018), but implementation was strong, e.g. a business based simulation where students operate in groups, engaging in collective decisions and sharing collective responsibility for these upon their business, as well as permitting between-group competition, allowing actions of other peer groups to be learned from (Yang, 2015). A final group of papers included fully realised collaborative elements (Hatton et al., 2008, Sung and Hwang, 2013, Yang et al., 2015, Squire and Klopfer, 2007), such as multiple groups simultaneously working on aspects within an augmented reality game, with teacher guidance allowing the actions of every student to contribute to group success (Hatton et al., 2008).

Deep Learning and Understanding was demonstrated in more papers than the mixed category (Margino, 2013, Liu et al., 2011, Yang et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007), and *Increased Responsibility and Accountability* also appeared within several studies (Sung and Hwang, 2013, Dickey, 2007, Liu et al., 2011, Yang et al., 2015, Stanley and Latimer, 2011), with MMO games arising again as an example of allowing players to perform

individually and as part of a group where players could see and compare their progress (Dickey, 2007).

A majority of papers were able to demonstrate or place emphasis on student *Sense of Autonomy* while playing (Hatton et al., 2008, Watson et al., 2011, Sung and Hwang, 2013, Margino, 2013, Yang, 2015, Dickey, 2007, Liu et al., 2011, Yang et al., 2015, Baydas et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007). This tenet was placed under particular emphasis in one study looking at student's autonomous or unguided experience in learning simulations created for the purpose (Baydas et al., 2015).

Like the other categories, *Teacher and Learner Interdependence* appeared in a smaller number of multiplayer papers (Hatton et al., 2008, Yang, 2015, Baydas et al., 2015), as did *Mutual Respect* (Hung et al., 2018, Baydas et al., 2015) and *A Reflexive Approach to Teaching and Learning* (Yang et al., 2015). Yet some examples of implementation were demonstrated, such as allowing students and teachers to play off each other's ideas and understanding within an Augmented Reality based learning module (Hatton et al., 2008), students cooperating to engage in activities, explore and build upon a world directly created by the teacher (Baydas et al., 2015), and a long-term learning study that specifically allowed students to see what effects they were having and adjust their actions and learning to better take part (Yang et al., 2015).

2.5.3.5 Digital Game Based Learning Principles

2.5.3.5.1 Learner Empowerment

As in other categories, *Decision Making* (Hatton et al., 2008, Watson et al., 2011, Sung and Hwang, 2013, Yang, 2015, Dickey, 2007, Liu et al., 2011, Yang et al., 2015, Baydas et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007, Hung et al., 2018, Bidin and Ziden, 2013) and *World Building* appear in most studies (Hatton et al., 2008, Watson et al., 2011, Sung and Hwang, 2013, Yang, 2015, Dickey, 2007, Liu et al., 2011, Baydas et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007). One study highlights the use of many games that speak to both facets of Learner Empowerment, including Civilization, which allows players both very fine control over aspects of the country they rule should they desire, and provides a world that responds to any such changes to allow the player to feel they are making a difference (Watson et al., 2011).

2.5.3.5.2 Problem Solving

Again, *Learning Cycles* were featured in a majority of papers (Hatton et al., 2008, Sung and Hwang, 2013, Yang, 2015, Dickey, 2007, Liu et al., 2011, Yang et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007, Hung et al., 2018), including multiple opportunities to attempt tasks, then see and learn from results, and more difficult goals for achieving students to build upon their skills (Yang, 2015).

Similarly, *Maintaining Engagement* was featured in the majority of papers, though the subcategories were not evenly spread. *Pleasantly Frustrating* (Sung and Hwang, 2013, Yang, 2015, Liu et al., 2011, Squire and Klopfer, 2007) and *Information Provision* (Sung and Hwang, 2013, Yang, 2015, Liu et al., 2011, Yang et al., 2015, Squire and Klopfer, 2007) were well utilised principles, along with *Fish Tank Learning* (Hatton et al., 2008, Sung and Hwang, 2013, Dickey, 2005, Liu et al., 2011, Squire and Klopfer, 2007). However, only one paper explored the principle of *Sandbox Learning*, comparing presence (free reign to explore an area) and absence (close teacher guidance) of this aspect (Baydas et al., 2015). By contrast, *Skills as Strategy* appears in many more papers compared to the other player categories (Watson et al., 2011, Sung and Hwang, 2013, Yang, 2015, Yang et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007, Hung et al., 2018).

2.5.3.5.3 Understanding

Meaning From Experience appeared in all but two papers (Hatton et al., 2008, Watson et al., 2011, Sung and Hwang, 2013, Yang, 2015, Dickey, 2007, Liu et al., 2011, Yang et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007, Hung et al., 2018), proving to be well-represented as in the other categories. However, *Systems Thinking* was very poorly represented, with a single paper using a game with realism as a key goal, organised around the simulation of the skills and ideas it intends to convey and the results of using them (Squire and Klopfer, 2007).

2.5.3.6 Reflective Summary

Findings for Game Type reflected the other two Player Engagement categories. For Study Type, greater use of mixed methods and quantitative data collection methods was employed compared to the Mixed category, and only a small number of theoretical papers were identified. Study design was primarily cohort-based, as in the Single Player category, and usage of case studies was far lower compared to the Mixed and Single Player categories. Again, follow-up was limited and interventions usually made available for a limited timeframe. Studies usually focused on older students with just a single paper addressing Primary level age groups. As in the Mixed category, Peer-Assisted forms of *Active Learning* were better represented compared to the Single Player category, although not in all papers. Within this category are the only examples of SCDGBL interventions with fully realised collaborative elements. Otherwise, findings for implementation of SCL tenets mirrored other Player Engagement categories. Findings for usage of DGBL design principles were similar to that of the Single Player category, but the Sandbox Practice method of *Maintaining Engagement* was represented in just a single paper within this category.

2.5.4 Overall summary of literature review findings

There was a reasonable distribution of study types, although the Mixed category for Player Engagement contained the majority of case study design papers. Use of follow-up periods and post-study evaluation of SCDGBL interventions was limited. While *Active Learning* was demonstrated in some form in a majority of papers (Neville et al., 2009, Annetta et al., 2013, ter Vrugte et al., 2017, Shahriarpour, 2014, Seng and Yatim, 2014, Su and Cheng, 2013, Lin and Lin, 2014, Shafie and Ahmad, 2010) (Kiger et al., 2012, Baytak and Land, 2011, Monteiro et al., 2011, Hwang et al., 2015, Hwang et al., 2013, Peng et al., 2017, Bowen et al., 2014, Liu and Chu, 2010, Diah et al., 2012, Yang et al., 2010, Garcia and Pacheco, 2013, Norton et al., 2008, Wang et al., 2018, Khamparia and Pandey, 2018, Ameerbakhsh et al., 2018), less evident was the integration of specific and popular *Active Learning* techniques routinely used in Student Centred Learning, such as Problem-Based and Peer-Assisted Learning. While a number of studies had some level of peer based learning (King, 2015, Kim and Yao, 2010, Kennedy-Clark, 2011, Ahmad et al., 2011, Barr, 2018), there was only one study within this category (Ahmad et al., 2011) that conclusively demonstrated higher level Collaborative and Cooperative Learning experiences or more engaged Peer Tutoring.

Few interventions (Bate et al., 2014, Baytak and Land, 2011, Annetta et al., 2013, Hwang et al., 2013, Kikot et al., 2013, Ciampa, 2017, Yang et al., 2015, Barr, 2018) provided deliberate opportunity for or emphasis upon *A Reflexive Approach to Teaching and Learning*, or placed priority on the integration of teachers into a game based learning experience in a robust manner to promote *Teacher and Learner Interdependence* (Kiger et al., 2012, Bate et al., 2014, Baytak and Land, 2011, Yang et al., 2010, King, 2015, Hatton et al., 2008, Yang, 2015, Baydas et al., 2015). *Mutual Respect* between teachers and students, and between students is a cornerstone of SCL, yet only a small number of studies make such outcomes a priority in the interventions explored (Bate et al., 2014, Baytak and Land, 2011, Baydas et al., 2015, Barr, 2018, Hung et al., 2018). Specifically in the Mixed category of Player Engagement, *Deep Learning and Understanding* was not well explored (Kebritchi, 2008, Kikot et al., 2013, Abrams, 2009).

While there are a number of studies that aim to fully integrate SCL in a multiplayer context (Dickey, 2007, Liu et al., 2011, Yang et al., 2015, Baydas et al., 2015, Stanley and Latimer, 2011, Squire and Klopfer, 2007, Hung et al., 2018), many papers did not offer a truly multiplayer experience (Hatton et al., 2008, Watson et al., 2011, Sung and Hwang, 2013, Margino, 2013, Yang, 2015). Of these studies, many did not have the group engagement take place within the game environment, instead opting to have a group of students around one terminal (Watson et al., 2011, Sung and Hwang, 2013, Margino, 2013, Yang, 2015) with one student taking the role of inputting the groups instructions. Despite emerging technologies

demonstrating significant potential in the area of education, few studies to date have utilised augmented reality or virtual reality within SCDGBL. A number of studies using mixed game types were primarily theoretical in nature without data to support them (Kim and Yao, 2010, Owston, 2009, Kebritchi, 2008, Cojocariu and Boghian, 2014, Ahmad et al., 2011). Such ideas need to be tested before they can be fully implemented.

The majority of studies reviewed promoted student understanding through *Meaning From Experience*. However, the other facet of understanding, *Systems Thinking*, which represents pervasive interlinking between game elements and learning outcomes within the game world, was not well represented throughout the literature sample. Although techniques to *Maintain Engagement* were widely used across all three Player Engagement categories, use of *Sandbox Learning*, a key principle of many digital games, was extremely limited.

2.6 Insights and Reflections

Organising the literature on SCDGBL using the conceptual framework presented in section 2.4 allows identification of which principles highlighted within it are, and are not, forwarded by current research. The conceptual framework gives equal weighting to all the DGBL principles and the SCL tenets detailed in section 2.2, therefore the central finding of this review is that a majority of the interventions claiming to be student centred do not deliver a full cross-section of the SCL experience. This will now be discussed in more detail, grouped by each SCL tenet and each DGBL principle.

2.6.1 Student Centred Learning

Key SCL principles of *Teacher and Learner Interdependence, Mutual Respect* and *A Reflexive Approach to Teaching and Learning* are poorly represented within current SCDGBL offerings, which also encompasses the majority of ideas expressed within theoretical papers, thereby demonstrating that these concepts are also not within the forefront of thinking in this area. An important linkage between these three under-represented tenets within SCDGBL is that they all encompass a ‘social element’ as discussed above. Despite the majority of the SCDGBL literature falling into the Single Player category (section 2.5.1), strong examples of implementation of these tenets were demonstrated across all Player Engagement categories, demonstrating there may be more to this under-representation warranting discussion.

2.6.1.1 Active Learning

Although *Active Learning* was embraced by the majority of papers presented across all three Player Engagement modalities, the specific delivery technique for this was frequently not specified or did not incorporate peer elements (e.g. Peer-Assisted Learning, Cooperative or Collaborative Learning), primarily within the Single Player category (Table 4). While this can

explain the limited representation of social elements within that category, even within the Mixed and Multiplayer categories (Table 5 and Table 6), which had many more instances of Peer-Assisted, Cooperative or Collaborative learning, the social elements of SCL were only represented within a small number of papers. This indicates increasing the number of players within the game experience does not necessarily serve to address all social elements of SCL, without thought and consideration given to game design.

Many of the 'Group' and 'Limited' multiplayer experiences covered in the papers presented (Table 6, Section 2.5.2 and 2.5.3) were not fully leveraging the potential of interaction with other players to incorporate these social elements of SCL, e.g. building in challenges requiring collaborative or cooperative learning to overcome. Many of these are subsequently isolated experiences within a multiplayer environment, that in some instances restrict student contribution/participation (e.g. single terminal studies). Such approaches risk impacting implementation of other SCL tenets such as *Deep Learning and Understanding* or even the degree to which *Active Learning* is communicated if students are unable to contribute or explore the world directly. Looking to the future, there may be potential to integrate auto-grouping elements as seen in MMO games such as World of Warcraft, where groups can be put together on the fly based on players identified and/or self-defined skills, strengths and needs, in keeping with Active Learning techniques that involve peers as defined above. Creating fully collaborative, in-game experiences that bring students together within the game client has the potential to combine *Deep Learning and Understanding*, and the social elements of SCL.

Further, peer based *Active Learning* techniques do not need to be confined to multiplayer games, as demonstrated in Section 2.5.1 by one study within the Single Player Engagement category which integrated class discussions before and after interactions with the game (Baytak and Land, 2011). Alternatively an opportunity for students to view others in real time to create peer-learning experiences may allow feedback and learning to flow both ways, with active students demonstrating techniques while student viewers may be able to offer feedback on where to improve (Livsey and Lavender-Stott, 2015).

2.6.1.2 A Reflexive Approach to Teaching and Learning

Few of the games used in interventions were pre-existing commercial games, with many being specifically developed for the research study it was used in. Due to the nature of academic interventions where an aspect of the onus for reflection is taken on by the researcher, there may be less opportunity for teachers and students to take a reflexive approach to their own teaching and learning during participation in the intervention. Follow-up studies after

intervention completion, or extension of an intervention to cross multiple topic areas over a longer period could address some of these issues. This rarely occurred in the papers reviewed, similarly it is not clear whether these academic interventions went on to be used long-term within the chosen setting, thereby allowing teachers and students to take on the reflective role previously assumed by the researcher. While a space still exists to build upon these ideas, within games the knowledge level required to adapt the experience based on reflection is high e.g. programming and graphic design skills. It is harder for teachers to therefore adapt an intervention to suit their class, even should an opportunity to do so be observed.

2.6.1.3 Teacher and Learner Interdependence and Mutual Respect

Robust integration of teachers into an active part of the game world may offer the opportunity to both build and build upon the relationship between students and teachers, encompassing the tenets of both *Teacher and Learner Interdependence* and *Mutual Respect*. Reducing the teacher's role to technical support given outside the game interface risks placing the teacher's position below that of the game in terms of importance in delivering student learning which may have longer term negative outcomes. Teachers should be provided with the opportunity to demonstrate skills both in the subject areas and in the game being played. Where teachers may not be familiar with the games, they should be open to learning from able students, allowing a role reversal to build respect for both the teacher and student involved.

Drawing from successful commercial games, it may be possible to integrate the teacher as a form of Game Manager, actively managing the game from inside the client and appearing as a presence there, able to interact with students on that level to offer help and rewards that players could ask for or enjoy; this may serve to increase both interdependence and respect as the teacher's presence expands in a positive manner. While it could be argued that greater embedding of *Teacher and Learner Interdependence* may come at the price of independent learning (Baydas et al., 2015), the study achieving this demonstrated that similar outcomes can still be achieved, although further studies to reinforce this would be helpful.

2.6.2 Digital Game Based Learning

All three areas of DGBL were well represented within the SCDGBL literature reviewed, but the component principles within each of those areas were not evenly represented. This would suggest that some DGBL principles are not as well utilised to deliver SCL tenets within current SCDGBL interventions. Possible explanations for this are discussed below.

2.6.2.1 Systems Thinking and Skills as Strategy

Systems Thinking is a DGBL principle linked to *Deep Learning and Understanding, Sense of Autonomy,* and Problem Based Learning techniques within *Active Learning* (Table 2). Despite these SCL tenets being well represented across all three Player Engagement categories, Systems Thinking did not appear to be utilised as a vehicle for delivering them, with just 8 studies within the literature pool discussing or implementing this. This may be due to the difficulties in implementing Systems Thinking within an educational game design, compared to other DGBL design principles conceptually linked to the same tenets (Table 2).

An effective implementation closely ties game world, mechanics and learning outcomes it seeks to deliver. A poorly integrated or superficial educational layer damages *Systems Thinking*, as students dissociate the skills learned through gameplay from those clearly intended to have educational value. It also impacts *Skills as Strategy*, as students who pick up skills or knowledge from the educational layer become unable to use these to effectively strategize and progress through the game. As discussed in the introduction, quality of the learning process affects quality of learning outcomes. If learning outcomes become something clearly discrete to the player from their ability to progress in the game, the worst case would be seeing the learning outcomes as an obvious impediment to game progress rather than an integral part of the experience, breaking immersion and compromising benefits associated with *Deep Learning and Understanding*.

Such impacts can be more keenly felt within multiplayer environments, where the expectation is that interactions with players, whether cooperative or competitive, is uninterrupted. As such, the greater representation of *Skills as Strategy* within the Multiplayer category (Section 2.5.3.5) may be attributed to the need for greater finesse in design and development to preserve a good player experience in real-world application. Although few studies made use of commercial games as vehicles for learning, use of these ‘off the shelf’ or with minimal adaptation is one situation that runs the risk of invoking the worst case of learning outcomes divorced from the game’s mechanics. While *Systems Thinking* is deeply embedded within many commercial games, this teaches mastery of the game, as opposed to understanding of the educational content that is sought to be delivered. It is therefore important to consider how learning outcomes can be not just surface level but foundational elements of how the fictional world functions.

World Building was well integrated into many SCDGBL offerings reviewed, embracing this as developers enables the creation of not just a game but a coherent learning world that the game takes place within. Further studies exploring the impact of deeper integration of *World Building*

could be helpful to better establish what kind of contribution a comprehensive implementation of *Systems Thinking* and *Skills as Strategy* could make to SCDGBL interventions.

2.6.2.2 Sandbox Learning

Sandbox Learning is utilised significantly in traditional gaming for player learning and practice in a threat free environment. Games such as Minecraft offer the ability to play the entire game in this way, making it popular in education contexts (Nebel et al., 2016), while players of multiplayer team games such as League of Legends pushed for developers to give them such a tool (Reddit, 2015). Few games reviewed fully realised this feature, limiting user approach to each of the game's elements to test out their abilities. While this may be difficult to achieve depending upon the game type and desired learning outcomes, allowing students to revisit and explore concepts, practising and developing skills is an important enabler of the under-represented SCL tenet *A Reflexive Approach to Teaching and Learning*, and opens up further usage of games as revision tools.

2.6.2.3 Use of Emerging Technologies

Systems utilised within interventions were often old/established, e.g. desktop systems, with limited attention paid to emerging technologies despite their promise. It has been suggested that the power afforded by a desktop system is an important factor in choice, particularly for multiplayer games such as MMOs (Dickey, 2007). Although questions remain over their suitability for deployment in school settings, which comprise a major proportion of these studies, the integration of emerging technologies could be further improved within a student centred context. Further studies to investigate the effect of such technologies from a student centred perspective could establish whether the potential benefits emerging technologies offer to game design carry over to learning outcomes and other benefits within a student centred environment. Although no longer an emerging technology, mobile as a platform was not utilised by the majority of papers. This may be because of concerns over practical deployment on this platform (e.g. device access, interoperability and cost) (Bidin and Ziden, 2013).

2.6.3 General Discussion

This review highlighted the need for better quality studies and deeper evaluation of SCDGBL interventions. Many identified papers were case studies, limiting generalisability, or theoretical papers lacking implementation. There were few longitudinal studies or use of follow-up to determine impact of SCDGBL interventions beyond 'research conditions', and exploration of the impact of interventions upon measurable learning outcomes, e.g. class tests, was often not carried out. These findings are supported by another previously published review that encompassed both digital and non-digital educational games without having a SCL focus (Petri and von Wangenheim, 2016). Testing interventions on larger cohorts may provide more

broadly applicable quantitative data, which may better establish the effectiveness of pioneered techniques. While low reach studies are valuable to establish viability and yield helpful qualitative insights, the area of education can be broad, with significant differences between cohorts based on area. The general viability of techniques would be better spoken to with a larger cohort that cuts across demographics.

2.6.4 Recommendations

This chapter demonstrated effective use of a conceptual framework developed from a thematic analysis of the SCDGBL literature (section 2.4) to organise, present and evaluate SCDGBL interventions or discussion papers. The framework gives equal weighting to both the design principles for DGBL (detailed in section 2.2.1) and the key tenets of SCL (detailed in section 2.2.2). In doing so, its use has demonstrated that not only do many SCDGBL offerings show poor integration of the social elements of SCL, but also that certain DGBL design principles have received only limited implementation and evaluation of their ability to deliver SCL tenets. Based on the insights and reflections drawn from evaluating the research literature presented in this study, the following recommendations for the future design of SCDGBL interventions are proposed:

- Greater use of follow up within study designs could capture reflections upon teaching and learning experiences on the part of students and teachers. This would allow effective assessment of longer-term learning effects as well as providing more opportunity to assess the integration of a *Reflexive Approach to Teaching and Learning*.
- Development of games that allow for the modification and adaptation by teacher-practitioners without deep programming and graphic design skills will enable teachers to implement a *Reflexive Approach to Teaching and Learning*.
- Longer study durations to utilise a game-based format for multiple topic areas would enable reflection upon progression through these areas. It may also allow the normalisation of game-based learning within a course which could form an interesting basis for future study, in contrast to discrete, constrained interventions.
- Increasing the number of cohort studies across all Player Engagement categories may provide more broadly applicable data, which may better establish the effectiveness and feasibility of pioneered techniques by cutting across demographics.
- Greater involvement of teachers within game environments in an active role should be considered as an opportunity to promote the SCL areas of *Teacher and Learner Interdependence* and *Mutual Respect*.

- Promote opportunities for role reversal in allowing students skilled at gaming to take on a demonstrating or leadership role, along with integrating cooperative gameplay to build *Mutual Respect.*
- Better integration of emerging technologies within interventions would allow deeper evaluation of the impact of the use of these technologies upon the student centred learning experience.
- A number of papers presented SCDGBL ideas within purely theoretical discussion; such papers should be accompanied or followed up by studies implementing or evaluating the ideas explored. While sharing ideas is important, it is necessary to explore these ideas in practice to identify those worth pursuing.
- Deeper integration of learning outcomes into world building at an early stage would reduce instances of broken immersion and promote *Systems Thinking*, thereby enabling use of *Skills as Strategy* and enhancing *Deep Learning and Understanding.*
- Offering learners a role to play within a game could enhance *Player Identity* and *Meaning from Experience*. As players engage with this role, the learning becomes more personal to the player and helps facilitate *Deep Learning and Understanding*.
- Deeper integration of peer-based *Active Learning* techniques, even within single player interventions, can provide a focus for discussion and engagement, delivering more comprehensively on the social aspects of Student Centred Learning to deepen engagement and enhance learning outcomes.
- Further usage of S*andbox Learning* design principles would enable students to practice their skills, allowing greater use of games as a revision tool and promoting a *Reflexive Approach to Teaching and Learning,* as students are given tools to explore and learn at their own pace.

2.7 Conclusions

Through this chapter, a conceptual framework of Student Centred Digital Game-Based learning is presented, derived from and used to classify a range of literature published between 2007 and 2018. The themes presented within the conceptual framework were derived from a thematic template analysis and comprise a logical, systematic method of categorising and classifying the literature.

SCDGBL interventions were stratified according to the conceptual framework and presented across three Player Engagement categories: Single Player interventions isolate the learner on their own within a game world and present learning as an individual process; Mixed interventions made use of different games or different engagement methods with varying or unspecified player numbers; Multiplayer interventions engage multiple learners in the same

game world at once. Within these categories, the nature of the games discussed, designed and/or deployed, and the Student Centred Learning tenets delivered was explored, categorising educational content and delivery of SCDGBL offerings according to the conceptual framework, which conceptually linked the design principles of Digital Game Based Learning and the seven tenets of Student Centred Learning.

Key findings from this process include a strong focus within Student Centred Digital Game Based Learning literature on certain SCL elements such as *Active Learning, Deep Learning and Understanding,* and developing a student's *Sense of Autonomy* and *Increased Responsibility and Accountability*, most often presented in Single Player games. With this focus, a number of 'social' SCL elements were found to be less well integrated, particularly areas such as *Mutual Respect*, *Teacher and Learner Interdependence* and developing a *Reflexive Approach to Teaching and Learning*. In addition to these, the utilisation of true multiplayer gaming involving either other students or teachers was found to be lacking. Emerging technologies that could promote innovative collaborative or cooperative learning to address such elements were utilised in a very limited fashion within studies reviewed, despite their popular usage for leisure gaming.

Gee's principles of good game design have been explored over time and provide a window through which to examine the literature on SCDGBL, highlighting the common groups of techniques games use to teach players. A lack of attention to a number of these principles may indicate areas future educational games may look to further both engage and teach players. The areas of *Skills as Strategy* and *Systems Thinking* imply a level of integrated world-building within game design which may form one area to explore. Further integration of principles such as *Learning Cycles* may offer an opportunity to deliver effective learning at a player's own pace. Taking an approach early on in game design that recognises the DGBL principles through which a game seeks to realise its educational content in an educational context may allow games to, through gameplay, story and other aspects provide a better rounded experience to deliver better learning outcomes. These principles require consideration early on in design, demanding that educational use be as core to the game as other aspects, but do not need to and should not come at the cost of making a bad game. Games developed in future should seek to embrace the potential of these principles, making good on the promise of 'Good Video Games, Good Learning' made by Gee.

While Student Centred Digital Game-Based Learning is an active research area, there remains a need to tie together more tightly the design of such games with existing research on how students learn. Without an understanding of the learning elements involved in both the games

presented and the student's existing teaching and learning environment, it may be difficult to identify the full value of Digital Game Based Learning techniques. Future studies may benefit from a more thorough exploration of all tenets of SCL, including those more socially focused such as *Mutual Respect and Teacher* and *Learner Interdependence.* Use of DGBL design principles to deliver such tenets may offer the potential to more fully realise the benefits of Student Centred Learning through digital video games, and to develop games that can be better utilised in the classrooms of the future.

2.8 Chapter Summary

This chapter provided a literature review, developing and utilising a conceptual framework to classify the state-of-the-art in Student Centred Digital Game-Based Learning. A number of challenges and gaps in the research domain are identified and recommendations for future practice are established. Evidence from the literature showed that a majority of games do not offer a complete Student Centred Learning experience that integrates all seven tenets. It is observed that a majority of games focus on a subset of tenets, particularly *Active Learning*, *Deep Learning and Understanding, Sense of Autonomy* and *Increased Responsibility and Accountability* while often neglecting the social tenets of *Mutual Respect*, *Teacher and Learner Interdependence*. In addition the findings highlight a lack of ability for teachers to customise experiences to suit the needs of individual student groups and apply a *Reflexive Approach to Teaching and Learning.* There is a need to embrace these neglected tenets and design games that effectively deliver a comprehensive Student Centred Learning experience. With this in mind, the following chapter details the research approach taken to achieve the research aims laid out in Chapter 1, along with details of the activities undertaken within each stage of this approach.

Chapter 3. Research Methods

3.1 Introduction

Chapter 2 presented a comprehensive literature survey of Student Centred Digital Game-Based Learning and the conceptual framework developed from this. A number of opportunities for future work were identified in the gaps identified, including the lack of fully developed collaborative game-based experiences and an absence of significant attention paid to the role of the teacher within such experiences. The overall consensus from the literature shows a number of frequently missing elements from Student Centred Learning which suggests the delivery of an educational game that incorporates all tenets of Student Centred Learning appears to present a significant challenge to game design. This research therefore addresses this challenge, exploring the design of a game that embraces a multiplayer approach designed from the core around the principles of Student Centred Learning.

To accomplish this, there is a need to design a game based upon the tenets of Student Centred Learning that delivers a fully featured educational experience incorporating these elements. Such an experience must account for good practice in the area of video games design, including following a systematic design framework, while also considering the needs of both students and teachers in engaging with the software presented. Such an approach considers both the need to incorporate particular elements to maintain the SCL focus and the overall design of the game. To achieve this, the research follows a Design Science Research (DSR) approach (Peffers et al., 2007, Hevner, 2007) including two iterations of the research and uses a mixed methods approach to explore how the game may best fit the needs of teachers and students.

This chapter explores the research paradigm followed in order to accomplish the aims and objectives of this research work. It further explores the methods and tools used in the course of this research and the justifications for their selection. The chapter proceeds as follows: Section 3.2 explores the Design Science research paradigm followed in this work, providing an overview of the DSR approach and the activities undertaken with a typical DSR project. Section 3.3 covers the Design Thinking framework and how this fits into the DSR activities. Section 3.4 explains the data collection and data analysis techniques applied within the project and the need for such an approach. Section 3.5 provides an explanation of the practical application of DSR to this research, mapping the DSR cycle steps to the steps undertaken and highlighting the associated methods, tool and outputs. Section 3.6 presents the considerations, ethical and otherwise that were taken into account during the process of creating this work. Section 3.7 presents conclusions from the application of the DSR approach

through this chapter. Section 3.8 then presents a summary of the chapter and its role in later chapters within this work.

3.2 Design Science Approach

Design Science Research is a well-established research paradigm used within Information Systems and beyond (Dresch et al., 2015) that stresses the creation and refinement of knowledge and understanding through the development of tangible artefacts. The artefacts created through DSR may be physical tools, computer programs or more abstract outputs such as guidance and methodologies (Peffers et al., 2007). Such artefacts are created to solve real-world problems through the development of or improvement of existing systems that address the particular needs of these problems and as such the DSR approach also takes into account users' reactions to the created artefact.

Consensus in DSR now breaks the process of undertaking a DSR project down into six common elements or activities (Peffers et al., 2007). Figure 5 shows these activities and their associated outputs.

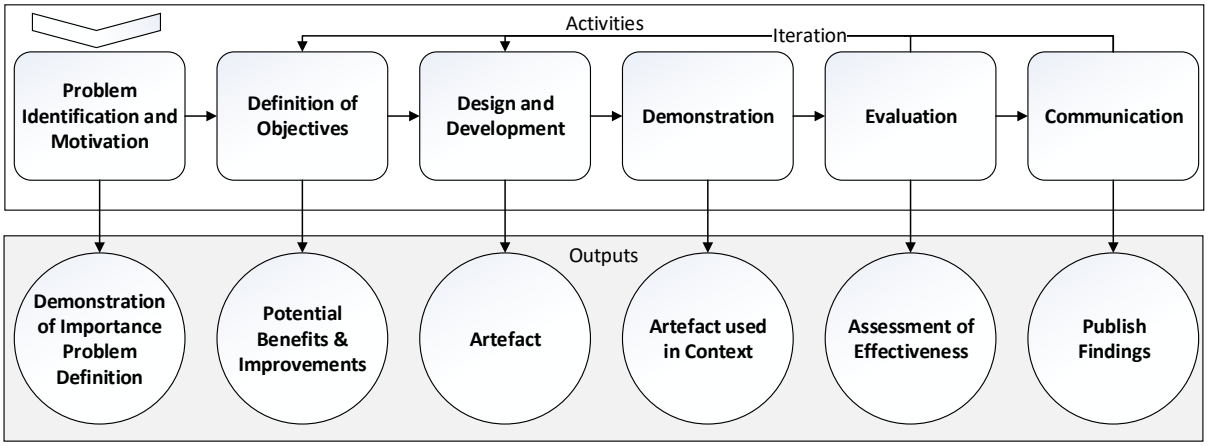

Figure 5: Design Science Research Activities and Outputs adapted from Peffers et al. (Peffers et al., 2007)

During *Problem Identification and Motivation*, the key outputs are a *Problem Definition* and a *Demonstration of Importance* for that particular problem. During this activity a researcher identifies a problem that exists in the world, and further identifies why this problem is important to solve. The problem will often be broken down into smaller aspects to better identify the full complexity and understand the component issues that may be addressed. The *Problem Definition* will form the basis of the artefact design that follows and is therefore important to realise as fully as possible. Solving the identified problem will provide the motivation for the research and design to follow. This activity may draw from aspects such as a literature review or upon previous qualitative or quantitative research.

Having identified the problem, the *Definition of Objectives* draws upon this to identify a solution that is feasible to produce and addresses the problems identified. Not every problem need translate directly into an objective as a key aspect here is that the solution should be a realistic prospect to develop. The key output from this activity is the objectives of the project in the form of the Potential Benefits and Improvements the proposed solution should offer above currently existing solutions. This work may draw further from resources such as a literature review or previous research as sources of knowledge on the current state of the art in solutions in this area.

Design and Development forms the third activity, wherein an iteration of the *Artefact* is created. Artefacts may be almost any kind of item produced that addresses the problem identified, with common examples including constructs, models, methods and instantiations. Within this activity the artefacts desired functionality is determined, followed by a design and production. This activity requires knowledge of both the theory of production and the practical skills to implement this in a solution.

Within the next activity, *Demonstration*, the artefact is taken and tested. In this activity the *Artefact is used in Context* and data collected on its performance as such. This may involve a real-world or simulated context and may take the form of an experiment, case-study, proof or other appropriate activity that tests the practical usage of the Artefact.

Following on from this, during *Evaluation* the Artefact's performance in context is observed and assessed to explore how well it performs as a solution to the identified problem. This requires a comparison between the objectives defined earlier and the observed results from deployment along with knowledge of the relevant metrics and analysis techniques used in the field. This may take the form of any sort of qualitative or quantitative metrics appropriate for the evaluation at hand or of a logical proof or similar technique. The key output from this activity is the Assessment of Effectiveness, upon which a researcher may decide to iterate back to Design and Development to further improve the Artefact, back to the Definition of Objectives should aspects have been missed or changed or to progress on to the final activity.

Communication forms the last activity undertaken within DSR. Within this activity the importance of the problem and the utility, novelty and effectiveness of the artefact are disseminated to researchers, professionals and to the wider public. The key output of this stage is *Published Findings*, both in academic journals and potentially backed up through other professional outlets. This activity requires an understanding of the discipline(s) addressed and the common areas where they are expressed. Following this and the feedback it may create, researchers have an additional opportunity to re-iterate on the artefacts objectives and design

and to further improve, such as between the publication of findings from the first study and revisions leading to future deployments.

Although presented sequentially, there may often be overlap in activities. Tasks such as identifying benefits may flow naturally during the identification of problems while concepts for potential solutions may arise during the definition of objectives to be further explored once the potential benefits are better understood. A key factor in this research is the nature of the created artefacts as a practical and useable SCDGBL experience. However, this then presents a challenge within the DSR process as DSR has been identified to focus on the creation of an artefact over the experience of utilising this artefact (Devitt and Robbins, 2013, Rai, 2017). With this in mind, there was a need to ensure that the process of artefact creation is as human-centric as the learning experience itself. One way this can be achieved is through nesting a human-centric design approach to the artefacts within the Design and Development phase of the DSR process. A popular human-centric design approach is Design Thinking, which has been applied to educational design problems in the past (Ewin et al., 2017, Fabri et al., 2016, Aflatoony et al., 2018).

3.3 Design Thinking Approach

Hevner and colleagues acknowledge that the three cycle view of DSR presented above is not sufficient in situations where the need for artefact is contextualised by the external environment or stakeholder views, namely a wicked problem (Drechsler and Hevner, 2016). It has been suggested that a Design Thinking approach can be complementary to DSR to boost the effectiveness of applying a DSR approach to address a wicked problem (Devitt and Robbins, 2013, Rai, 2017, Grobler and De Villiers, 2017, Dolak et al., 2013). It can be argued that the current SCDGBL design challenge constitutes a wicked problem through its human-centred nature (the focus on SCL), the desire to design and develop an artefact that produces a collaborative learning experience, the need to meet specified learning outcomes within a curriculum framework, and the need to co-locate both demonstration and evaluation of the designed artefact within a classroom which is not a standardised setting (Devitt and Robbins, 2013). Overall, the design of a game that creates an SCDGBL experience can be considered a complex problem that may not be fully addressed by a single design approach.

3.3.1 Designing for learners and teachers

Design thinking is a human-centric approach where the focus is on the experience generated by the artefact being designed (Rai, 2017). This is in contrast to DSR, where the artefact is the key output of the process, and the other elements of DSR such as demonstration and evaluation are oriented towards the improvement of the artefact. The user experience with the artefact from a DSR perspective is a natural extension of the artefact's design and creation,

rather than being a purpose or goal in itself (Rai, 2017, Dolak et al., 2013). This makes Design Thinking a helpful approach when considering the process of designing a game that creates an SCDGBL experience when deployed. It supports the idea that the experience of learners and teachers is inextricably integrated with the artefact itself (Rai, 2017), and that designers of such experiences need to fully account for this within the artefact design process, rather than considering user experience as a consequence. However, this approach is not without its problems when used in isolation.

Design Thinking has been utilised in a variety of areas to facilitate the development of effective, user centred artefacts, particularly within the domain of education (Ewin et al., 2017, Fabri et al., 2016, Aflatoony et al., 2018), with its strong user-centric philosophy aligning well with the focus of Student-Centred Learning.

The Design Thinking approach consists of 5 stages, through which a systematic design and innovation process is followed. This process seeks to enable the production of well designed artefacts that meet the requirements of an end user from the outset (Roberts et al., 2016). The 5 stages of Design Thinking are approached linearly at first, before an iterative process is entered by which the artefact is revised and improved. Figure 6 shows the stages of the Design Thinking Approach, and identifies common routes between those stages during the iteration process.

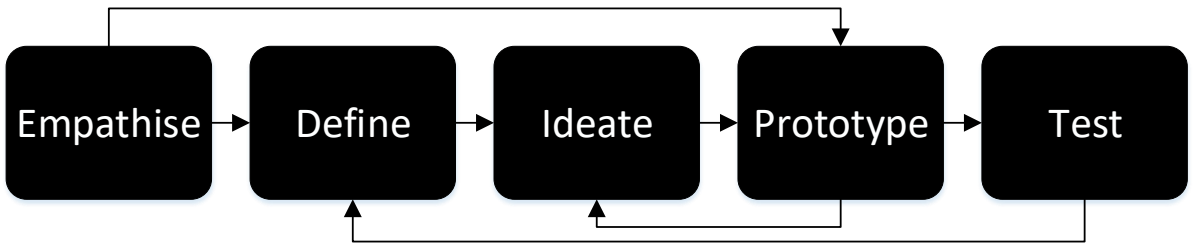

Figure 6: The Design Thinking Approach including routes between stages

The first stage in Design Thinking is to ***Empathise***. This stage in the process involves research, taking on board the opinions of experts and users of the systems and area in order to gain an empathic understanding of the needs within the area.

This leads into the second phase, ***Define,*** this stage in the Design Thinking Process takes the output from the empathise phase and utilises it in the creation of a problem statement to take forward into subsequent stages. The third phase is ***Ideate***, which seeks to address the problem statement, defined from background information obtained during the Empathise process, it is necessary to utilise ideation techniques to identify possible solutions. This can encompass a number of approaches, including reframing the problem with techniques such

as inversion or challenging assumptions, and brainstorming approaches such as mind-mapping, sketching and storyboarding. A key aspect of the Ideate phase is to initially generate many ideas or solutions and then test these through techniques such as those mentioned above to identify the best solution or the required components to take forward to the prototyping phase. ***Prototype*** forms the 4th phase in the framework, where an initial version of the artefact is created through an iterative process using the Ideate and Prototype phases to develop and improve the intended output. ***Test*** is the final phase, where the artefact is deployed to establish its suitability, after which it is revised and further improved through repeating earlier phases.

3.3.2 Blending Design Science Research and Design Thinking

A recurring problem with SCDGBL offerings reviewed in Chapter 2 was that their evaluation was often extremely limited. Although Design Thinking is a suitable approach to address the requirement for the artefact design process to be human-centric, a common critique of the Design Thinking approach is that the evaluation process lacks rigour (Dolak et al., 2013). This is in contrast to DSR where the evaluation process and the knowledge base informing the artefact are subject to methodological rigours which increase the validity and generalisability of the artefact beyond merely solving the problem in order to make a contribution to knowledge.

Although Design Thinking and Design Science Research are considered to be separate processes, they have a shared origin and many overlapping features (Dolak et al., 2013, Devitt and Robbins, 2013). These two approaches to design have been combined to produce a hybrid approach which offers the human-centric design approach embraced by Design Thinking while maintaining the academic and design rigour integral to the DSR process. Figure 7 presents the combined Design Thinking and DSR frameworks as adapted from Devitt and Robbins, which informed the use of these approaches within this work.

Within this adapted framework the DSR model has been expanded, with the initial Relevance Cycle now extended to cover the cycles of *Empathise* and *Define*, both drawn from the Design Thinking framework (Devitt and Robbins, 2013). Empathise draws experience, expertise, knowledge, behaviours and values from the people designed for, while feeding back empathy, understanding and meaning from the designer (Devitt and Robbins, 2013). The *Design* cycle remains, with the Design Thinking stages of Ideate, Prototype and Test sitting firmly within this cycle (Devitt and Robbins, 2013). This cycle draws the problem specification and opportunities to improve from the environment, and will deliver the finished artefact back to this environment for practical use; it also draws upon the methods and principles expressed within Design Science Research (Devitt and Robbins, 2013). The *Rigour* Cycle is untouched by the

combination, drawing from existing knowledge and expertise and from theory and contributing new knowledge to the knowledge base for future design to build upon (Devitt and Robbins, 2013, Hevner, 2007).

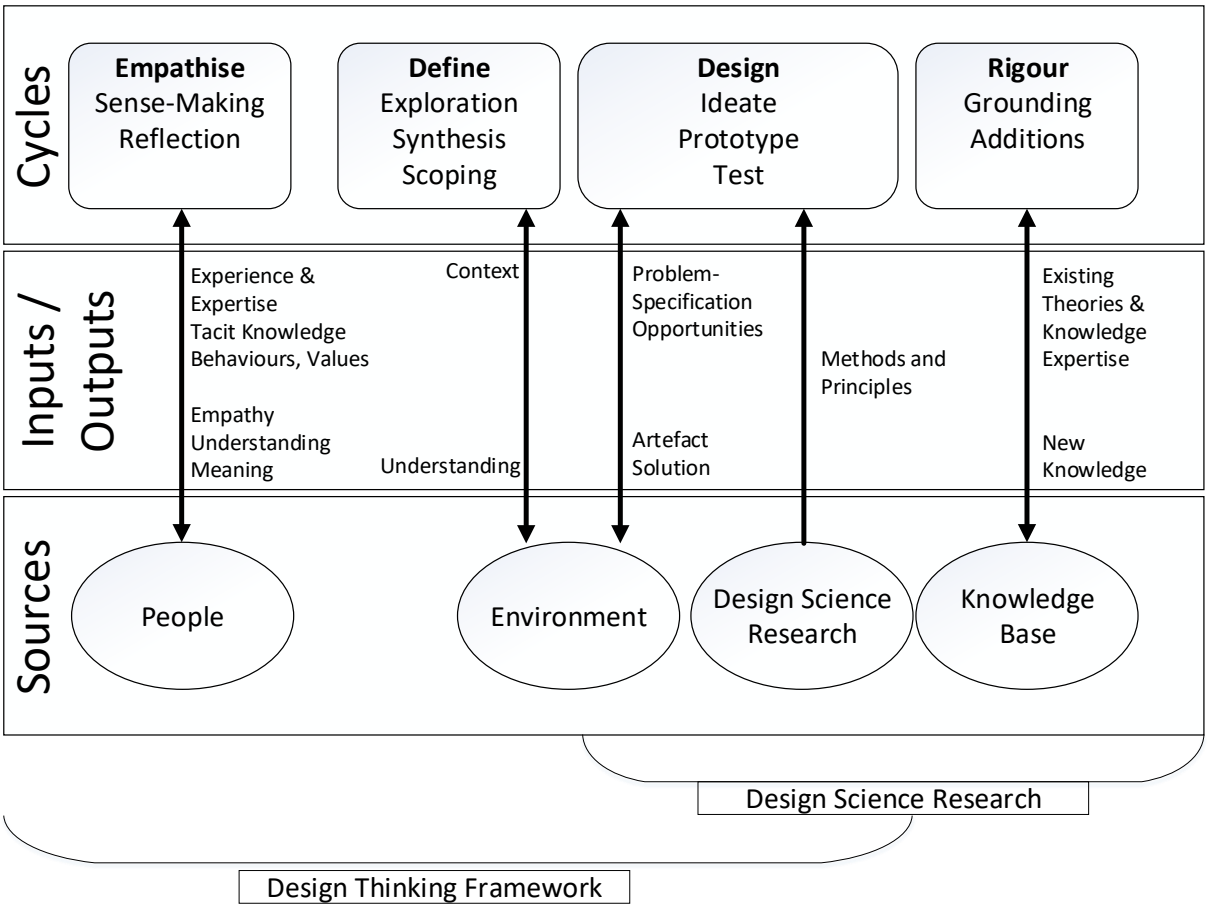

Figure 7: Integrated Design Science and Design Thinking frameworks adapted from Devitt and Robbins

Design thinking was employed within this work to address a specific problem identified during the Design Science Research process: The need for a suitable game design framework to guide the design of games that create SCDGBL experiences. The application of Design thinking therefore sits within the Design Science Research process presented above, as a complementary methodology to solve the human-centric design challenges faced within the iterative Design and Development, Demonstration and Evaluation cycles (Devitt and Robbins, 2013). This blended approach was utilised specifically when creating the game design framework presented in 4.3. The game design framework is therefore an artefact produced during the DSR process, using this blended approach. This framework was a necessary output to inform the design of further artefacts to address the overall design problem identified at the start of this chapter, that is to say, the game design framework created using the Design Thinking approach was in turn used in Chapter 5 to design a game based upon the tenets of SCL.

3.4 Data Collection and Analysis

The core of any research is data collection, which remains true in DSR as in other paradigms: data collected during the Demonstration stage can be analysed to inform evaluation of the artefact. A number of techniques and instruments, both qualitative and quantitative in nature, were used to gather data for this project. Each study is presented in detail in the following self-contained chapters along with the methods, tools and instruments used to gather data for that individual study (Chapter 5 and 6). Both descriptive and inferential statistical analysis was performed upon the quantitative datasets collected through questionnaires and class tests. These tests were selected based upon the individual datasets and the purpose of the study. Qualitative data was analysed through an inductive coding process which involved transcription and repeated reading of the data. This repeated reading offers the opportunity to become immersed within the dataset, a key aspect of familiarisation which allows the analyst to gain a stronger understanding of the data and reduce the likelihood of bias that may compromise the coding and future analysis and conclusion (Ritchie and Spencer, 1994).

Developing an artefact that improves upon existing solutions or solves an existing problem requires an understanding of the ways that artefact is received and treated by typical users. To this end it is vital to get as wide a range of views as possible that cover all considerations users have in the use of the artefact. For this reason it was considered vital to collect both qualitative and quantitative data in what is known as a mixed methods approach. Mixed methods research is an approach often utilised within DSR; the combination of qualitative and quantitative research when effectively and appropriately executed allows for the exploration of a problem under examination in different ways and may focus on different aspects to create a greater understanding of the whole (Cleven et al., 2009, Ågerfalk, 2013). Given the educational focus of this research and in particular the focus on social aspects as expressed through the SCL tenets, the mixed methods approach provides opportunity to explore more fully concepts such as students perception of others as sources for knowledge and help.

In such situations, qualitative research can be said to excel where the integration of personal views on a topic is an important aspect of the research undertaken (Cope, 2014). Qualitative data allows the researcher to access more in depth thoughts from the user on the personal impact of and feeling on the use of the artefact. While it is important to consider these as personal experiences, techniques such as thematic analysis allow the researcher to categorise topics and identify those found important in a widely recognised way. Conversely, situations such as determining educational effectiveness of the created system form a vital part of demonstrating the artefact's overall effectiveness, as demanded in the evaluation stage of DSR (Figure 5). Quantitative data allows the researcher to directly compare through recognised statistical tests the results gained from an applicable assessment of the artefact

with those from other situations, addressing this dimension of evaluation. This provides reliable evidence in such situations where direct comparisons between test results may be drawn, to demonstrate for example a difference in academic performance. Combined together, these techniques allow the researcher to identify any meaningful change created by the use of the artefact, while exploring the reasons behind those changes and assessing the level of acceptance and engagement users feel towards it.

3.5 Applying DSR

This section discusses the details of the DSR cycle as applied to this research, it includes the six DSR activities and highlights the tools and methods utilised as well as the particular outputs from each activity created during this project. Figure 8 presents an overview of these activities and iterations as applied to this research and how they were applied. The following sections expand upon these activities in greater detail and explore the iterations between these activities undertaken as a part of this process.

3.5.1 Problem Identification and Motivation

This initial stage of research focuses on the definition of a problem and demonstration of its importance. In this project the primary method for realising this was the undertaking of a structured literature survey focused on Student Centred Learning and Educational Video Games. This literature review enabled the construction of an up-to-date conceptual framework for the research area allowing gaps in the research to be identified along with advancing a series of observations and recommendations to address those gaps. A thematic analysis of the literature dataset was performed utilising Microsoft Excel to code and categorise the contents of included surveys. A hybrid approach blending both inductive and deductive theme development was undertaken to allow the utilisation of both existing themes in the form of Student Centred Learning tenets and the integration of emerging themes. A number of knowledge gaps were identified particularly in key areas such as the integration of social aspects of Student Centred Learning (*Mutual Respect*, *Reflexive Approach to Teaching and Learning* and *Teacher and Learner Interdependence*) along with the use of multiplayer gaming; these areas then formed the focus of this research. To address these areas a Problem Definition was created covering these areas with the Demonstration of Importance addressed through the literature review in the demonstration of the effectiveness of both Student Centred Learning utilising these social elements and Game based Learning in other contexts.

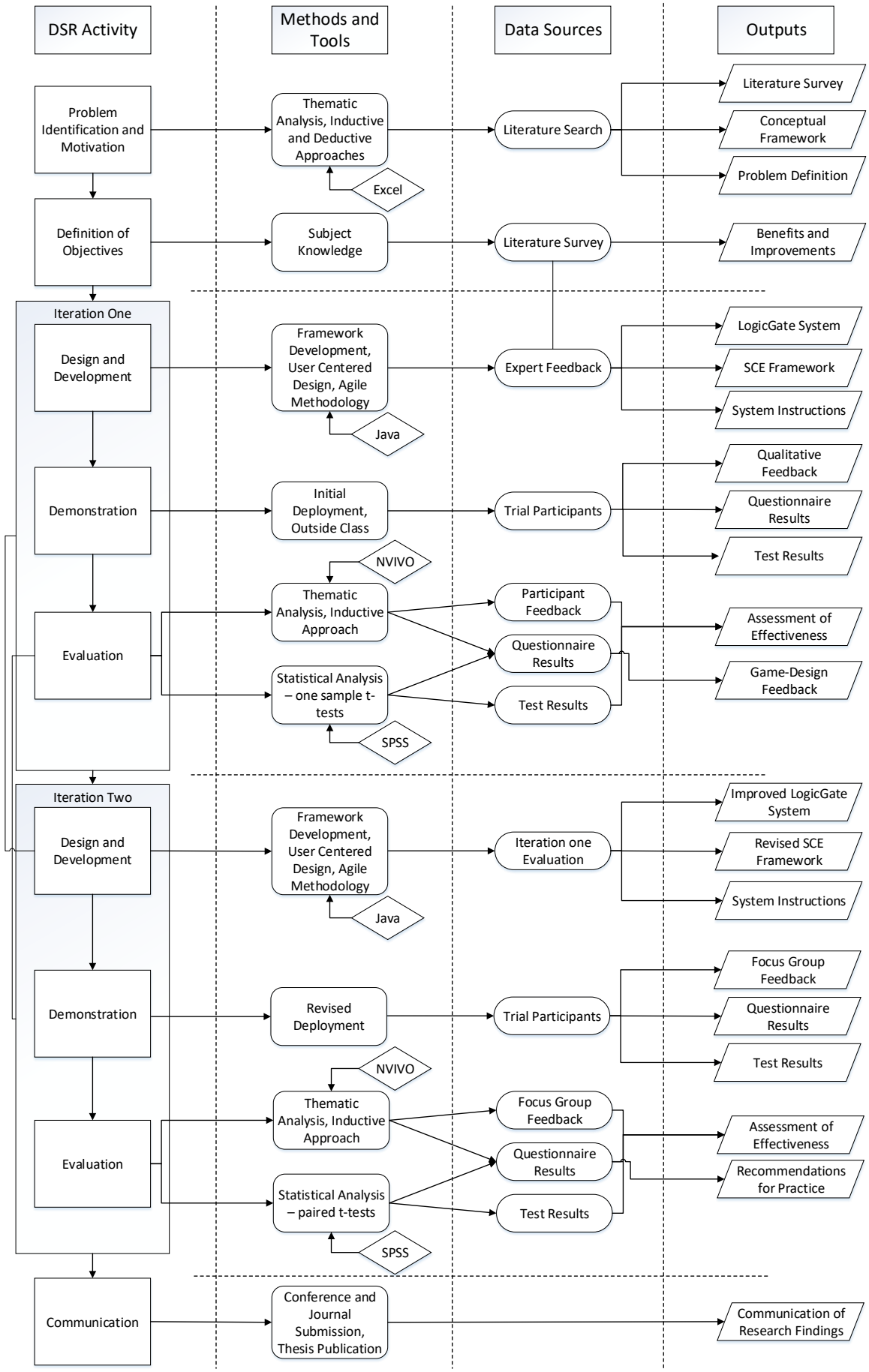

Figure 8: Design Science Research process as implemented in practice

3.5.2 Definition of Objectives

From the key knowledge gaps and issues observed in the literature survey, a series of recommendations were developed to address each observation. These problems and recommendations were considered alongside knowledge of existing solutions to draw up potential objectives for the development of an improved solution in later activities.

The key gaps identified within the literature review were chosen as the objectives, seeking to develop a solution which, while fully integrating all aspects of Student Centred Learning from the design phase, would offer a multiplayer experience that:

- Promoted student interaction and the growth of mutual respect.
- Fully involved the teacher as an active participant to promote student-teacher interdependence.
- Allowed students to reflect upon their own previous experiences to promote a reflexive attitude.

From these objectives, the potential benefits and improvements were drawn up, codifying the benefits a system developed according to these principles should achieve.

3.5.3 Iteration One

This section covers the three activities undertaken in the first iteration of development, including the conducting of Experiment 1. This study and its results can be found in full in Chapter 4, while this section discusses the role played in the context of Design Science Research.

3.5.3.1 Design and Development

The Design Thinking approach was utilised to develop a framework for the design of games that create SCDGBL experiences, taking into account issues identified through the literature review, and through an analysis of existing frameworks to identify the best basis upon which to build. This lead on to the definition of the goals the framework sought to achieve, in the form of a problem statement. An iterative design process then brought together the theoretical understanding from the literature review and framework analysis, alongside seminal literature in the fields of Student Centred Learning and Game Design. From the process, a prototype framework was created, which would then be utilised and tested through the remainder of this iteration. The development of this framework is presented in full detail in Chapter 4.

A number of initial designs were considered for this stage, from the development of an entirely new system from the ground up to building upon an existing game or software package.

Potential packages were investigated and compared with a fresh design looking at elements of packages which already delivered SCL elements or could be adapted to do so, along with developmental factors such as the ease of modification and social factors such as the existing user demographic (Amory et al., 1999). It was decided to use Minecraft as the basis for the game; Minecraft has a history of use in education and research (Nebel et al., 2016, Overby and Jones, 2015, Repenning et al., 2014) while offering a base for development that is highly modifiable to a researcher's needs. In addition while widely popular, Minecraft has a 40/60% Female – Male gender split in player base (Ames and Burrell, 2017) making a game based upon this less prone to bias than other DGBL experiences, which may be based upon packages with more polarised user-bases (Kinzie and Joseph, 2008).

As a DSR project the key output of this research is a game-based educational artefact, in this case the LogicGate System and its instructions. While development and programming were not the primary focus of this work, seeking to present approachable ways for non-programming education professionals to utilise its findings, some development work was undertaken. As a software project there is a body of research and industry practice which presents a number of software development methodologies that may be used. A software development methodology is a guideline or process by which software is designed and developed, typically using a series of phases that describe different aspects of development. Many software development methodologies exist, each of which guides the development of software in a different way and each of which may be suitable for different situations. Given the nature of this work and the importance of integrating user needs, a loose Agile methodology was chosen as the guideline for this project's development (Highsmith and Cockburn, 2001) within the Design and Development aspect of DSR. Agile allowed for short iterations of development, each of which created or adapted the modifications utilised in the game further, while presenting a functional version at the end of each iteration which was tested in the creation of the developed map and puzzles for the game, after which feedback on applicability and further needs were taken on board and the software further improved. This implementation of Agile allows the integration of continuous feedback from users into the development cycle helping reduce wasted development time and ensure tools created are needed and useable (Highsmith and Cockburn, 2001). Figure 9 Shows the Agile lifecycle utilised in this project, used for both iteration one and iteration two.

3.5.3.2 Demonstration

The produced game, named the LogicGate System, was deployed in Experiment 1 with 30 trial participants in a live classroom environment, as experienced in the normal course of the students learning. A mixed methods approach was used for data collection, with quantitative data collected through subject matter tests and through a questionnaire assessing students

experiences using the software and their perception of other students and teachers within their learning environment. Qualitative data was collected in the form of free text responses to questionnaires and through the use of focus groups where participants could discuss their experience.

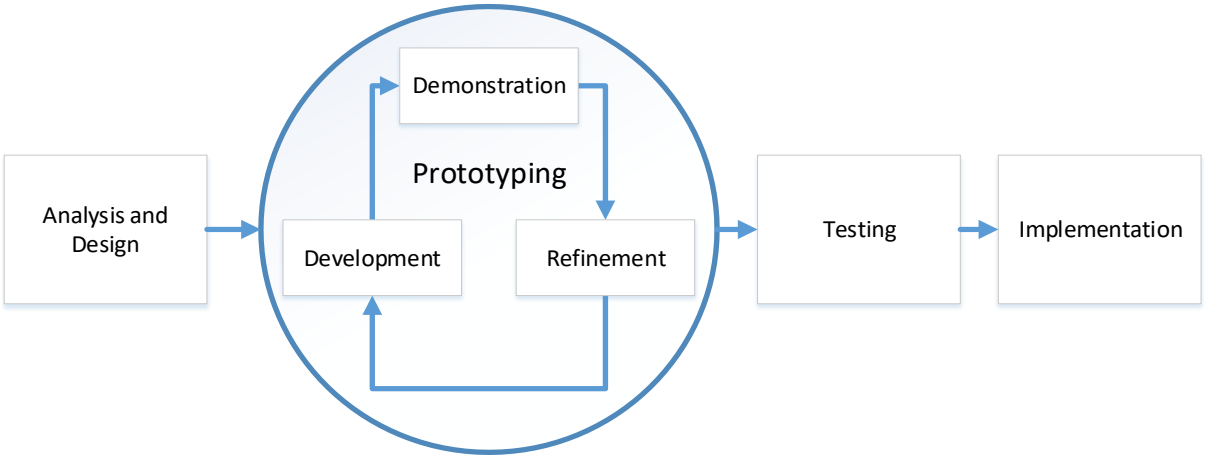

Figure 9: Agile software development lifecycle

3.5.3.3 Evaluation

Quantitative data must be analysed utilising quantitative techniques; accordingly questionnaire responses were analysed using IBM SPSS 22.0. SPSS is an industry standard statistical analysis package and is utilised regularly in many academic fields. Focus groups were recorded, and the recordings transcribed for use in text analysis. The qualitative data collected from both focus groups and free text responses was analysed both together and separately to ensure both individual responses and group discussions were taken into account fully and the views of all participants were included. An inductive approach to this analysis was taken, looking at the emerging topics from users' experiences and drawing themes from these topics discussed. Details of the thematic and statistical analysis of these results from Experiment 1 can be found in Chapter 5, Section 5.3.4. Following on from this, a further iteration was decided upon to draw from user experience and improve the LogicGate System as well as developing further variants of the LogicGate System exploring particular effects of individual SCL aspects, to better assess the source of any observed effects and to allow students further choice in their learning, as typified through the SCL tenet of offering students a sense of autonomy.

3.5.4 Iteration Two

Based upon the initial version of the LogicGate System, a revised version, LogicGate-R, was created to deliver the benefits and improvements sought earlier. This section covers the development and testing of this improved game across the three DSR activities repeated.

3.5.4.1 Design and Development

Utilising the initial design as a basis, a second development cycle focused on the improvements to the LogicGate System highlighted in Experiment 1 from iteration one. Improvements resulted in the LogicGate-R System, which focused on further developing the communication and teamwork aspects of the game, enhancing feedback and improving emotional engagement from students.

3.5.4.2 Demonstration

The LogicGate-R System was deployed in Experiment 2 with 32 trial participants in a simulated laboratory environment designed to replicate as many aspects of students' regular laboratory sessions as possible. A crossover design was utilised whereby students were randomly assigned to a traditional student-centred non-digital group task or to use the LogicGate-R System, before crossing over to the other task. A mixed methods approach was again utilised for data collection with a majority of elements repeated to allow comparison and assessment of change between the iterations. Quantitative data was collected through subject matter tests before the session and after each task, and through a questionnaire assessing students' experiences using the software and their perception of other students and teachers within their learning environment. Qualitative data was collected in the form of free text responses to questionnaires and through optional participation in focus groups where participants could discuss their experiences with others who shared similar and different variants of the LogicGate-R System.

3.5.4.3 Evaluation

For purposes of comparison and accurate assessment of changes, a similar process to that carried out in iteration one was followed. Quantitative statistical analysis was performed using IBM SPSS 22.0.0. Qualitative data from the focus groups was recorded and transcribed, while free text responses were used from the survey responses; this data was analysed and coded using NVIVO. A hybrid Inductive/Deductive approach was taken, utilising the themes and subthemes identified through iteration one while parsing the data for any additional themes emerging from the changes. Details of the thematic and statistical analysis in Experiment 2 can be found in Chapter 6, Section 6.4.5. At this stage, a decision was taken on the benefit of future iterations of the DSR process. The goal of the research project was to develop an artefact that successfully realised all 7 tenets of Student Centred Learning. While additional iterations could further improve and refine this artefact for wider release and/or commercial deployment, the artefact was found to be sufficient to answer the research objectives established and therefore further iteration was not undertaken as a part of this body of work.

3.5.5 Communication

The results and conclusions established Experiments 1 and 2, as well as earlier outputs of this project, were then communicated to a variety of audiences. Papers were published in peer reviewed academic journals and presented at doctoral consortiums. Communication of knowledge is essential in research to further understanding and reduce repetition of work between researchers and peer review provides an essential role within this to ensure a high quality of research is distributed for future research to build upon. Further details of publications and other dissemination efforts may be found at the beginning of this work.

3.6 General and Ethical Considerations

Research was designed and carried out according to best practice as applied within the university and the wider academic world. Participants' safety and security were of paramount importance throughout the study and steps were taken to ensure their rights respected at all times. These steps included taking into account participants privacy and anonymity, as well as physical considerations which must be considered in all research involving humans but particularly where there may be a discrepancy in power or social standing. Participants were offered compensation for taking part in the study, in the form of a £10 Amazon or Google voucher.

Working with a student population requires some additional considerations over and above those involving purely external participants. As students at the university may be under pressure to succeed and may look to lecturers, researchers and laboratory demonstrators as having power to influence that success through favourable reports and recommendations or through direct grading and marking it was important to assure students that their participation was voluntary and did not affect their standing within the university or grading in any way. The student population may have a varying degree of competence in English and in IT literacy, as well as potentially having additional support needs. These factors were considered in the language used within the LogicGate System and the surrounding documentation, as well as the design of the LogicGate System. Further considerations came in the form of accessibility, where text communications were available for those with hearing/speaking difficulties while the LogicGate System design took accessibility into account with colours picked to allow free play despite colour-blindness.

Ethical approval for the studies was granted by Brunel University Research Ethics Committee prior to any data collection commencing, these approvals may be found in Appendix 1. Fully informed consent was obtained from each participant prior to them taking part in the research with the consent form found in Appendix 2A. Participants were guaranteed anonymity and confidentiality in any publications arising including this document, however the group nature

of the study meant it was impossible to secure participants identities from others partaking in the same research session or study group, participants were fully briefed on this prior to taking part in these sessions. Each participant was informed both in writing and verbally of their right to withdraw from the research at any time without reason or prejudice. All participants volunteered to take part and were given full information on the goals and methods by which the research was carried out.

This research followed best practice, with participants receiving information sheets (Appendix 2B) by email for the study they were participating in before arrival at their session to allow time to consider their participation fully without undue pressure to participate. Data storage is vital to consider, particularly in research affecting humans. Data collected was stored securely on the university network and accessible remotely only through a securely encrypted virtual private network service presented by the university for these purposes. All access to the data was password protected and any successful log into the LogicGate System was logged. Data from questionnaires and tests was entered manually into SPSS while recordings were transcribed by the researcher before entry alongside further questionnaire responses into Nvivo through which data analysis was performed. Questionnaires were completed digitally leaving no hard copies of the data.

3.7 Conclusion

This chapter has explained the research approach, Design Science Research, and how this was used to achieve the aims and objectives of this research. The methods chosen to deliver within this research style have been visualised, explained and justified. The two iterations of development were explored and summarised with reference to the full write-ups presented in later chapters. The nature of data captured, both qualitative and quantitative has been explored and the mixed methods approach to this data collection discussed. Further the ethical and practical considerations taken into account in the design of this research are acknowledged along with issues that may have arisen in these areas. Finally a discussion of the software development methodology employed throughout the design and development of the LogicGate System is presented with a rationale for this methods selection.

3.8 Chapter Summary

Throughout this chapter the research aims and objectives are presented, along with the methodology by which those aims were developed and the rationale by which steps were taken to achieve those aims. The Design Science Research paradigm is introduced and explained with an exploration into its application in this work. The activities outlined in Design Science Research are then examined and the methods and techniques used justified. The mixed methods approach to data collection is explored and justified with explanation on the

benefits of integrating both qualitative and quantitative data into the research. Ethical considerations are examined and the steps undertaken and practices employed to ensure appropriate treatment of participants and participant data is explored. This chapter then explores the software development methodology utilised in the development of the artefact presented. Subsequent chapters will explore the two design iterations and accompanying studies which inform the conclusions presented.

Chapter 4. Game Design Framework

A key message from the Literature Review completed in Chapter 2 was that there is a need to develop educational games that implement all tenets of Student Centred Learning. To that end, this chapter will establish that the development of such a game should be guided by a game-design framework, which are known to have a key role in the development of appropriate educational games that are effective learning tools (Kiili, 2005). This section justifies the need for a focused game design framework by examining existing game design frameworks currently applied to educational games and argues that development of a framework with a SCL focus would be beneficial to guide the design of future SCDGBL games and experiences. Subsequently it steps through the design thinking process that gave rise to this new framework, drawing upon and integrating existing independent theories within the field. It then concludes with a presentation of the resulting framework that aims to guide the design of a game for deployment with students that delivers a comprehensive SCDGBL experience, providing an example of how the framework and its users, namely teaching practitioners and game designers, may interact within the phases of a typical development lifecycle that could be applied in creating an educational game.

4.1 Introduction

As Digital Game-Based Learning is often utilised as a platform to deliver Student Centred Learning (Wang et al., 2018, Khamparia and Pandey, 2018, Hung et al., 2018, Barr, 2018), it follows that educational game designs may wish to take in this popular educational theory. As established in previous work, such designs should seek to integrate all aspects of Student Centred Learning as well as providing a high quality game experience that players/learners will enjoy (Gee, 2005).

4.2 Need for a Framework

To fulfil the aim of integrating all tenets of Student Centred Learning in a game to create an SCDGBL experience, such integration should take place within the design process (Moreno-Ger et al., 2008, Amory and Seagram, 2003). While a number of game-based studies were examined in the literature review (Chapter 2), many utilised existing games developed without an educational audience in mind (Ahmad et al., 2011, King, 2015, Barr, 2018, Watson et al., 2011), or where a specific SCDGBL intervention was developed, there was often no mention of a design framework followed (Yang, 2015, Sung and Hwang, 2013, Owston, 2009, Neville et al., 2009), that could be utilised to help ensure these games integrated all aspects of Student Centred Learning. Engaging in a game design process according to a defined framework or process can guide the design of meaningful play to deliver the intended goals (Salen et al., 2004). A survey of the literature in this area identified the need to deliver a more

comprehensive Student Centred experience, a need which a framework designed to incorporate all elements of SCDGBL would serve to alleviate, as identified in Chapter 2. However, one question that arises is whether indeed such a framework exists at this present moment in time. The absence of a focused design framework to guide development of such experiences may be one of the key reasons why the majority of SCDGBL applications surveyed in Chapter 2 did not incorporate the full range of SCL tenets. To answer this, it is necessary to take a closer look at existing game design frameworks applied to educational games, and their purpose.

The role of a game design framework is to guide the game designer (Mora et al., 2015) and to provide perspective to them upon where they would consider making design choices. A framework also serves to shed light upon the effects such design choices may have upon factors within the game. Its role is not to prescriptively lay out the game design for them (Schell, 2014, Mora et al., 2015). Frameworks exist for educational game-design, one such example being the EFM framework (standing for effective learning environment, flow experience & motivation) which draws heavily upon the concepts of Flow and its role in motivating students to learn (Song and Zhang, 2008). Flow is defined as a consciousness state achieved by the unification of multiple elements, for example concentration, clear feedback and activity goals, resulting in motivation (Czikszentmihalyi, 1990), previously identified as a key benefit of many *Active Learning* techniques within SCL (Table 3). Flow in and of itself is not an educational theory, but it has been shown to have some utility when applied to the design of learning activities (Chan and Ahern, 1999). Moreno-Ger et al.'s seminal work provides a further example, looking at the design of educational games using Finite State Machines (Moreno-Ger et al., 2008). A literature search was completed through which it was identified that a framework that comprehensively delivers all aspects of Student Centred Learning does not currently exist. Table 7 presents a summary of popular game-design frameworks which are used within educational and Student Centred games design, making these frameworks the closest candidates to such a framework that could be identified. The frameworks included within this table were identified to be those most frequently utilised and cited within the literature reviewed in Chapter 2 which aimed to capture the state of the art in the field of Student Centred Digital Game-Based Learning. Within the table the Educational Basis, Areas of Focus, Intended Audience and areas of SCL incorporated into each framework is identified. While these frameworks provide excellent models for tasks including the integration of assessment and adaptation to the game, they do not address many of the particular elements of a SCL experience and therefore cannot be said to comprehensively guide SCDGBL design.

To further evidence this point, each of these Frameworks will now be examined, providing further detail on the Educational Basis, Areas of Focus, Intended Audience and SCL tenets

implemented. While these frameworks do not actively seek to use the tenets of Student Centred Learning, a number incorporate related educational theories and may cover some of the same ground.

Table 7: Comparison of Game Design Frameworks

	Framework Details			SCL Tenets						
Framework	Educational Basis	Areas of Focus	Intended Audience	Active Learning	Deep Learning	Responsibility	Sense of Autonomy	Interdependence	Mutual Respect	Reflexive Approach
Generic Game Design Frameworks										
Hunicke et al. (Hunicke et al., 2004)	N/A	How designed mechanics and implementation create fun. How to characterise and design for different aspects of fun.	Commercial Game Designers				X			
Schell, J (Schell, 2014)	N/A	The connection between different elements of games design. Methods of delivering story through games.	Commercial Game Designers				X			
Education Specific Game Design Frameworks										
Aleven et al. (Aleven et al., 2010)	Bloom	Establishing learning objectives as a guiding principle for educational game design work.	Educational design students	X	X		X			
Echeverria et al. (Echeverría et al., 2011)	Bloom, CMPG (CSCL)	Classroom-based multiplayer. Constraints of Tetrad elements by educational demands.	Educators/ Designers	X				X	X	
Moreno-Ger et al. (Moreno-Ger et al., 2008)	Constructivist	Modelling of games as Finite State Machines. Games adaptation and response to player actions.	Educators/ Designers	X		X	X			
Song & Zhang (Song and Zhang, 2008)	ARCS (Motivation)	Maintaining player motivation and establishing Flow experience in learning environments.	Chinese Educators	X			X			
Winn, B.M. (Winn, 2009)	Bloom	The interaction between Learning, Storytelling, Gameplay and User Experience.	Serious Games' developers	X	X					

4.2.1 Educational Basis

Looking at the educational basis behind frameworks, it can be seen that a number of those with a basis in education derive their focus from Blooms Taxonomy (Winn, 2009, Echeverría et al., 2011, Aleven et al., 2010). While well respected and widely used, Blooms Taxonomy provides an understanding of the ways learners process information, it does not address wider concepts such as the situation of learning nor does it seek to engage the learner as more than an engine for processing learning. Bloom leaves to the reader the methodology by which to stimulate the higher levels of thinking and by which to identify and engage with learners.

Blooms Taxonomy has significant value as a tool by which to identify learning objectives and describe learning processes, but does not offer guidance on the social and personal aspects of learning which are relevant to today's classrooms. Outside of Bloom, a number of other educational theories were cited in studies: The EFM framework discusses the relevance of Motivation as a major foundational theory, drawing upon the ARCS Model (Attention, Relevance, Confidence, Satisfaction) to support itself, however it does not appear to draw upon any other theory to a significant level (Song and Zhang, 2008). Echeverria et al. draw background for their framework from the CMPG (Classroom Multiplayer Presidential Games), which itself draws from the CSCL (Computer Supported Collaborative Learning) model to describe ways to use computers to mediate social collaboration between students (Echeverría et al., 2011). Moreno-Get et al. cite no specific educational theory behind their framework, though the frameworks direction towards Assessment, Reflection and the role of the Teacher conveys a broadly constructivist philosophy (Moreno-Ger et al., 2008). The Elemental Tetrad and MDA frameworks provide no direct educational application and correspondingly include no direct links to pedagogical theory (Hunicke et al., 2004, Schell, 2014).

4.2.2 Areas of Core Focus

Alongside the educational basis, a number of different core areas of focus are summarised which often differ between frameworks. The MDA framework offers particular focus on the evolution and creation of different types of 'fun', as viewed through its Aesthetics lens (Hunicke et al., 2004). This focus asks designers to look at the tools they offer players (Mechanics), the systems, incentives, situations and economies these may create (Dynamics) and what kind of results and emotional experiences these will create (Aesthetics) (Hunicke et al., 2004). The Elemental Tetrad offers a view of game design divided into four separate areas: Technology, Mechanics, Story and Aesthetics (Schell, 2014). Each of these elements is co-dependent and each can be adapted and adjusted by the designer to create the intended end results (Schell, 2014). Neither of these models have a particular educational focus. The EFM Model draws heavily on theory of Motivation and of Flow within games to create what it calls an Effective Learning Environment (Song and Zhang, 2008). The focus on multiplayer aspects by Echeverria et al. is relevant to Student Centred Learning, however this focus here is exclusively on the peer to peer connection in multiplayer games and on the design of interactive elements (Echeverría et al., 2011). Aleven et al. explore the combination of Blooms taxonomy with the MDA framework, blending in a number of instructional principles, however the list of 70+ principles drawn directly from four sources which overlap and contradict in a number of areas makes the framework difficult to comprehend and apply in a practical situation (Aleven et al., 2010). The DPE framework again explores an extension of MDA, with a focus upon the added layers of Learning, Storytelling, Gameplay and User experience (Winn, 2009).

This provides a basis to connect pedagogical theory to the established framework, however the framework while touching upon related ideas, such as connecting storytelling to learning, does not address social needs nor does it offer guidance on the mechanical connections between game activities and learning (Winn, 2009). Moreno-Ger et al.'s work places a direct focus on a games response to player actions and on the ways to assess a learner through these actions (Moreno-Ger et al., 2008). Overall, there is a limited degree of student-centred focus within the majority of the frameworks evaluated.

4.2.3 SCL Implementation

While the frameworks indicated do not advertise Student Centred Learning as a focus or contributor to the frameworks developed, some aspects of Student Centred Learning are touched upon through other educational techniques and theories, as well as through game-design methods. Accordingly this section explores the SCL tenets as integrated in the existing frameworks.

4.2.3.1 Active Learning

Concepts of Active learning are explored within five of the frameworks (Aleven et al., 2010, Echeverría et al., 2011, Moreno-Ger et al., 2008, Song and Zhang, 2008, Winn, 2009). Covering learning through active participation in activities, this tenet of SCL is covered by all frameworks seeking to advise designers on the creation of educational games. Of the frameworks that did not use this tenet, both sought to have the player actively engaging with the game but lacked the educational content to be used during learning (Hunicke et al., 2004, Schell, 2014).

4.2.3.2 Deep Learning

Deep Learning and Understanding was observed to be embedded within two frameworks (Aleven et al., 2010, Winn, 2009). This tenet explores the embedding of learning within experiences the player has during gameplay. While many frameworks sought to deliver learning through their designed games, the two identified give particular attention to how this learning is delivered. Emphasis is placed on the integration with storytelling and upon the emotional investment of players, building experiences through these elements (Winn, 2009) or upon the matching up of the learning to be delivered with the skills needed to progress such that improving in both is a natural process (Aleven et al., 2010).

4.2.3.3 Responsibility

Increased Responsibility and Accountability was explored only within one framework (Moreno-Ger et al., 2008). The focus on assessment provided and on the continual evolution and testing of students abilities could, if utilised effectively, allow players to know how well they are doing and identify both areas to improve and ways to do so (Moreno-Ger et al., 2008).

4.2.3.4 Sense of Autonomy

A focus on providing players a Sense of Autonomy was found within a number of frameworks (Aleven et al., 2010, Moreno-Ger et al., 2008, Song and Zhang, 2008, Hunicke et al., 2004, Schell, 2014). This tenet is notable in that its use was observed within both frameworks that did not have an educational basis (Hunicke et al., 2004, Schell, 2014). Sense of Autonomy covers players experience of being able to progress through the game at their own pace and using their own skills and this need for player control is explored in the majority of frameworks. Where it was not observed, this may be attributed to a core focus on single-screen multiplayer experiences, which prevent one individual player from having this degree of control (Echeverría et al., 2011) or to an exploration of more linear game design, allowing for the possibility to design games that specifically exclude this tenet (Winn, 2009).

4.2.3.5 Interdependence

Student-Teacher Interdependence was found embedded within one framework (Echeverría et al., 2011). Within this context the teacher acts as a guide through the game, leading the students in their exploration through the use of a single-screen, multi-user approach where the teacher retains primary control of the game (Echeverría et al., 2011). The role of the teacher is not explored within the majority of frameworks.

4.2.3.6 Mutual Respect

The tenet of Mutual Respect, built between learners was observed to be core to only one of the frameworks examined (Echeverría et al., 2011). The multiplayer focus of the work of Echeverria et al. explores this tenet, seeking to encourage players to work together in groups to achieve success (Echeverría et al., 2011). Other frameworks do not specifically explore the concept of learning from or building relationships with other players, though do not rule out or exclude this potential.

4.2.3.7 Reflexive Approach

Reflexive approach to Teaching and Learning was not observed as a focus of any of the frameworks explored. This forms the clearest absence in the design of games through the use of the frameworks examined, with the player's ability to reflect upon and learn from parts of their SCDGBL experience not addressed.

It can be seen from the table, that existing frameworks' focus is placed upon the design of the game and upon other educational considerations, neglecting aspects vital to a SCL experience such as the relationship to the teacher expressed through Student and Teacher Interdependence (Lea et al., 2003). This absence is supported by the observation in Chapter 2 that existing serious games that seek to offer a SCL experience fall short, missing out a number of tenets of SCL and therefore not providing a full experience. With this in mind, there

is a need for a new framework that draws upon established theory of game design, as well as the literature within the domain of SCDGBL. This new framework should address the issues with existing frameworks, providing a solid pedagogical basis in Student Centred Learning and allowing for the incorporation of personal and social aspects such as relationships between students and teachers. This framework should provide a flexible tool which can be used in the design of games to draw out opportunities to integrate the tenets of SCL into learning through gameplay, creating an SCDGBL experience.

4.3 Development of a SCDGBL Framework

The aim in developing a SCDGBL framework is to provide evidence-based guidance to games developers to assist in the design of games for use within a range of situations to create an SCDGBL experience. The key considerations for developing a SCDGBL Framework are as follows – the integration of SCL tenets and DGBL principles has already been performed in the previous work. This serves as an excellent starting point to ensure the SCL tenets and DGBL principles can together be incorporated into an education game, ensuring a high quality game experience while coupled with a comprehensive delivery of learning content in a fully student-centred manner. The next step would therefore be to identify a suitable game design framework with the potential for linkage to these coupled concepts, in order to take this forward into a framework design process. To avoid the complexity issues experienced by those attempting to combine and extend frameworks (Aleven et al., 2010), the selection of a single game design framework was preferred. However, because existing frameworks available for selection lack a SCL focus, their linkage to the coupled SCL tenets and DGBL principles still represents a complex exercise. For this reason, it is necessary to adopt a systematic approach to the design and refinement of the resultant SCDGBL framework, that is oriented towards complex problems.

4.3.1 Design Thinking

Design Thinking is a five stage systematic innovation and design process, which aims to facilitate the production of well-designed artefacts that meet the requirements of the end-user from the outset (Roberts et al., 2016). The Design Thinking process includes five distinct stages which are approached initially linearly, before adopting an iterative approach to improvement. Further details on the Design Thinking process are found in Section 3.3. These 5 stages, along with the common pathways between them and activities undertaken at each stage, are shown in Figure 10.

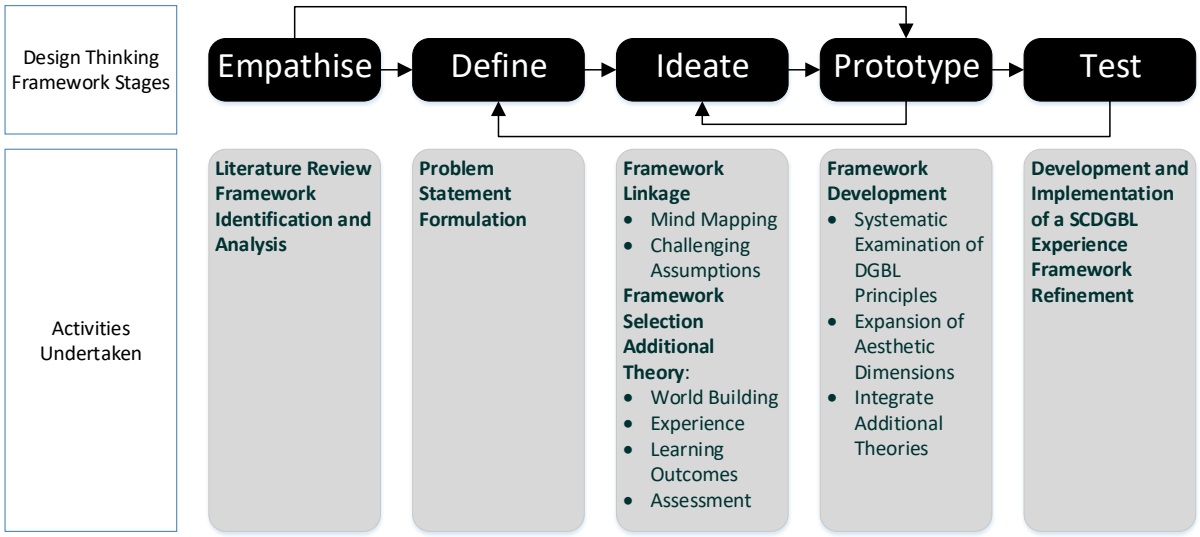

Figure 10: The Design Thinking process showing common routes between stages

4.3.1.1 Empathise

Some applicable work has already been completed towards the empathise process, in the form of the *Literature Review* presented in Chapter 2. Key points arising from this *Literature Review* included establishing the linkage between SCL tenets and DGBL principles; a linkage that allowed the identification of key areas of SCL which are omitted from current educational games. The information on the areas of success and of future improvement would inform the *Framework Identification and Analysis* exercise undertaken to investigate existing game design frameworks.

Framework Identification and Analysis was undertaken because it was necessary to gain an overview of the available game design frameworks with a view to identifying the best candidates for further linkage to the SCL tenets and DGBL principles. Game design frameworks were identified through a scoping review of the literature and consideration of their degree of focus upon SCL and integration of SCL tenets. This focus was selected due to the DGBL principles falling more naturally within the remit of a game design framework, therefore integration of SCL tenets represents the more complex problem to solve within this design thinking exercise. The existing state of SCL tenet representation is shown in Table 7.

To summarise the output of this *Empathise* process, it was identified that the delivery of SCL tenets is not currently a key focus of any game design framework as discussed previously. Despite this lack of key focus, some tenets of SCL are delivered through games. As existing game design frameworks function well for the creation of games, a SCDGBL framework should seek to build upon this success to deliver guidance in areas relating to SCL.

4.3.1.2 Define

Having evaluated the literature within the *Empathise* phase, the nature of the problem could then be defined based on the background information obtained. It is customary to orient *Problem Statement Formulation* to be human-centric, which aligns well with the core ideal of Student-Centred Learning, putting the human, in this case the student, at the centre of the learning. With this in mind, the following problem statement was formulated:

"To create a focused game design framework that integrates SCL tenets and DGBL principles into its foundations will help game designers to design games that create cohesive and comprehensive SCDGBL experiences for learners to participate in."

4.3.1.3 Ideate

For this work, multiple game design frameworks identified during the *Empathise* phase were explored for their potential linkage to SCL tenets, and consequently the coupled DGBL principles. Sketch techniques were used initially within this *Framework Linkage* process to annotate frameworks and create linkages, and the frameworks demonstrating the most potential for integration of SCL tenets were then further explored in the latter part of the Ideate phase through use of *Mind Mapping* and *Challenging Assumptions*. From this work it was identified that existing frameworks which sought to enable the development of Educational Games were often already complicated by the educational theory they sought to operationalise which may at times conflict with that of Student Centred Learning. For these reasons it was felt that the ideal candidate framework should focus solely on Game Design, providing an effective blank slate to mesh with the concept of SCDGBL.

This *Framework Selection* process resulted in a single game design framework being taken forward from the *Ideate* phase into the *Prototype* phase. This framework was not SCL-focused, but was considered through *Challenging Assumptions* that the initial grounding framework must demonstrate such focus, and showed the most potential for linkage and integration of SCL tenets during *Framework Linkage*. The framework chosen at this stage, was the MDA framework, standing for Mechanics, Dynamics and Aesthetics. The MDA framework was chosen as a basis from the frameworks examined due to a combination of its wide application within the academic and game development areas, alongside its flexibility. MDA does not have a direct connection to pedagogical applications which allowed a clean introduction of these elements through SCL theory.

MDA, presents the concepts of Mechanics, Dynamics and Aesthetics as 'lenses' through which aspects of the game to be designed may be viewed. The MDA framework puts forward these lenses with the idea that decisions made in relation to an aspect of the game will have

different effects when seen through these different lenses, which are described below (Hunicke et al., 2004):

- **Mechanics** includes the actions and ability to control the game the player is given, along with the games levels, models and other elements directly created by the designer/developer (Hunicke et al., 2004). This lens of the framework can be used to view desired dynamics for a game to determine what kind of mechanics may be needed to encourage such dynamics, thereby achieving the set aesthetic goals. Implementing mechanics within the game creates the opportunity for players to respond to or utilise these mechanics, resulting in player behaviours that can be observed through the Dynamics lens. For example, implementing a scoring system based on the number of moves taken in a puzzle game encourages players to repeat the puzzle even after successful completion to see if they can complete it more efficiently. Multiple mechanics within a game can interact, which can affect the player's behaviour and the types of enjoyment encountered within the game, as determined from viewing through the Aesthetics lens. Using the puzzle game example, adding an 'Undo' button allows players to experiment and enjoy discovering different paths to the solution from individual steps taken. Game mechanics therefore represent an important mechanism by which to encourage dynamics that evoke a desired aesthetic.
- **Dynamics** shows the tendencies within gameplay that arise from the mechanics implemented, it seeks to illuminate what the mechanics of the game will encourage players to do or why the aesthetics appear as they do (Hunicke et al., 2004). This lens of the framework can be used to view the impact of the implementation of game mechanics upon player actions and the aesthetics evoked, or to consider what kind of dynamic is desired in order to achieve an aesthetic goal, which in turn can be considered through the Mechanics lens to determine the required mechanics to give rise to this dynamic. Such considerations also help to avoid negative player experiences, for example, use of rubber-banding mechanics in competitive games help to ensure players who have fallen behind can still have a chance of winning, ensuring their continuing engagement and enjoyment.
- **Aesthetics** encompasses a taxonomy of emotions and experiences that a game seeks to evoke from a player. These include, but are not limited to, Sensation, Fantasy, Narrative, Challenge, Fellowship, Discovery, Expression and Submission. These are linked to different aspects of enjoyment a player may seek to obtain from their gameplay experience, respectively sense-pleasure, make-believe/escapism, drama, a series of obstacles for negotiation, a social framework, unexplored territory, self-discovery or simply a way of spending some time.

A game can have multiple aesthetic goals captured by this taxonomy, which has been expanded to add other dimensions of enjoyment over time. This lens of the framework is for viewing and considering the different ways in which a player can enjoy the game, allowing the setting of aesthetic goals that aid consideration of other game design aspects through the Dynamics and Mechanics lenses, to evoke such aesthetics (Hunicke et al., 2004). For example, Challenge can be evoked by presenting obstacles, such as a time limit or other players.

As the MDA framework does not have a direct connection to pedagogical applications, to support the introduction of SCL elements to the MDA framework in the *Prototype* phase, it is necessary to consider *Additional Theory* in the areas of both educational game design and Student-Centred course design. There are a number of other areas of games design research that have been found relevant to educational game design, which were identified during the *Ideate* phase to provided support and guidance during the *Prototype* phase when formulating a solution to the problem statement. There is an established value to the concept of *World Building*, which covers the areas of design looking towards the provision of an intricate world through which a story can be told and a player can engage (Fullerton, 2018). *World Building* can contain concepts like Simulation, Role-Play and Story-driven play as well as other ways to build a world that engages the player (Wolf, 2014, Wouters et al., 2009). Within game design it can be said that player *Experience* is the core design consideration, with the other elements of game design pushing towards this (Hagen, 2011, Fullerton, 2018), within educational games it remains a key factor but must share centre stage with educational concepts as the game by nature serves this additional purpose (Kiili et al., 2012). This is why Student-Centred course design must also be considered as part of the *Ideate* phase to support framework development during the *Prototype* phase.

Building upon the established linkage between SCL tenets and DGBL Principles which forms the basis of SCDGBL, there are further concepts within Student-Centred course design that must be acknowledged. *Learning Outcomes* are considered important in SCL literature, acknowledgement and presentation *Learning Outcomes* are a key aspect of learning, to provide students with the understanding of their goals and in turn empower students to seek those goals (McLaughlin et al., 2014, Wouters et al., 2009). Appropriate *Assessment* is given importance by several authors in SCL course design, with particular drive towards concepts such as ongoing practice, which takes the form of later assessments to ensure students are put at the centre of not just their day to day experience in the classroom, but remain the focus during the design and implementation of the *Assessment* process (McLaughlin et al., 2014, Biggs and Tang, 2015, Rust et al., 2005).

At the end of the *Ideate* phase, the key contributors to a framework have been identified, bringing forward the existing understanding of SCDGBL from the undertaken literature review, along with the key game-design concepts and understanding from the established MDA Framework, and additional theory related to both educational game and Student-Centred course design. This foundation would be taken forward to develop the initial prototype of the framework within the next stage.

4.3.1.4 Prototype

As a result of the *Ideate* process, the selected game design framework was then taken forward into the *Prototype* phase. Within the *Framework Development* phase, the mind maps and diagrams created for this framework during the *Ideate* phase were reviewed to produce the first iteration of the solution to the problem statement, namely a new, Student-Centred Experience framework founded upon the selected MDA game design framework, that fully integrates SCL tenets and DGBL principles to provide a guide to designers seeking to design games that create SCDGBL experiences when deployed. This initial prototype includes the foci identified within the *Ideate* stage, with development supported and guided by *Additional Theory* pertaining to educational game and Student-Centred course design.

The aesthetic dimensions of the MDA framework have been expanded to cover the concept of Mastery. The *Expansion of Aesthetic Dimensions* is intended and supported by the MDA framework as a method by which to recognise specific needs (Hunicke et al., 2004). This introduced Mastery dimension covers enjoyment of the game from demonstrating ability and/or control over the game, it has been observed as an important source of enjoyment within digital games (Trepte and Reinecke, 2010) and further reinforced in other activities where participants are encouraged to seek improvement (Scanlan et al., 1989).

Through *Systematic Examination of DGBL Principles*, each DGBL principle was examined through each lens of the MDA framework. Applying this process, made clear which lens was the most appropriate through which to view each DGBL principle, while viewing the same DGBL principle through other lenses made visible the implications of implementing that principle. This is then laid out within the framework for the benefit of the designer, to capture the full implications of implementing each particular DGBL principle as viewed through each MDA lens.

Having identified the placement of DGBL principles within the MDA lenses, representing the relatively more straightforward aspect of the *Prototype* process, it was necessary to *Integrate Further SCL and Game Design Research* identified during the *Ideate* stage. Integrating research and understanding based in Student Centred Learning, as well as existing game design theory provided four overarching categories. These four categories were identified as

Learning Outcomes and *Assessment,* which would draw primarily from Student Centred Learning literature, along with *World Building* and *Experience,* which are explored primarily as extensions of game design theory. This balanced approach maintains the dual focus of developing a game which serves as an educational activity and must maintain effectiveness in both learning and fun. Section 4 presents the prototype framework in full detail.

4.3.1.5 Test

Testing is the final phase of the Design Thinking Process, but it is important to acknowledge the process as not being strictly linear, thus findings from testing can provide further background information to inform potential return to other phases of the process. This framework, which represents an initial iteration of the solution to the problem statement identified during the *Define* phase, will then be tested in Chapter 5 through the *Development and Implementation of a SCDGBL Experience*. *Framework Refinement* will be performed in Chapter 6, based on the findings from this first test, and the framework used to further develop the next iteration of the artefact.

4.4 The Student Centred Experience Framework

The initial version of the Student Centred Experience Framework, an artefact designed through the Design Thinking Process, is presented in Figure 11.

The Mechanics, Dynamics and Aesthetics lenses are represented at the top, with each lens expanded upon below. Each row of the framework includes one DGBL Principle (rounded, grey box), and shows through which lens the DGBL principle is best viewed (denoted by the lens beneath which the Principle is presented), along with the implications of the DGBL principle when viewed through other lenses (pointed green box). The DGBL principles are categorised utilising four overarching categories, representing goals in design: Learning Outcomes, Assessment, World Building and Experience. These categories, viewed to the left of the framework, offer guidance on which goals the effective implementation of a particular DGBL Principle most effectively serves. Where a DGBL principle has implications within the Aesthetics lens, these are additionally expressed through the aesthetic dimensions identified in MDA research (yellow box), showing the types of engagement or fun that are most closely associated with realisation of that principle (Hunicke et al., 2004). The Aesthetics lens may have less direct control from the designer and often arises as a result of the dynamics explored elsewhere (Hunicke et al., 2004).

The tenets of Student Centred Learning (blue circles) are presented with the DGBL principles they are associated with, and collected within the categories to show a collection of these tenets that may be integrated through the implementation of the DGBL principles associated with those categories. Through this it may be seen that appropriate utilisation of the Principles

of Digital Game-Based Learning provides an avenue by which all tenets of SCL may be realised at the design stage.

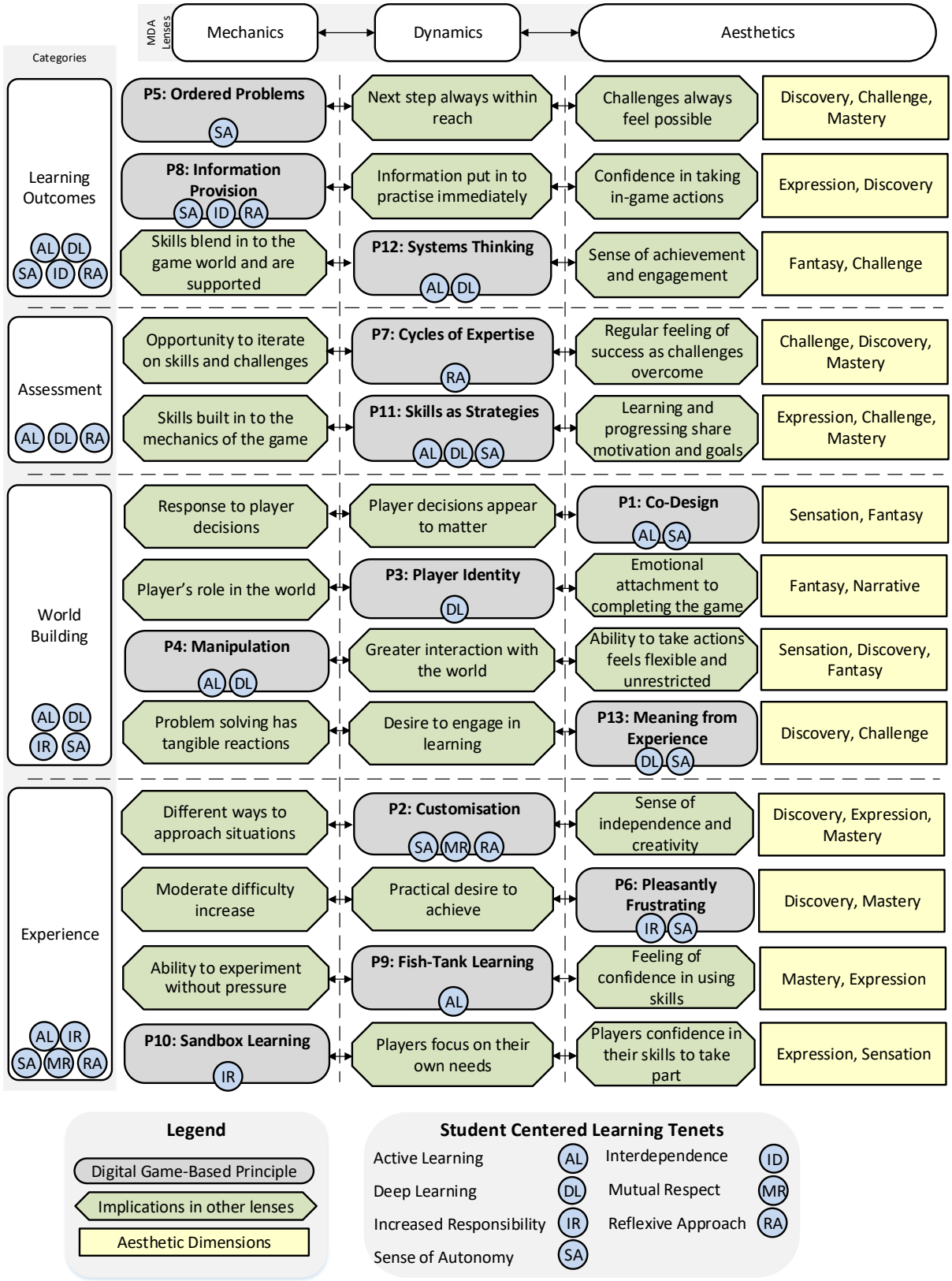

Figure 11: The Student Centred Experience Framework

The SCE Framework demonstrates here a clear focus on offering designers guidance on the ways to integrate the tenets of Student Centred Learning into a digital game-based learning offering from an early stage. By engaging with the elements of game design expressed above, a designer may understand both the tenets directly applied and see the implied effects of that tenet in other areas and expected player responses to an effective implementation. This fulfils the intention behind a framework to inform a designer and not to prescribe a design, while basing this information on established and effective pedagogical theory.

4.4.1 Utilisation of the SCE Framework.

When designing a game that creates an SCDGBL experience, a designer/practitioner may use the SCE framework as a guide towards the goal of a comprehensive integration of Student Centred Learning. Each of the Principles of DGBL has been examined and its implications in alternate lenses identified, by identifying the principles a game seeks to implement these implications can be used as a guide to the design needs in Mechanics/Dynamics and to the likely emotional responses in Aesthetics.

4.4.1.1 Learning Outcomes

P5: Ordered Problems falls within the Mechanics lens, being a design constraint upon the challenges offered to the player. When implemented successfully, it creates a situation viewed through the Dynamics lens for the player where the next step towards success is always within reach and therefore encouraging players to pursue that achievable next goal. This means that within the Aesthetics lens, a player should always feel that conquering the next challenge is something that appears possible for them to achieve, encouraging them to pursue this goal. This leads to the Aesthetic dimensions of Discovery, as players learn further skills and explore their application in the world, of Challenge as the player is constantly offered the next step forwards and encouraged to reach for it, and of Mastery, as the player is able to show off at a later time their ability to effortlessly complete tasks which were once found difficult. Ordered Problems deals with the way in which learning challenges are set, which makes it a natural fit for the Learning Outcomes category.

P8: Information Provision sits within the Mechanics lens, the provision of information to the player being something the designer directly plans and controls. It carries implications into the Dynamics lens where players will be encouraged to put information into practice immediately after it is received, and further that players will have access to the information they need without needing to rely upon asking for help. Carried forwards into the Aesthetics lens, this information provision engenders player confidence in taking in-game actions, thereby offering experiences of Discovery as players learn new information and can use it to progress, along with Expression as players are able to experiment with the techniques they are taught and

achieve success by using them. As the information provided and application of it are so closely connected to learning, this principle sits primarily under the Learning Outcomes category. The Dynamics most visible here are the players' ability to focus on the task at hand, enabled by timely provision of information to ensure the player has the tools needed to do so. From this view the aesthetics promoted are that of Sensation, players having fun simply engaging in gameplay, and of Fantasy as players are able to continue play without breaking immersion.

P12: Systems Thinking is placed within the Dynamics lens as it is an emergent behaviour to be encouraged within players. Within the Mechanics lens this can be through designing the skills examined to be blended into the game world as story or world-building concepts, and supported through it. This creates In the Aesthetics lens a sense of achievement and engagement for players, as using the intended curriculum knowledge and understanding helps them to progress further, drawing the player deeper into engagement with the learning process. Through this, it encourages the Aesthetic dimensions of Fantasy, as the skills the player is exercising are a part of the make-believe world, along with Challenge as those skills are tested and the player strives to improve. As this principle deals primarily with the embedding of skills into the activities undertaken, it has been placed under the Learning Outcomes category.

4.4.1.2 Assessment

P7: Cycles of Expertise fits in the Dynamics lens, being the activity of players practising and evolving skills over time to improve and adapt to new challenges. Within the Mechanics lens this principle implies that the designer should provide opportunities during mechanical and level design for the player to iterate on the skills and challenges. In the Aesthetics lens this allows the player to feel a regular feeling of success as challenges are overcome, before the cycle begins again introducing the next skill. Looked at through the Aesthetics lens this principle can give rise to Challenge, Discovery and Mastery; Challenge as players are pushed to evolve these skills to overcome difficulties, Discovery as players explore the challenges and find out new ways to overcome them, and Mastery as players are able to demonstrate their skills overcoming challenges in different ways. It is placed under the Assessment category as it forms a further way to evaluate players' progress and assess their abilities within the game.

P11: Skills as Strategies also fits into the Dynamics lens, covering behaviour where players will employ the different skills they have been taught in attempts to progress or defeat the game. To promote this behaviour it is important in the Mechanics lens to ensure the desired learning skills are built into the mechanics of the game, giving players access to a range of options to utilise these skills as desired. Seen through the Aesthetics lens, implementation of Skills as Strategies allows learning and progressing in-game to share the same goals as

learning intended curriculum content. This can promote the dimensions of Expression, as players are free to apply the skills in different ways as they attempt to progress, Challenge, as players are utilising the skills to try and overcome in-game difficulties and Mastery as players are able to use their skills in creative ways to overcome problems. This element was placed in the Assessment category as the use of learned skills to overcome difficulties and achieve goals forms a key way to track assessment through games.

4.4.1.3 World Building

P1: Co-Design deals with players' perceptions and experiences of their own impacts on the game, as such it is one of the principles to fit directly within the Aesthetics Lens, dealing with the kind of enjoyment players get from the game. This links with the Aesthetics dimensions of Sensation, as the player enjoys forging their own path and taking their own actions, and Fantasy, as they are able to take part in the world and engage in the ongoing narrative. Within the Dynamics lens, players' decisions appearing to matter, and have significant impact on the way the game plays out, will encourage this feeling within players. Drawing back further to the Mechanics lens, the responses to player actions should be immediately identifiable and clear, and where players may make decisions these are designed to take players down apparently different paths. This principles' connections to the decisions players take during gameplay and within the branching story make it a clear fit under the category of World Building.

P3: Player Identity, the player being presented as a character or role within the game and given a connection to the world or story through this forms a natural fit for the Dynamics lens. The groundwork for this should be completed through the Mechanics lens, where the players' role in the world should be positioned and prepared. Looking to the Aesthetics lens, this principle can help players form an emotional attachment to completing the game. This can encourage the Aesthetic dimensions of Fantasy, where players can feel more tightly connected to the world and the ongoing story, along with Narrative where the dramatic elements of a story can provide further emotional connections to the ongoing story elements. The deep connections in this element to the story or background world elements makes it a clear fit to the World-Building category which deals with the world and story.

P4: Manipulation addresses players' ability to act upon and engage with objects within the game world, making it most relevant to the Mechanics lens. This gives rise in the Dynamics lens to greater incentive for players to engage with the world through their ability to take actions within it, exploring and experimenting with different interactive elements and using skills and abilities granted by the game. In the Aesthetics lens, it appears to players that their ability to take actions feels flexible and unrestricted. This in turn can promote the Aesthetic dimensions of Sensation, where players are able to enjoy engaging with the game world, Discovery where

players can look to find out more about the game world and about their skills through experimentation and to Fantasy as players are able to feel more a part of and engaged with the world when they can interact with that world, building emotional connections. The direct connections to the world created and ability to explore and engage with it make this principle fit primarily under the World Building category of the SCE Framework.

P13: Meaning from Experience addresses the players learning coming from activities they have performed and being based around ideas with which they have a personal connection, this emphasis on players' response and personal understanding makes it a fit for the Aesthetics lens. This links with the Aesthetics dimensions of Discovery, realised as the player has the opportunity to piece together their own solutions, while Challenge is realised as progression continually pushes the limit of players' ability. In order to ensure players' learning comes from personal experiences, first those connections are built within the Mechanics lens through creation of tangible in-game reactions to successful or unsuccessful problem-solving, setting up the player to have the relevant experiences to learn from. With the connections set, through the Dynamics lens players are given incentives to progress and so to learn, stimulating a desire to engage in learning through the game. This engagement is what provides the experiences and embeds the learning within these. The emotional connection and deeper meaning make this element a strong fit for the World Building category, where these connections can be established and the meaning conveyed.

4.4.1.4 Experience

P2: Customisation deals with players being able to choose their own methods of playing the same, placing it within the Dynamics lens as there are mechanics needed to support this type of gameplay. In the Mechanics lens, challenging aspects of the game should be built to be tackled in different ways where possible, offering players different ways to approach situations. In the Aesthetic lens, the ability to experiment and discover these approaches gives a sense of independence and creativity, as players perceive they have forged their own path through the game. The Aesthetic dimensions associated with this include Discovery, as players' different approaches allow them to identify new elements of the game world and of their learning, Expression, as players approach the game in different ways and can complete challenges in ways they feel are unique and Mastery as players can learn multiple different ways to accomplish problems and demonstrate their ability to do so in different ways. It is placed in the Experience category as it covers players' approaches to the gameplay and the decisions they will make during this.

P6: Pleasantly Frustrating covers players experiences during gameplay, particularly the emotions and responses engendered when confronted by tasks, this makes it a clear fit for

the Aesthetics lens. Within the Aesthetic lens the evident dimensions are Discovery, as the player encounters challenges and use the game aspects presented to work out the solution, and Mastery, from the feeling of success as the player is able to conquer each challenge. Within the Mechanics lens tasks are presented with a moderate difficulty increase to push players' skills each time, appearing on the edge of a player's ability. This gives rise in Dynamics to a practical desire to achieve, encouraging players to stretch for those achievements that are just out of reach, leading to the realisation of the principle where players reach for the achievement and eventually grasp it, thus extending their comfort zone and leading to the next challenge. Because this element deals so strongly with players feeling and drive it fits best within the Experience category.

P9: Fish-Tank Learning covers the ability of players to experiment with specific skills without significant risk, as it requires mechanical support it has been placed in the Dynamics lens. Within the Mechanics lens, areas of the game must provide players with the ability to experiment without significant pressure, particularly when new skills or abilities are introduced. Looking to the Aesthetics lens, this builds confidence in using a new skill in a 'safe' environment, assisting players to feel less daunted about taking their newly developed skills outside this environment into the rest of the game world, where pressure may then be present. Implementation of this principle offers benefits in the Aesthetic dimensions of Mastery, as players feel they have understood or grasped a skill before being faced with difficult scenarios involving its use, and in Expression as players can freely apply the skill early on. Dealing with the way players are able to approach parts of the game and how they may respond makes this element a fit for the Experience category.

P10: Sandbox Learning is a specially designed area which allows the player freedom to practice and apply multiple skills and abilities with minimal risk and without a large degree of external pressure, this requires specific implementation and makes its placement within the Mechanics lens clear. This creates the Dynamics of encouraging players to engage with a focus upon their own needs in the game, rather than a direction towards externally set goals. Following on to Aesthetics, through risk-free experimentation, players are able to build confidence in their own skills, increasing their enjoyment in demonstrating and exercising these skills. Within the Aesthetic dimensions, players are likely to experience enjoyment through Expression as they develop, build or create according to their own desires, and through Sensation as the rewards for such play become the expansion of their own ability to play the game. This element deals with a method of playing the game, making it a fit for the Experience category of the framework.

Having introduced the SCE framework and its components, it is appropriate to provide some guidance on how the framework may fit within a typical development lifecycle for a SCDGBL application, the role of teaching practitioners and game designers within each phase of the lifecycle, and how their interaction with the framework may inform each phase.

4.4.2 Applying the SCE Framework

This section explores the positioning of the SCE Framework during a typical systems development process, including the intertwining roles of teaching practitioners, designers, and their interaction with the framework. The phases of software development may be concisely described as *Understanding*, *Design*, *Development*, *Testing*, *Deployment* and *Maintenance* (Mishra and Dubey, 2013). For the development of a game that seeks to create an SCDGBL experience, the SCE Framework has an integral role in the *Understanding* and *Designing* phases primarily, however work completed in these phases impacts throughout the lifecycle, and an understanding of the SCE Framework may therefore guide and inform work completed at other times. The role of the SCE Framework and of its primary users, namely teaching practitioners and designers, is visualised in Figure 12.

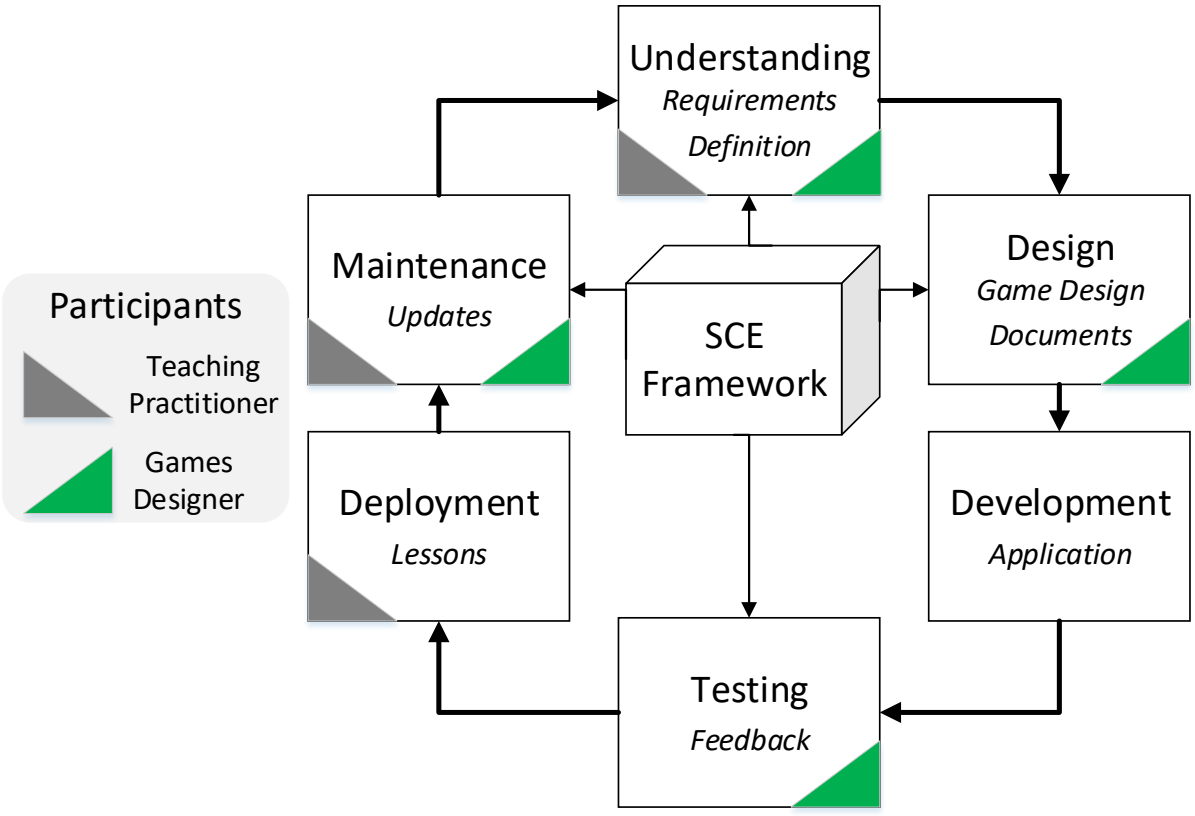

Figure 12: Software development utilising the SCE Framework, including key participants and outputs

During the *Understanding* phase, the primary activity is requirements gathering to produce the *Requirements Definition*. This is undertaken by both teaching practitioners and designers, with practitioners seeking to identify curricular goals for the project while identifying the

environment in which its deployment is intended including the nature of assessment. This work will inform the SCE categories of Learning Outcomes and Assessment, guiding the deployment of the principles within. The game designer at this time is considering questions relating to the world the game creates and the high level experience presented to the player, identifying in broad strokes the type of game sought and how it is to be presented to players. At this time, the SCE Framework categories provide a guide, each presenting a question that must be answered: What Learning Outcomes should it deliver? How will Assessment of learning be completed? What sort of world will the players explore? How will the players experience the game and its learning? With the answers to these questions, along with the completion of any associated technical requirements definition, it is possible to begin a more detailed design process.

The *Design* phase is the most closely associated with the SCE framework, at this stage the Game Designer takes the primary role in the creation of the *Game Design Documents*. As mechanics of the game take shape, the game designer may look to the framework to guide how these mechanics embody or give rise to DGBL principles and to the associated SCL tenets. The SCE Framework (Figure 11) may be read from left to right, as a designer would see it, or from right to left, as viewed by a player, and provides guidance as to how each principle may be viewed through different lenses. For example, implementing the principle of **P5: Ordered Problems**, which is rooted in the Mechanics lens, will give rise in the Dynamics lens to players finding that achieving the next obstacle, and hence solidifying the next step of their learning, is always an achievable objective, with this repeating as the player then takes that next step. From the player's emotional perspective, explored in the Aesthetics lens, the challenges posed by the game appear as something the player is capable of surmounting and thus they are less likely to disconnect from the game. In this way, the implementation of the principle gives rise to a positive emotional effect on the player and encourages continued play. The designer's interaction with the SCE Framework throughout this phase is to consider the elements of their games design in these different ways, and to use it as a guide to where a DGBL principle may be directly worked towards in the game's core Mechanics, where it may form derived activity in Dynamics and where it is primarily an emotional reaction or feeling to be created in Aesthetics. The teaching practitioner's role at this stage is to ensure that curricular objectives and assessment criteria are integrated and that these retain their links to game mechanics and world building elements.

The *Development* phase will take the design created by the designer as a reference, and put it into practice developing the *Application*. As with all phases of the software development lifecycle, it is unlikely that the development phase is completed in isolation, with elements of *Design* and *Testing* being completed and revised throughout. The work completed during this

phase is informed by the design, which draws from the SCE framework, but no restriction is placed by the framework on the nature or method of implementation.

During the *Testing* phase, the SCE framework may be utilised through *Feedback* to identify the successful integration of principles into the created game. While testing is ongoing, the SCE framework offers guidance as to how the successful integration of a DGBL principle, and its associated tenets, may be viewed by players through its Aesthetics lens implications. For example, if players express they have an emotional attachment to progressing in and completing the game, that may indicate the successful implementation of **P3: Player Identity** and so the SCL tenet of *Deep Learning and Understanding*. During this phase, the SCE framework provides a reference for the designer to identify where principles are meeting with success and where further revision may be considered.

The *Deployment* phase is primarily guided by the teaching practitioner, who will utilise the game that is made available as a teaching tool in *Lessons*. While knowledge of the SCE framework is not required for the deployment of an SCDGBL activity, its understanding may assist the teacher in framing and setting up the work undertaken in the classroom, by prompting external activities that build further upon the DGBL principles deployed and the aesthetics created by the game.

The *Maintenance* phase is guided by both the designer and practitioner to create relevant *Updates* to the application. During this phase the game is adjusted and kept up-to-date and relevant, for example in response to a change in curriculum and desired Learning Outcomes. A practitioner may have the ability to do this through either tools provided by the application or through the framing and delivery of lessons which utilise the game; a designer may more directly be able to make changes and have these developed and the revised game redeployed. In both cases, the SCE framework may be utilised as in the design and testing phases to understand where principles are meeting with success and to target areas to improve.

Throughout the lifecycle of a SCDGBL application, the SCE framework may be used as a guide to identify and explore what the application could or should be achieving and to understand how this may be achieved.

Having presented examples of how to apply this framework, it is appropriate at this stage to frame our proposed SCDGBL offering, which leverages a game design framework founded in the pedagogy of Student Centred Learning, in the context of other ‘serious games’ that deploy a digital game in an education setting to achieve learning objectives. The previous literature review of DGBL offerings in Chapter 2 had a conceptual focus upon the delivery of SCL tenets, and the mini-review of game design frameworks in 4.2.1 was also oriented towards evaluating

generic and education-oriented frameworks against SCL tenets. Thus it is helpful to take a step back to emphasise the relative novelty of the proposed game in the broader field of serious games for education, taking a look at the pedagogical basis of these games, their links to a curriculum and their outcome measures.

4.4.3 Framing of Proposed SCDGBL Game Within Serious Games Literature

To give the reader a broad overview of where the proposed game would sit in relation to other recent digital educational games that are described as serious games, Table 8 presents some examples of digital serious games for education, published within the last ten years, drawn from two recent meta-analyses of this field (Wouters et al., 2013, Backlund and Hendrix, 2013), as well as a limited number of new papers from the 2015-2020 period drawn from a Google Scholar search (search string: "learning OR "education" AND "serious" AND "games" -review). Inclusion criteria were applied to select games that enabled some degree of comparison to the proposed game as presented here:

- Designed or adapted for the desired learning outcomes (i.e. not off the shelf, commercial games)
- Deployed and evaluated in formal education environment (not healthcare, business, etc)
- Study presenting the game was published in the last ten years

Within this table the games are presented according to their pedagogical basis, usage of a game design framework for the original design process, linkage to the curriculum and evaluation methods or outcome measures used.

It can be seen from this table that there are many serious games for education do not have a pedagogical foundation (Bakhuys Roozeboom et al., 2017, Rowe et al., 2011, Barab et al., 2012, Brom et al., 2011, Suh et al., 2010, Hainey et al., 2011, Mavridis et al., 2012, Hannig et al., 2012, Khan and Kapralos, 2017). Pedagogical foundations stated were Kolb's experiential learning cycle (Wrzesien and Alcañiz Raya, 2010, Bai et al., 2012, Rubin-Vaughan et al., 2011), constructivism (Kordaki, 2010, Pellas et al., 2014), Dewey's experiential learning theory (Bai et al., 2012), Gardner's Theory of Multiple Intelligence (Wrzesien and Alcañiz Raya, 2010), Bull and Kay's open learner model (Liao et al., 2011) and Evidence-Centred Design (Capuano and King, 2015).

Only one serious game utilised a game design framework to guide the design of their game (Hannig et al., 2012), which utilised the Input-Process-Outcome Game Model (Garris et al., 2002). The remainder did not (Rowe et al., 2011, Barab et al., 2012, Brom et al., 2011, Suh et al., 2010, Hainey et al., 2011, Mavridis et al., 2012, Wrzesien and Alcañiz Raya, 2010, Bai et

al., 2012, Kordaki, 2010, Bakhuys Roozeboom et al., 2017, Rubin-Vaughan et al., 2011, Liao et al., 2011, Khan and Kapralos, 2017, Pellas et al., 2014, Capuano and King, 2015).

Table 8: An overview of recent serious games for education deployed and evaluated in formal education environments.

Game	Pedagogical Basis	Game Design Framework	Curriculum link	Evaluation method/outcome measures
T-Challenge (Bakhuys Roozeboom et al., 2017)	None	No	No	Student self-report of proficiency
Crystal Island (Rowe et al., 2011)	None	No	Yes	Post test (Student engagement, gameplay experience) Knowledge test
DimensionM (Bai et al., 2012)	Dewey (Dewey, 1986), Kolb (Kolb, 2014)	Not stated	Yes	Post test (Student engagement) Knowledge test
Quest Atlantis (Barab et al., 2012)	None	Not stated	Yes	Post test (Student engagement) Knowledge test Semi-structured interviews – gameplay experience, student motivation
Orbus Pictus Bestialis (Brom et al., 2011)	None	No	Yes	Comparator: Traditional teaching Post test (Student engagement, gameplay experience) Engagement/experience questionnaire Knowledge test (repeated 1 month later)
Nori School (Suh et al., 2010)	None	No	Yes	Comparator: Traditional teaching Post test (Student motivation) Knowledge test
E-Junior (Wrzesien and Alcañiz Raya, 2010)	Kolb (Kolb, 2014), Gardner (Gardner, 2011)	No	Yes	Comparator: Traditional teaching Post test (Student engagement, motivation, gameplay experience, perceived usefulness) Knowledge test
Quest for the Golden Rule (Rubin-Vaughan et al., 2011)	Kolb (Kolb, 2014)	No	No	Post test (Student engagement) Knowledge/attitudes test
Untitled game (Kordaki, 2010)	Constructivist (Vygotsky, 1997)	No	Yes	Post test (Student engagement) Knowledge test
My-Mini-Pet (Liao et al., 2011)	Bull (Bull and Kay, 2010)	No	No	Post test (Gameplay experience) Knowledge test (repeated 1 month later)
Requirements Collection and Analysis Game (Hainey et al., 2011)	No	No	Yes	Comparator: Traditional teaching Post test (Gameplay experience, perceived usefulness) Knowledge test
Grafica (Mavridis et al., 2012)	No	No	Yes	Post test (Gameplay experience) Semi-structured interview with teacher
EMedOffice (Hannig et al., 2012)	No	Input-Process-Outcome Game Model (Garris et al., 2002)	Yes	Post test (Gameplay experience) Self-reported knowledge improvement
Fydylyty (Khan and Kapralos, 2017)	No	No	No	Post test (Gameplay experience)
Co.Co.I.A. (Pellas et al., 2014)	Constructivist (Vygotsky, 1997)	No	No	Post test (Student engagement)
Untitled evacuation training game (Capuano and King, 2015)	Evidence-Centred Design (Mislevy and Haertel, 2006)	No	No	Post-test (Student engagement, gameplay experience)
LogicGate System (proposed)	Student Centred Learning (Lea et al., 2003)	SCE framework	Yes	Post test (Student engagement, gameplay experience) Knowledge test Semi-structured focus groups (Student engagement, gameplay experience)

Most games had linkage to existing curriculum objectives (Rowe et al., 2011, Barab et al., 2012, Brom et al., 2011, Suh et al., 2010, Hainey et al., 2011, Mavridis et al., 2012, Hannig et al., 2012, Wrzesien and Alcañiz Raya, 2010, Bai et al., 2012, Kordaki, 2010), but some did not (Bakhuys Roozeboom et al., 2017, Rubin-Vaughan et al., 2011, Liao et al., 2011, Khan and Kapralos, 2017, Pellas et al., 2014, Capuano and King, 2015).

A majority of studies utilised an administered knowledge test pre- and post-experience as an outcome measure, to determine whether the game was effective in knowledge improvement while accounting for an individual's pre-existing knowledge of the topic (Rowe et al., 2011, Barab et al., 2012, Brom et al., 2011, Suh et al., 2010, Hainey et al., 2011, Wrzesien and Alcañiz Raya, 2010, Bai et al., 2012, Kordaki, 2010, Rubin-Vaughan et al., 2011, Liao et al., 2011). A student's baseline topic knowledge is considered to be a source of individual differences in their learning effectiveness (Ke and Grabowski, 2007, Moreno, 2002). However, the impact of this or prior experience with computers/games upon knowledge improvement has been found to vary when evaluating serious games for learning (Kebritchi, 2008), and only one study reviewed here attempted to model the impact of baseline knowledge as a predictor variable (Suh et al., 2010). In general, the preferred approach to mitigate this factor in the reviewed studies was to express an individual's knowledge gain as a gap score for pre versus post learning intervention, thereby placing the focus on the change in score rather than what the baseline was. Two studies relied on self-report post-test to determine knowledge improvement (Bakhuys Roozeboom et al., 2017) (Hannig et al., 2012), therefore the impact of the serious game upon knowledge gain is more difficult to characterise for these studies.

Other outcome measures were evaluated on a post-test basis, such as student engagement (Capuano and King, 2015, Pellas et al., 2014, Rowe et al., 2011, Bai et al., 2012, Barab et al., 2012, Brom et al., 2011, Wrzesien and Alcañiz Raya, 2010, Rubin-Vaughan et al., 2011, Kordaki, 2010), motivation (Suh et al., 2010, Wrzesien and Alcañiz Raya, 2010), the gameplay experience (Capuano and King, 2015, Khan and Kapralos, 2017, Hannig et al., 2012, Mavridis et al., 2012, Hainey et al., 2011, Wrzesien and Alcañiz Raya, 2010, Liao et al., 2011, Brom et al., 2011, Rowe et al., 2011, Barab et al., 2012), and perceived usefulness (Wrzesien and Alcañiz Raya, 2010, Hainey et al., 2011). Only four studies attempted to compare the serious game offering to an equivalent standard classroom learning experience (Brom et al., 2011, Suh et al., 2010, Hainey et al., 2011, Wrzesien and Alcañiz Raya, 2010), and just two utilised qualitative data collection methods such as semi-structured interviews to augment quantitative survey data in their evaluations (Mavridis et al., 2012, Barab et al., 2012). The impact of not following a game design framework upon successful deployment can be seen in studies such as the Grafica study (Mavridis et al., 2012), where the teacher commented that the game seemed divorced from the learning it was trying to deliver. The lack of comparison studies

creates issues for future deployment of many of these serious games for education, as there is insufficient evidence in many cases that the serious game offers at least an equivalent knowledge advancement over traditional classroom teaching.

Criticisms of serious games for education relating to the lack of a clear pedagogical foundation, insufficient documentation of design, poor linkage between the game design and the learning objectives, and limited evaluation have been levelled time and again in reviews of the state of the art in this area (Wouters et al., 2013, Backlund and Hendrix, 2013, Kebritchi, 2008, Law et al., 2008). During this mini-review it was identified that recent literature focuses primarily on the deployment of existing, commercial games, and offering theoretical advice on game creation and design, with a limited number of studies presenting a novel experience that was deployed in a formal education setting. Recent endeavours in this area have primarily been theoretical or present a design without deploying it.

The proposed game can be seen to address many of these issues through a pedagogical foundation in Student Centred Learning, use of the Student Centred Experience framework to guide the design of the game, and the intention to evaluate the game for acceptability to students, learning engagement and knowledge improvement, in comparison to a traditional classroom task.

4.5 Conclusion

Through the examination and evaluation of existing game design frameworks applied to educational games, it was established that the development of games as a vehicle for delivery of a Student Centred Learning experience did not have a strong structure. A lack of appropriate guidance was identified for practitioners to support the design of a Student-Centred Learning experience that fully integrated all SCL tenets. Through the application of a systematic Design Thinking process, which identified the current state of the field and defined a student-centred problem statement to address through ideation and prototyping, the SCE framework was developed to provide that guidance. The SCE framework integrates SCL tenets, DGBL principles, and the MDA game design framework to direct practitioners on the implementation of the tenets of Student Centred Learning and enable them to identify the common implications of such implementations. It presents a reference for designers, educators and academics to examine the games they create and use and see avenues where SCL provision can be further developed or where it may be supported with additional structure. To conclude the final stage of the Design Thinking process for the SCE framework, the next chapter describes the design, implementation and testing of the LogicGate System as a complete SCDGBL learning experience utilising the SCE model. This proposed game has been framed in this chapter within the context of recently designed serious games for

education that have been deployed in formal education environments, highlighting that present novel DGBL offerings rarely combine a solid and well-integrated pedagogical foundation, usage of a game design framework, appropriate curriculum linkage and a comprehensive evaluation.

Chapter 5. Experiment 1

5.1 Background

In Chapter 2, it was established that current SCDGBL offerings do not fully deliver all tenets of Student Centred Learning. SCDGBL experiences offer teachers a number of potential benefits through the ties into the tenets of Student Centred Learning, defined by Lea et al. (Lea et al., 2003) as *Active Learning, Deep Learning, Increased Responsibility, a Sense of Autonomy, Student and Teacher Interdependence, Mutual Respect* and a *Reflexive Approach to Teaching and Learning*. These SCL tenets can integrate effectively with games: Active participation within games covers aspects of *Active Learning*, with students taking part and putting learning immediately into practice (Coller and Scott, 2009). The potential for *Deep Learning* is enhanced with the ability of games to offer immersive settings for players to experience, learners are able to play as and embody a role, which can create a more personal learning experience as learners may feel more directly affected. Such personally involved learning has been shown to affect learners more strongly and can have significant effects on self-perception (Vandenbosch et al., 2017, De Freitas, 2006). *Increased Responsibility* and a *Sense of Autonomy* are well served by the degree of apparent control that can be offered to a student in a game-based experience, where progression can be made at their own pace and the students own actions can reveal more about the world (Garcia and Pacheco, 2013). Social aspects may be addressed through multiplayer play, while ongoing exposure may offer students the chance to reflect upon and revise their understanding of a topic. In addition studies may tout increased student motivation and engagement as benefits of SCDGBL to be realised (Denis and Jouvelot, 2005).

In Chapter 4, integrating this understanding with games design theory, the Student Centred Experience framework was developed using the Design Thinking process. The SCE framework provides guidance on the design of games that create SCDGBL experiences, through integrating the SCL tenets from the earliest stage. Taking this further, this chapter will provide an instantiation of this framework through its use to design of a game that delivers all tenets of SCL, creating a SCDGBL experience for learners in its deployment.

Although the list of potential benefits and links into Student Centred Learning tenets appears to provide significant opportunity to develop successful games that deliver these tenets, a majority of educational games discovered or explored within Chapter 2, provide single player experiences that do not appear to tap into all areas of Student Centred Learning. This lack of focus is particularly apparent in the implementation of social aspects of SCL, aspects which take a key role in governmental policy on education being seen as vital to preparing students for life and roles in future (Humphrey et al., 2010).

5.1.1 Social Aspects within Student Centred Learning

The tenets of Student Centred Learning involve a degree of social or peer involvement. Different tenets are more tightly associated with social interactions, this is shown in Figure 13, which orders the tenets of SCL by the degree to which social involvement is integral.

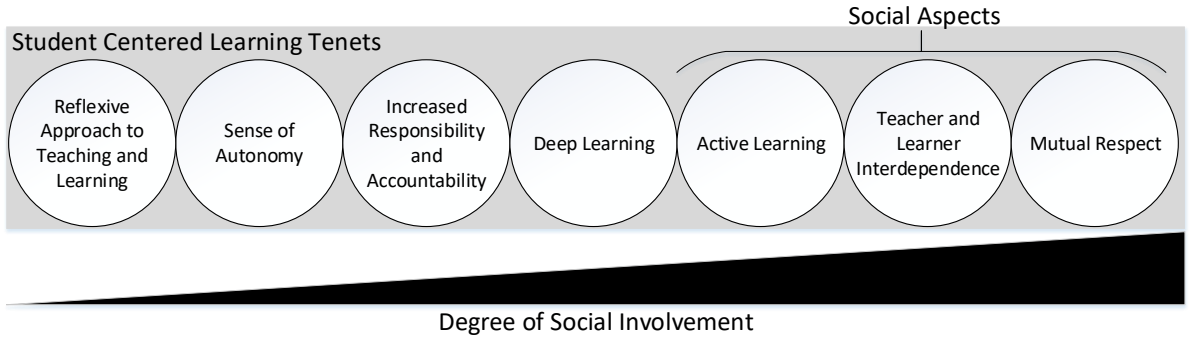

Figure 13: Social Involvement in Student Centred Learning tenets

The *Social Aspects* of Student Centred Learning may be described as those which involve students' relation to both their peers and the teachers around them. These aspects most closely associated with social involvement primarily form three of the seven tenets: *Active Learning*, *Teacher and Learner Interdependence*, *Mutual Respect* (Lea et al., 2003) and will be henceforth identified as the *Social Aspects*. *Active Learning* is the first of these *Social Aspects*, while individual *Active Learning* is possible a number of techniques within this tenet have been identified with a majority of these, for example Peer Learning and Collaborative Learning, requiring a degree of social engagement (Bishop and Verleger, 2013). *Teacher and Learner Interdependence* can be described in contrast to a complete dependence by the learner on the teacher for their education, or the opposite: a complete independence where learners pick up information under their own drive (Fay, 1988). Through this tenet, SCL offers a middle ground where teachers are able to lead, inspire or guide on a topic, and students are given the skills and tools to learn further themselves (Grow, 1991). In order for this to function it requires a relationship between teachers and learners, that allows the learner to look to the teacher for guidance and direction when needed, without worry or fear of dismissal or punishment (Wentzel, 2003). *Mutual Respect* is the SCL tenet where social involvement is the most integral, stressing the need for students to be able to build respect for and from their peers and teachers. It offers the opportunity to build working relationships based on many aspects, including work undertaken together, and so helps to mirror and prepare for the working relationships students will build in future (Topping, 2005).

These *Social Aspects* are typically delivered through traditional learning techniques, but are rarely featured within SCDGBL applications as seen in Chapter 2, where a number of such applications are evaluated. For example, *Teacher and Learner Interdependence* may be developed through techniques such as Peer Teaching where teachers support students to

deliver a talk or lesson on a new topic area to the class (Rubin and Hebert, 1998) and through effort of teachers to maintain this sort of relationship in their usual teaching and learning in the classroom. *Mutual Respect* may be addressed through collaborative and team based work, where students work together on projects. This type of work is well explored and promoted in well-rated courses and institutions, being seen as a cornerstone of modern education (Galton et al., 2009). Building up a student's *Reflexive Approach* requires opportunities to look back over work done previously and see how far a student has come, along with leaving enough control in students' hands that the lessons learned appear to be of practical use, and the student is not simply carried on to the next question or topic regardless (Niemi, 1997). Due to the saturation of single-player games within the SCDGBL sphere, these social aspects of SCL are rarely delivered within current SCDGBL offerings, despite the central role of these aspects within current education policies to promote student engagement and effective learning (Wright, 2011, Rohrbeck et al., 2003).

5.1.1.1 Topic Selection

The topic area, Boolean logic, was chosen as a core area of understanding for students within many courses at Brunel University as well as one which is covered under many other examining bodies such as the AQA A-Level syllabus. This topic would ensure a large potential audience for the designed system. Furthermore the existing software included some functions related to logic, increasing the chance some participants would be able to utilise existing knowledge from other games and therefore providing additional peer learning opportunities.

This study presents the LogicGate System, which was developed as an instantiation of the SCE framework presented in Chapter 4 designed around the topic area of Boolean Logic. It provides a Student Centred Digital Game Based Learning experience designed to deliver all tenets of Student Centred Learning, including the *Social Aspects* based around social and peer engagement which were identified as not the focus of previous SCDGBL entries.

5.1.2 Research Questions

This study explores the relative accessibility and engagement of the LogicGate System from a student's perspective, along with assessing the effectiveness of the LogicGate System on academic learning of a selected topic. Specifically the following research questions are addressed in Experiment 1:

E1RQ1: Does the LogicGate System deliver all tenets of Student Centred Learning, and to what extent are these tenets delivered?

E1RQ2: Are students engaged through use of the LogicGate System to learn educational content, and to what extent does this engagement occur?

E1RQ3: What are students' views on learning through Student Centred Digital Game-Based Learning?

Section 2 presents the LogicGate System architecture, educational concept mapping and application walkthrough. Section 3 explores the methods used to evaluate the LogicGate System, followed by the results in Section 4 and discussion of these results in Section 5. Section 6 presents the conclusions of this evaluation and further work.

5.2 LogicGate System Walkthrough

This section presents an overview of the LogicGate System. It includes a technical exploration of the LogicGate System architecture, provided in Section 2.1, followed by a map of the game world and a full application walkthrough in Section 2.2. It concludes with the mapping of the SCL tenets to elements of the LogicGate System through a progression map presented in Section 2.3.

5.2.1 System Design and Architecture

The LogicGate System forms a Student Centred multiplayer educational experience based on a modified version of the popular game Minecraft. It creates an SCDGBL experience for students designed to engage with all aspects of Student Centred Learning, and be deployed as a part of a course that teaches Boolean logic concepts such as AND, OR, NOT and XOR. The architecture of the LogicGate System is presented in Figure 14, and its contribution to realising aspects of the Learning Outcomes, Assessment and World Building categories of the Student Centred Experience Framework highlighted according to the DGBL principles they help to support.

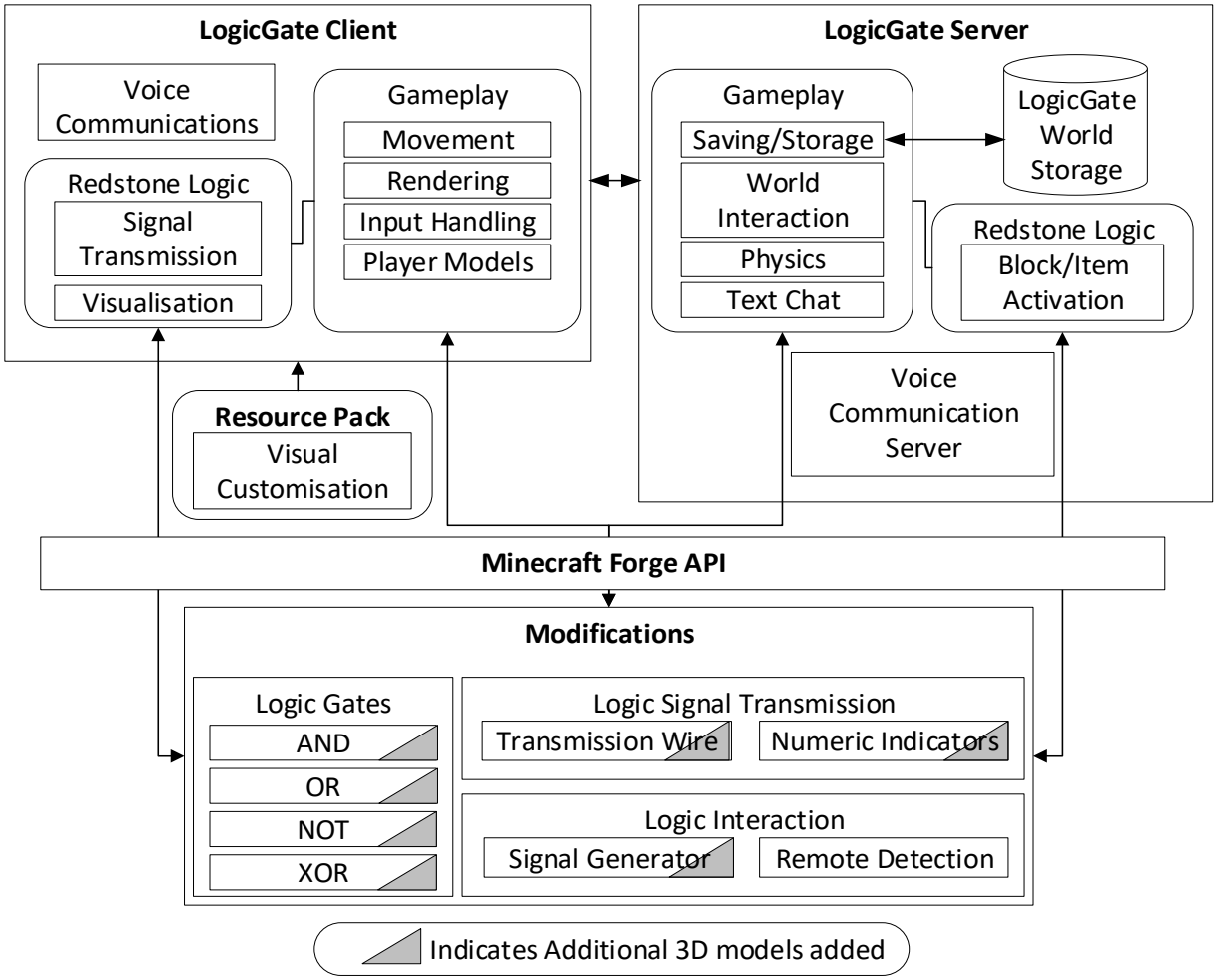

Figure 14: System Architecture of the LogicGate System

The *LogicGate Client* (based upon Minecraft Java edition 1.12.2) provides the basis for the experience and a majority of core gameplay functions and aspects were preserved from basic Minecraft. A number of features within this provide the core *Gameplay* experience: *Movement* is the ability of the game to handle student movement which is core to **P3: Player Identity**, as well as any mobile objects that operate within the game such as carts used for travel. The Minecraft *Rendering* engine is a bespoke system produced by Mojang, which works using the OpenGL system and handles objects including the blocks that make up the world, decorative objects such as leaves and the UI elements that allow student interaction. Models within Minecraft are typically rendered as blocks, which are typically square and use a 2D texture map for each side, however provision exists for more complex models such as pistons and levers. Input handling is covered through the client and is customisable to a student's wishes, allowing them to set which keys are active and control the sensitivity of the mouse for movement etc. This interaction allows for the integration of **P4: Manipulation** as explored in the SCE Framework as well as the emergence of **P1: Co-Design** as the game can respond to these inputs. *Redstone Logic* is the system most explored and expanded within the

LogicGate System: Within the base game Minecraft makes provision for *Signal Transmission*, allowing a signal to be sent across a short distance through the in game item ‘Redstone Dust’. Blocks are able to read this simple signal and use it to turn on or off. Further provision is made for *Visualisation*, with Redstone Dust lighting up to indicate a signal being sent, increasing students’ opportunity to experience the Sensation component within the Aesthetics dimension of the Student-Centred Experience Framework. The LogicGate client utilises voice communication software which is associated with the client package; the open-source system Mumble was used to both handle communication between students and teacher, and to record this communication for later analysis.

Resource Packs provide a simple method of customisation, being a collection of textures that replace existing ones in the game. While not able to make changes to behaviour, this functionality was used within the LogicGate System to provide a clearer look and feel, and therefore draw attention to and increase readability of the puzzles.

The *LogicGate Server* is a separate application, typically run on a different machine. Within the LogicGate System it holds the sole copy of the world and handles all *Saving/Storage*, passing this data to clients as required in 16x16x128 areas of the world referred to as chunks. Upon receiving information from the client about a user’s actions, the server will check the World Interaction to ensure the actions sent are correct before updating the *LogicGate World Storage* as necessary. In a multiplayer setting the server handles calculations for the game’s *Physics*, ensuring blocks which are affected by gravity fall and water flows as the game requires, and updating clients in turn with the new world state. The Text Chat functions of the game are handled by the server out of necessity, passing messages between clients and maintaining a log of such messages for future review. The server console allows such messages to be sent directly from the server if required. In a multiplayer setting the Server handles the *Block/Item Activation* aspects of Redstone Logic, checking a signal is present and activating entities the signal is transmitted to. The LogicGate Server also handles the voice communications, allowing students to communicate.

The *Minecraft Forge API* provides a further way to modify the behaviour of Minecraft. The Forge project sits around the core Minecraft program and provides an API for Modifications, often referred to by the community as ‘mods’ written in Java, to change game features. This API runs at a low level which opens up almost all game features to modification, from adding new in game items to changing core concepts such as score systems or the behaviour of light. The API provides a core aspect of the LogicGate System, as it allows the addition of not just the core modification but a number of publicly available supporting modifications that contribute to the overall system.

A number of *Modifications* provide the enhancements to Minecraft that enable the LogicGate System: The most significant of these modifications, the SimpleLogic modification adapted for this project, adds formal *logic gates* that mirror the function of such gates in reality (Siekierka, 2019). Adding concepts such as NOT, AND, OR, XOR, NAND etc. is core to teaching logic. Further modification work provides the LogicGate System with *Transmission Wires* as a reliable way to transmit signals a long distance, circumventing the original limits and enabling more complex puzzle design which assists in the presentation of **P5: Ordered Problems**. The combination of these allows students to participate in puzzle solving utilising the logic skills and thereby assists in the realisation of the principle of **P12: Systems Thinking**. It includes *Power Generation and Storage* to expand upon the logic signals and the 3D models to ensure these additions are fully realised within the system and visualised within the game world. These additional cosmetic blocks allow more customisation, such as more obvious signage to prompt students and more diversity and clarity in design. These additions support the implementation of **P8: Information Provision** within this design.

5.2.2 Game Layout and Walkthrough

Having established the system architecture, the LogicGate System was developed utilising the SCE Framework to incorporate the tenets and principles of SCDGBL and deliver a set of learning outcomes. This section provides a walkthrough of the LogicGate System, highlighting key areas of interaction and design. Figure 15 shows an overview of the game world while highlighting the specific DGBL principles, as drawn from the SCE framework, which are particularly relevant within each area. Further detail on the application of these principles may be found in the discussion of these areas.

The following subsections step through the LogicGate System, exploring students' goals activities at each stage. Design decisions are presented with reference to the sections of the SCE framework that guided them.

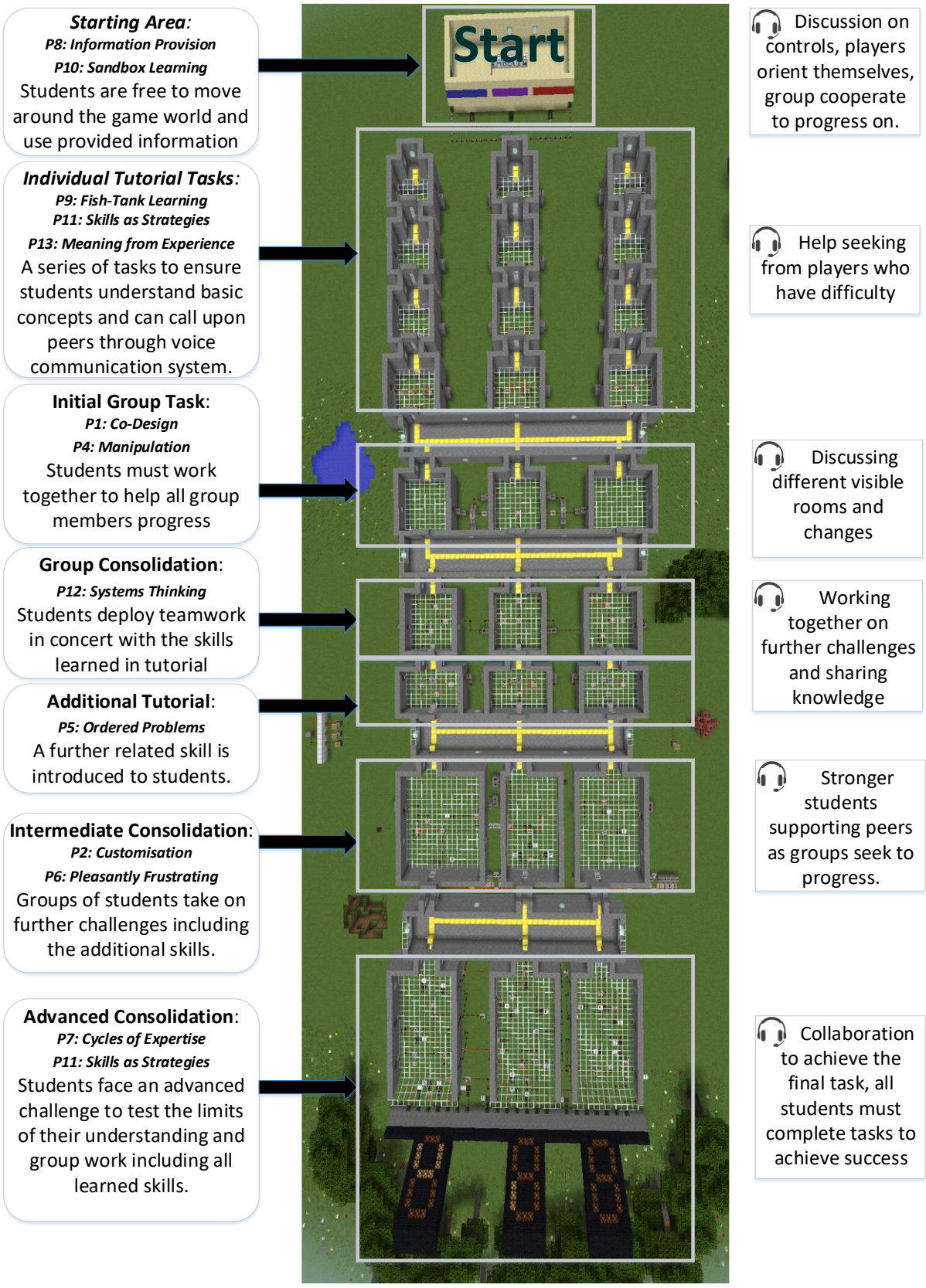

Figure 15: Aerial view of the game world showing key progression areas and expected discussion topics.

5.2.2.1 Main Menu

Students will initially be greeted by the main menu. Students are directed by the teacher to the Join Game screen and to the server their group has been assigned to. Figure 16 shows the main menu screen as it appears to the student. Upon joining a game as directed, the student finds themselves in the start area.

Figure 16: Main menu and Server Selection

5.2.2.2 Start

Students begin in this area, as students join the world and voice communication system, they may begin to familiarise themselves with the controls and to share any understanding from similar experiences with group members. Figure 17 shows the initial game screen, annotated with a number of key game and user interface aspects.

As students progress through the game, they will trigger additional messages and information that show up in the text chat area to the lower left of the screen. These messages (triggered by pressure plates such as the one pictured) help inform students of their progress and may be accompanied by further information in the form of in-game books that provide an ongoing reference for students. This applies the SCE framework to establish **P8: Information Provision** to stimulate student expression and discovery from the earliest stages of the game. When all students are in the game, they are able to leave this area and begin the game. GE1 and GE2 are realised at this stage as voice and text communication is set up to be utilised throughout the group's time playing, while players are offered at this stage the freedom to move around and explore the game world without consequence, acting as **P10: Sandbox Learning**, an opportunity to facilitate student expression and develop their mastery of game

controls. GE3 is also first available in this phase, as the teacher is able to join the students in the game world at any time, if deemed necessary.

Figure 17: Starting area screen, showing the students initial view of the game world

5.2.2.3 Individual Tutorial Tasks

While students remain in audio contact, this initial area provides a tutorial, introducing each of the three basic logic gates, AND, OR and NOT, giving each student a written explanation of their function to use and refer back to. Each student is required to demonstrate an understanding of each gate's basic functionality before progressing. This provides the first example of students learning curricular content through gameplay (**P13: Meaning from Experience**). These are built into the mechanics of the game, with students utilising subject skills to progress (**P11: Skills as Strategies**). **P9: Fish-Tank Learning** is in evidence as students are able to experiment with their understanding of each individual concept without punishment. Figure 18 shows one of these tutorial areas.

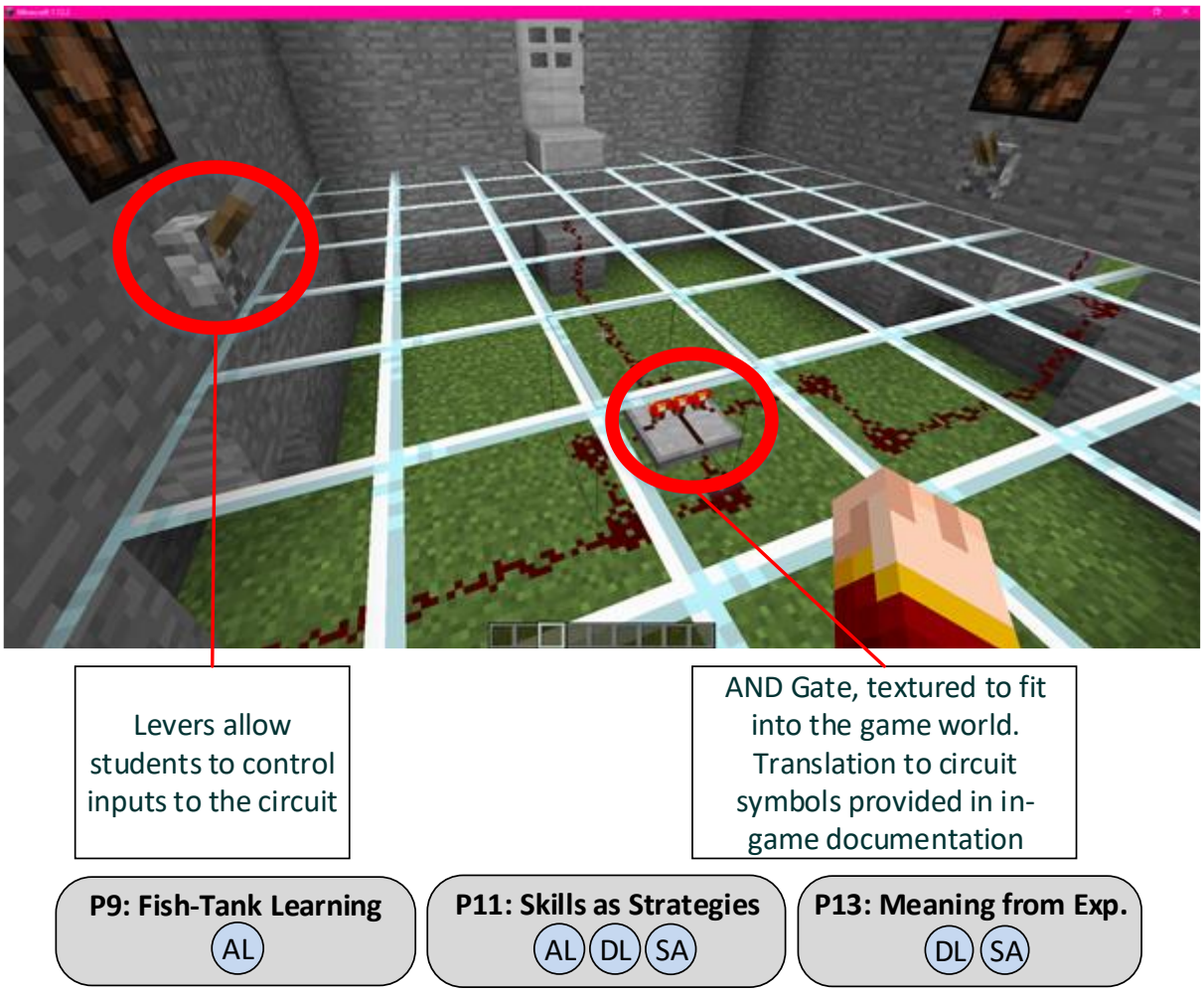

Figure 18: Individual AND gate Tutorial Area

The logic puzzle is presented below the student, visible through the glass floor. Activating one of the two levers will turn on or off the signal, a signal causes the wire visible below to glow red while also causing the lamp above the lever to light up, indicating to a student what is active. When the student activates both inputs of the logic gate, the door at the end will open, allowing them to progress and access the next task. The doors form an ongoing indication of progression, always being the target of an area when open. The voice communication system remains active, offering the opportunity for students to seek and offer help and support within their group to assist all members in completing the tasks. Within this area GE4 is realised, offering interactive puzzles students must complete in the 3D environment and establishing the solving of these puzzles, utilising subject knowledge as the primary skill to do so, as the core game mechanic.

5.2.2.4 Initial Group Task

The initial group task area asks students to cooperate, introducing fully the teamwork aspect of the LogicGate System. Figure 19 shows the first player's view of the group task area.

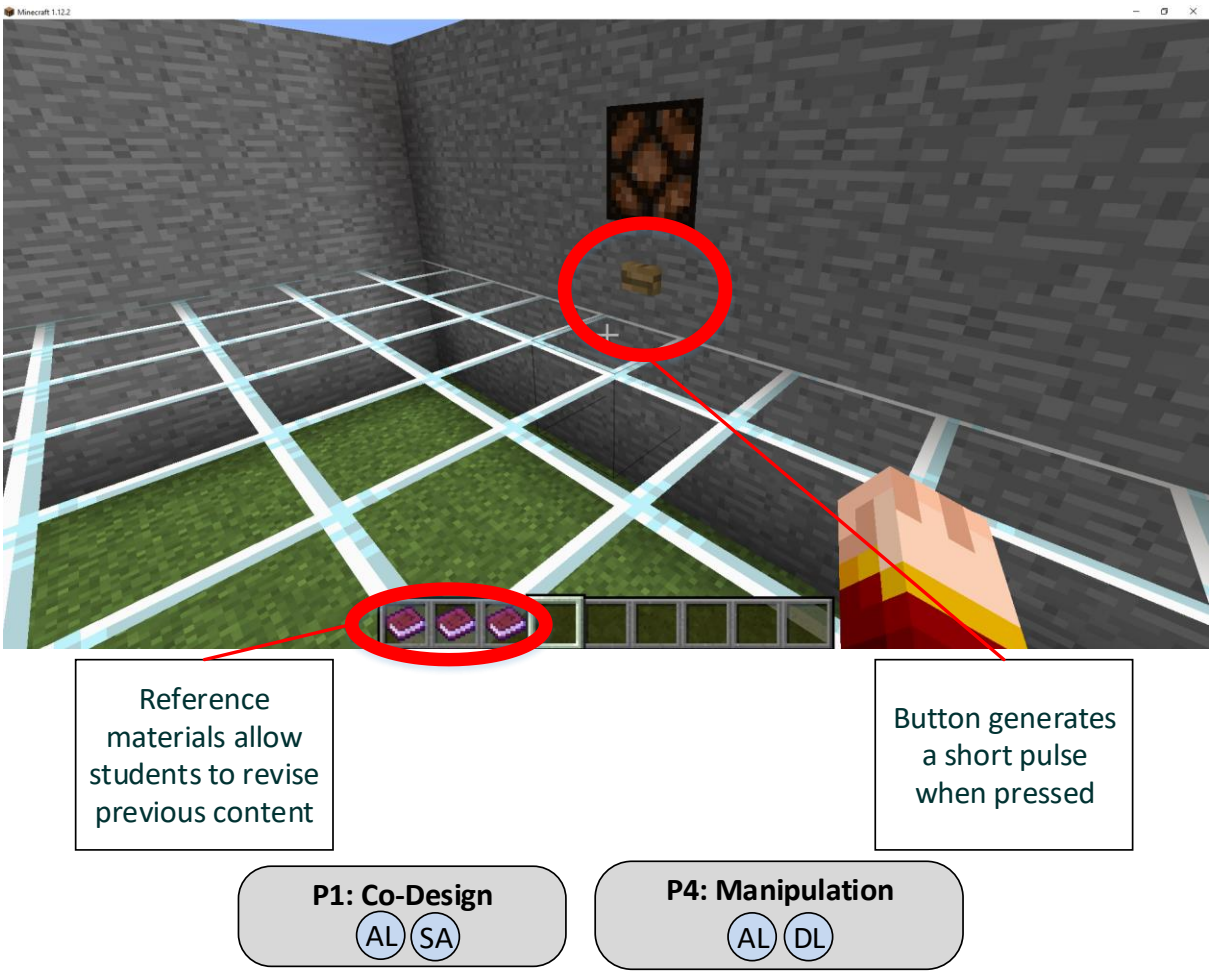

Figure 19: One student's view of the Initial Group Task area

For the initial group task, two students must work together to allow a third to progress. Each student must press their button at the same time. This requires students to collaborate through the voice communication system to identify the features of the area and the changes visible. **P4: Manipulation** of the environment in a cooperative way allows students a greater degree of interaction with the world, while the clear responses to student actions indicates to students that their decisions and actions have a meaningful impact on game progression (**P1: Co-Design**). Within this area GE5 is realised through the student's ability to see clearly both the effects of the buttons and when the route is open (visibility of errors for rapid iteration), alongside GE6, the opportunity to repeat and retry consequence free, as students can continue experimenting with the task until ready to proceed.

5.2.2.5 Group Consolidation Area

The group consolidation area offers collaborative puzzles to be completed which utilise the teamwork elements established in the Group Task area, alongside the subject knowledge gained through the Tutorial Tasks. Challenges faced by students utilise the skills they have been taught according to the Learning Outcomes, and therefore present an implementation of

P12: Systems Thinking. Retaining the existing game elements carried forwards from earlier sections, this area introduces some particular focuses, GE7 and GE8. GE7 is realised as individual students must work with others to affect the other zones for the group to progress, while GE8 is realised through the group's reliance upon each individual contributing.

5.2.2.6 Additional Tutorial

Following the consolidation work, additional learning is offered to extend the subject specific learning. This area introduces the more advanced XOR gate, asking students to utilise it to progress while providing the student with information on its functions to refer back to as required. Through this area, GE9 is realised, as players have progressed through previous challenges demonstrating understanding of basic concepts, and are now introduced to further learning. This represents **P5: Ordered Problems** to enable students to feel a sense of mastery as challenges are overcome.

5.2.2.7 Intermediate Consolidation

This area provides further opportunity for students to face more advanced tasks. Figure 20 shows two views of the same challenge area from different students.

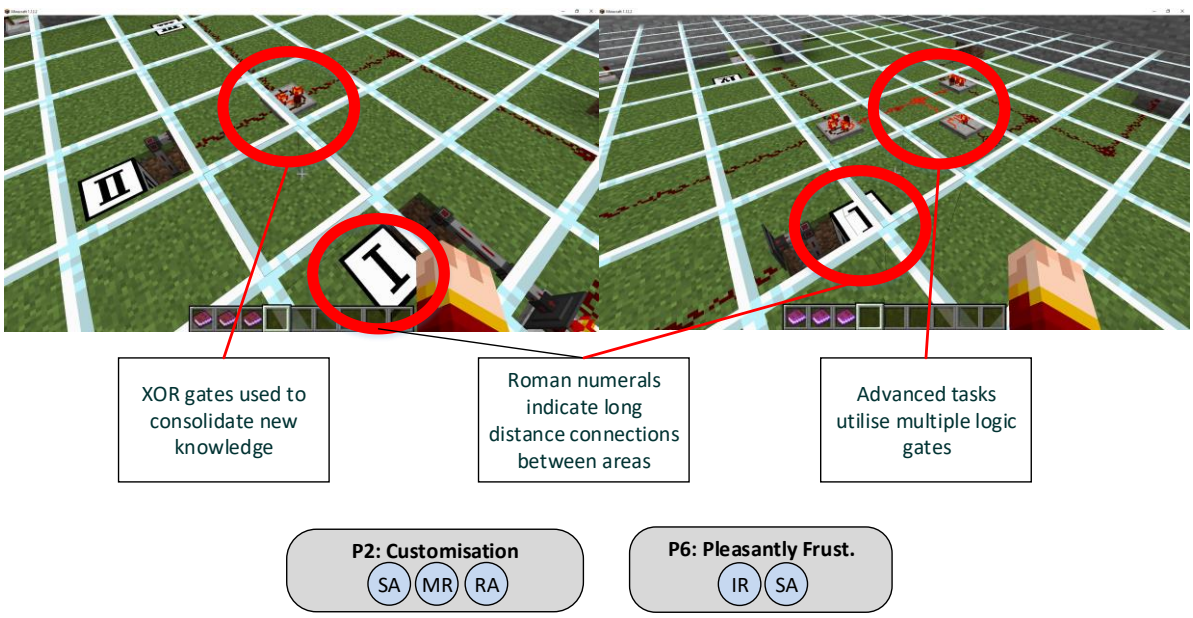

Figure 20: Views of Intermediate puzzles from player 1 and player 3, showing long distance connections between areas

In these puzzles students must cooperate, explaining to each other verbally what they can see and how the elements connect. Connections between the zones are indicated using roman numerals to enable easier communication. A signal may be transmitted between connections that share a roman numeral indicator, making complicated circuits easier to visualise in the shared areas. As with earlier areas, students are required to take actions to open not just their own but also other peoples' access doors to ensure the whole group is able

to progress. GE10 is evident at this area, as the tasks make use of many forms of interactivity and response to offer a steadily increasing challenge to groups of students. This moderate difficulty increase presents a challenge to students as they are stimulated by this gradual stretching of their ability (**P6: Pleasantly Frustrating**). As tasks are increasingly challenging, students may utilise a variety of strategies (**P2: Customisation**) to help understand the layout of the logic circuit and therefore the problem presented.

5.2.2.8 Advanced Consolidation

The final area presents a further extension of the challenges offered by previous puzzle areas. Students engage in a further challenge that seeks to stretch their understanding of the topic area, delivering GE11. This is the culmination of **P7: Cycles of Expertise** implemented through the staged puzzles and allows students to demonstrate a mastery of the topic area through implementation of **P11: Skills as Strategies**. Following the completion of this challenge, students are able to return and explore the other areas, including those completed by other students within their group; this allows students to reflect upon and review content, delivering GE12.

5.2.3 SCDGBL Progression Template

The LogicGate application, presented in Figure 21, has been designed from the ground up following the SCE Framework, which aims to guide designers in the integration of the tenets of Student Centred Learning into a game for education from an early stage. The progression template demonstrates the integration of these SCL tenets within different elements of the game. Under the First Introduction of Game Elements and Student Centred Learning tenets header, all game elements (orange boxes, indicating game elements GE1-G14) give rise directly to SCL linked outcomes (blue circles, appended to game elements) as the group of three students progress through the challenges listed beneath Player Progression Through Challenges (clear boxes). Relevant DGBL principles drawn from the SCE framework are addressed during these challenges and have been discussed in Section 4.4. From each challenge, subject specific learning outcomes (grey boxes) as listed under the Specific Learning Outcomes header are flagged. During each phase, new game elements are introduced while others are maintained from prior phases. Active game elements in each phase are denoted in the parallel chart within Figure 1 (Presence of Game Elements During Progression) by blue shading.

Phase 1: *Initial Orientation and Collaborative* task, provides a simple initial task to complete, representing an opportunity for students to get used to the game world, the controls, and to the voice and text communication.

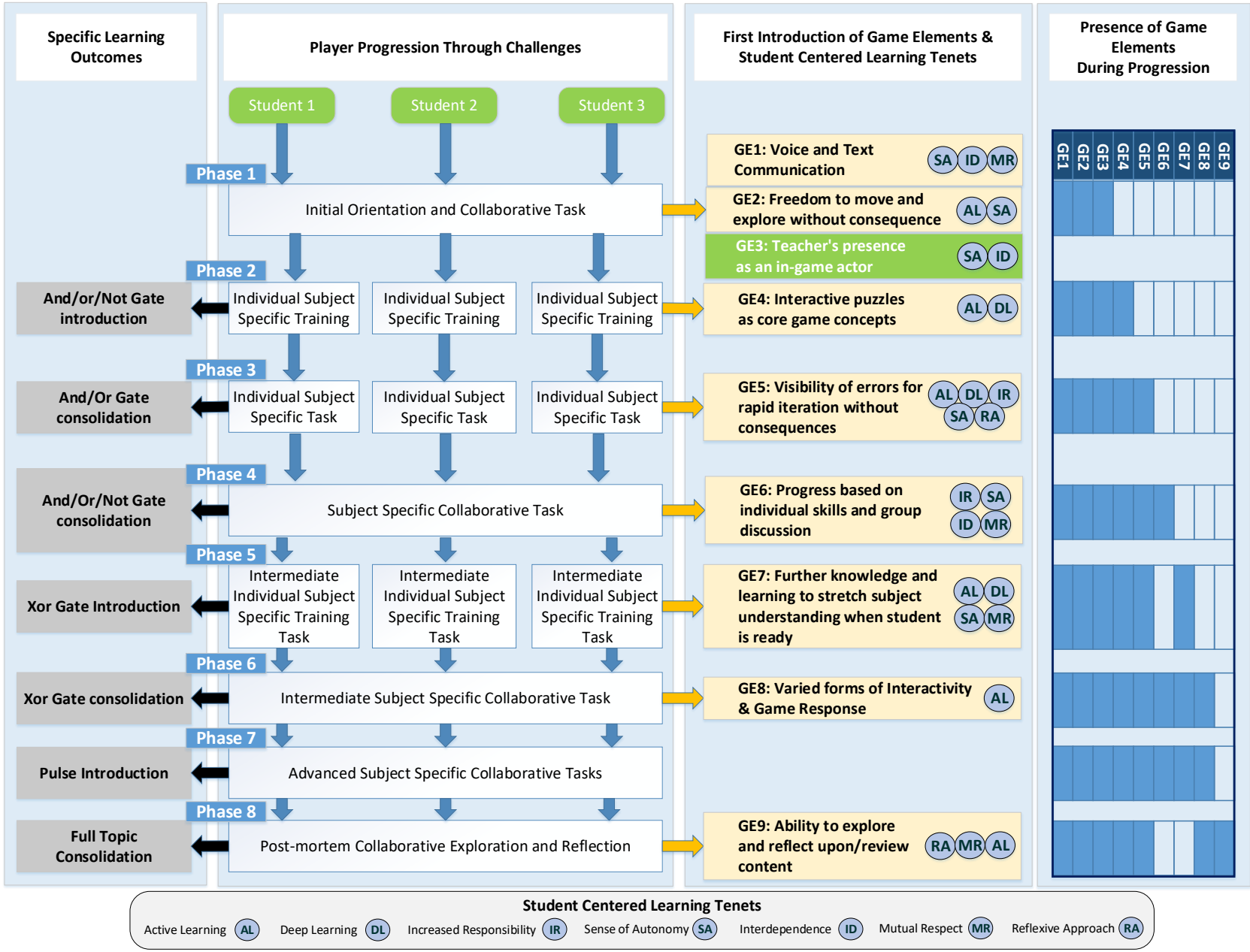

Figure 21: SCDGBL Game Structure, Progression Template & Student Centred Learning Concept Mapping

There are no subject specific learning outcomes at this stage. It introduces Game Element (GE) 1: the *Voice and Text Communications* systems (available in parallel for students to use), which feeds into the SCL tenets of *Mutual Respect* and *Teacher and Learner Interdependence*. This game element enables students to both describe and solve problems, and work with each other and their teacher. This creates a level of equivalence between peer communication and student-teacher communication. Ensuring students are able to communicate clearly while being physically separated avoids one of the common issues of group work, where stronger students are able to complete the work in place of weaker students. Making students' workspaces separate both physically and in-game addresses this challenge, as this encourages students to work together both with each other and with their teacher, as discussion via this game element is easy where students are discouraged from taking direct control of others' computers. This game element also engenders the SCL tenet *Sense of Autonomy*, as help when needed is offered from within the game environment and during the activity they will not encounter anyone taking over their control of the keyboard and mouse outside of technical issues. This stresses to a student that their own real-world space is theirs.

This phase also introduces GE2: the *Freedom to move and explore without consequence* within the game world. This GE maps onto two SCL tenets: *Active Learning*, as the LogicGate System allows students to look at a puzzle from different angles to aid understanding of what each task asks and does, enabling active engagement; and *Sense of Autonomy*, as the LogicGate System allows students to control their own position and viewpoint while they find their way around the world. This type of control allows students to individually customise their own experience and progress at their own pace.

Also introduced is GE3: *Teacher's role as an in-game actor*. Teachers possess a similar avatar in-game to students however with wider reaching power to move, change and create items students cannot. This role allows them to see and demonstrate puzzles and concepts on the same level as students, and make active changes to explain and add or remove complexity as appropriate without breaking student engagement with the game. This is core to the SCL tenet of *Teacher and Learner Interdependence*. The teacher is also able to join and communicate with individual student groups through the same voice and text communications used by students, to make help offered and sought personal. However, the teacher does not have to be present within the voice channel or game world at all times. This provides students a *Sense of Autonomy* as students are not always being watched and listened to by the teacher. All three of these GEs are present throughout game progression.

Phase 2: *Individual Subject Specific Training* introduces students to the individual logic gates they will be using to progress. Curricular outcomes are the introduction of AND, OR and NOT gates, as will be utilised throughout the experience. GE4: *Interactive puzzles as core game concepts* is introduced within this phase as a distinct and interactive part of the game world that persists through all phases. This game element maps to SCL tenets of *Active Learning* and *Deep Learning*. The puzzles represent a form of Problem Based Learning, a well explored technique within *Active Learning*, and students engage with puzzles as an activity, rather than a problem to solve on paper, which may help further embed understanding into the experience, representing *Deep Learning*. Expressed through this, the game integrates logic elements to the puzzles and into the game world. As students progress through puzzles, their acquisition of knowledge to meet the intended learning outcomes becomes indistinguishable from the understanding of the game world needed to progress; progression and victory come from a combination of understanding these educational concepts and communication with peers. While tackling these puzzles, students are given a significant amount of free reign within the 3D space the game provides. Provided are abilities to jump, crouch and sprint as they explore, giving them freedom to move as they desire, changing their view point and meaning that even while considering puzzles or discussing with peers, there are some actions that can be taken with a perceived effect on the game.

Phase 3: *Individual Subject Specific Task* provides an opportunity for students to put the learning immediately into practice. This activity consolidates knowledge gained from the previous step while introducing GE5: *Visibility of errors for rapid iteration without consequences*, which allows students to immediately see the effect of their interactions with the puzzles and adjust their answers as much as needed without negative in-game consequences. This enables meaningful iteration as students can clearly see the results of their actions and identify if progress was made. Providing a method to identify problems and successes is important as otherwise students may not realise their errors, making revision a more frustrating experience. As students take in game actions everything is reversible and repeatable, allowing students to explore the world and experiment to work out what is effective without the pressure of failure, revising their strategy each time. Problem-solving is therefore an active process, thus this GE maps onto the SCL tenet of *Active Learning.* This extends to previous parts of the game, where students can return and re-explore and attempt previous puzzles to learn from their previous exploration. This gives students a measure of responsibility for picking up their own learning and self-correcting errors they see, speaking to three SCL tenets: *Increased Responsibility and* Accountability, a *Reflexive Approach to Teaching and* Learning, and *Sense of Autonomy*. Each time additional concepts are introduced, students immediately encounter these concepts within the game world and

approach them using the knowledge and understanding of previous concepts gained through earlier puzzles. This represents the SCL tenet of *Deep Learning* and allows students to further embed knowledge, as the puzzle solving task becomes a goal rather than a test of knowledge. This game element is maintained throughout the remaining phases.

Phase 4: *Subject Specific Collaborative Task* is the first task involving working with other students. It offers further consolidation opportunities, presented with greater incentive for other students to teach and guide. The game element introduced in this stage comprises the progression system; individual students learning and putting into practice the skills they've obtained in discussion with their group allows the whole group to progress. This represents GE6: *Progress based on individual skills and group discussion*. A key SCL tenet that maps onto this GE is *Increased Responsibility and Accountability*, as students of all levels are both able and required to contribute to their group's success. This can occur in a number of ways. Firstly, completion of the puzzles is available for all students, with a minimum contribution of describing the puzzles visible from their section and responding to peer instructions. As other students are not able to complete the work without cooperation, even a small contribution is vital, allowing weaker students to participate, while students with a greater level of understanding are able to take leadership roles with the additional responsibility this offers. Separately from the academic aspects, students are also able to take responsibility within the group for communication or coordination, an opportunity that remains open to students who may be academically weaker. Lastly, through the communication opportunities, students are able to seek help from others in their team as required, which becomes both the easiest avenue for support and one that supports other students' responsibility. This progression system also offers students a *Sense of Autonomy*, as within the team work context a student's individual area is unique to them, allowing them to exercise a measure of control over their own progression through the game while working with their group. Other group members can advise and suggest courses of action, but in the end a student's actions and decisions are their own to take. However, the group's progress depends on all members of the group both acting in their own areas and communicating with others in their group. Students must rely upon both the others they are working with and their communication with them to complete the challenges. Allowing all students to contribute to an individual student's 'eureka' moments through communication, coordination and action means students are able to build respect for the others in their team, sharing in those moments as they progress through the learning experience. Thus the SCL tenets of *Teacher and Learner Interdependence* and *Mutual Respect* are built through this game element.

Phase 5: *Intermediate Individual Subject Specific Training Task* provides students additional knowledge by introducing how XOR gates function. Further knowledge can be provided at this

stage as students have completed tasks involving the previously explained gates, and by completing this phase they will be suitably equipped to stretch their understanding of the subject by putting this additional knowledge into practice. This represents game element GE7: *Further knowledge and learning to stretch subject understanding when student is ready*. GE6 is still maintained in this phase despite the training task being individual, as the persistence of GE1 through every phase allows group discussion to take place even during these individual tasks. GE7 maps onto a number of SCL tenets. *Active Learning* is maintained by challenging students to again put their understanding into practice and to evolve that understanding to address the more complex puzzles. Students confronted with these more complex puzzles are also able to see their teammates grow with them as their subject understanding is stretched to tackle the more difficult tasks, promoting *Mutual Respect*. *Deep Learning* is also addressed, as this GE allows learning to be immediately applicable rather than appearing for its own sake, helping students see it as the tool to progress in the game rather than esoteric facts. This also encourages students to be creative and apply their understanding in different ways, promoting deeper thinking about the subject matter and creating experiences as they realise how to adapt their play. This GE also provides students with the knowledge that the tools they have are enough to answer all issues encountered, and that when a new tool is given to them, it will immediately be useful. Further, students are not pushed into a more advanced topic before they have completed the earlier challenges on easier topics, ensuring they can take learning at a pace suited to them while helped by those in their team with greater understanding. This encourages a *Sense of Autonomy.* Due to the individual nature of this task, while communication is available GE6 is not a focus, this Game Element will recur in future areas as students return to collaborative play.

Phase 6: Intermediate *Subject Specific Collaborative Task* asks students to consolidate their XOR gate knowledge in a familiar format, thereby stretching their understanding through practice (GE7) and collaborating through group discussion (GE6). The game element introduced here is modifications of the way students are able to interact with the puzzles and receive a response (GE8: *Varied forms of Interactivity and Game Response*). Students are able to engage practically in changing the game world through a variety of switches, panels and other interactive elements. The game world responds to these interactions in various ways, with the triggers themselves changing as levels are raised or lowered, and their effects triggering lights to go on, wires to light up, elements to move position and doors to open and close. This provides additional visual indicators of success or error when applying this new knowledge so that students can continue to rapidly iterate based on visible errors (GE4). This clearly maps to the SCL tenet of *Active Learning*.

Phase 7: *Advanced Subject Specific Collaborative Tasks* sustains previously introduced game elements by offering students the opportunity to consolidate their knowledge, through freely exploring a series of increasingly difficult puzzles (GE2, GE4). This introduces students to additional knowledge (GE7), namely the concept of pulsed or changing signals from a curricular perspective, and builds upon students' ability to collaborate and explain to progress (GE1, GE6). These are accompanied by additional puzzle interactivity and modifications to puzzle responses based on integration of this new knowledge (GE8), so students can continue to iterate (GE5). The teacher is able to support the students within this phase, as all others, however required (GE3).

Phase 8: *Post-mortem Collaborative Exploration and Reflection* is the final phase and represents a facility for students to collaborate and reflect upon the content completed. This fosters student *Ability to explore and reflect upon/review content* (GE9), by ensuring students can continue exploring and learning from the LogicGate System even when puzzles are completed. This maps to the SCL tenet *Reflexive Approach to Teaching and Learning*. At this stage students may review work completed by themselves and others, and be able to answer any questions arising from the inability to view other students' viewpoints in-game. It allows for a full topic consolidation exercise, while taking advantage of students' ability to return to and review content to better understand. This final game-phase does not promote GE6 and GE7. As this phase involves reviewing previously completed content there is no direct progress to attribute to GE6, while GE7 is limited as this phase is not providing further knowledge but reviewing existing learning.

5.2.4 Summary

In this section, the LogicGate System was presented as a SCDGBL vehicle to achieve learning outcomes related to Boolean logic concepts. The LogicGate System was created through adaptation of the existing game Minecraft, guided by use of the newly-developed SCE model. This demonstrates usage of the model in the creation of a SCDGBL intervention, and how the resulting artefact fulfils the tenets of Student Centred Learning, encompassing also the crucial social aspects thereof. The next stage is to evaluate the intervention for acceptability, feasibility and the extent to which it is able deliver the identified learning points in a way that engages students and promotes a high quality learning experience. From here the remainder of this chapter will focus on the evaluative study that was performed to meet the research aims identified at the beginning of the chapter.

5.3 Methods

This section provides details of the data collection and analysis techniques used to answer the study's research questions. These particular aims are focused upon the student

experience with the LogicGate System (**E1RQ2** & **E1RQ3**), as the first test of delivering social SCL tenets through a game designed using the SCE model (**E1RQ1**). To effectively answer the research questions, a mixed methods design was selected to evaluate the experiences and outcomes of students who had undertaken a session using the LogicGate System. A mixed methods approach was chosen as, while the surveys selected provided data to be statistically analysed on a number of areas of the experience, it was felt qualitative data would provide additional depth and insight into the reasons behind these results, as well as more valuable feedback towards future revisions (Canossa et al., 2011). Figure 22 presents the participant and data collection and analysis procedure for the study.

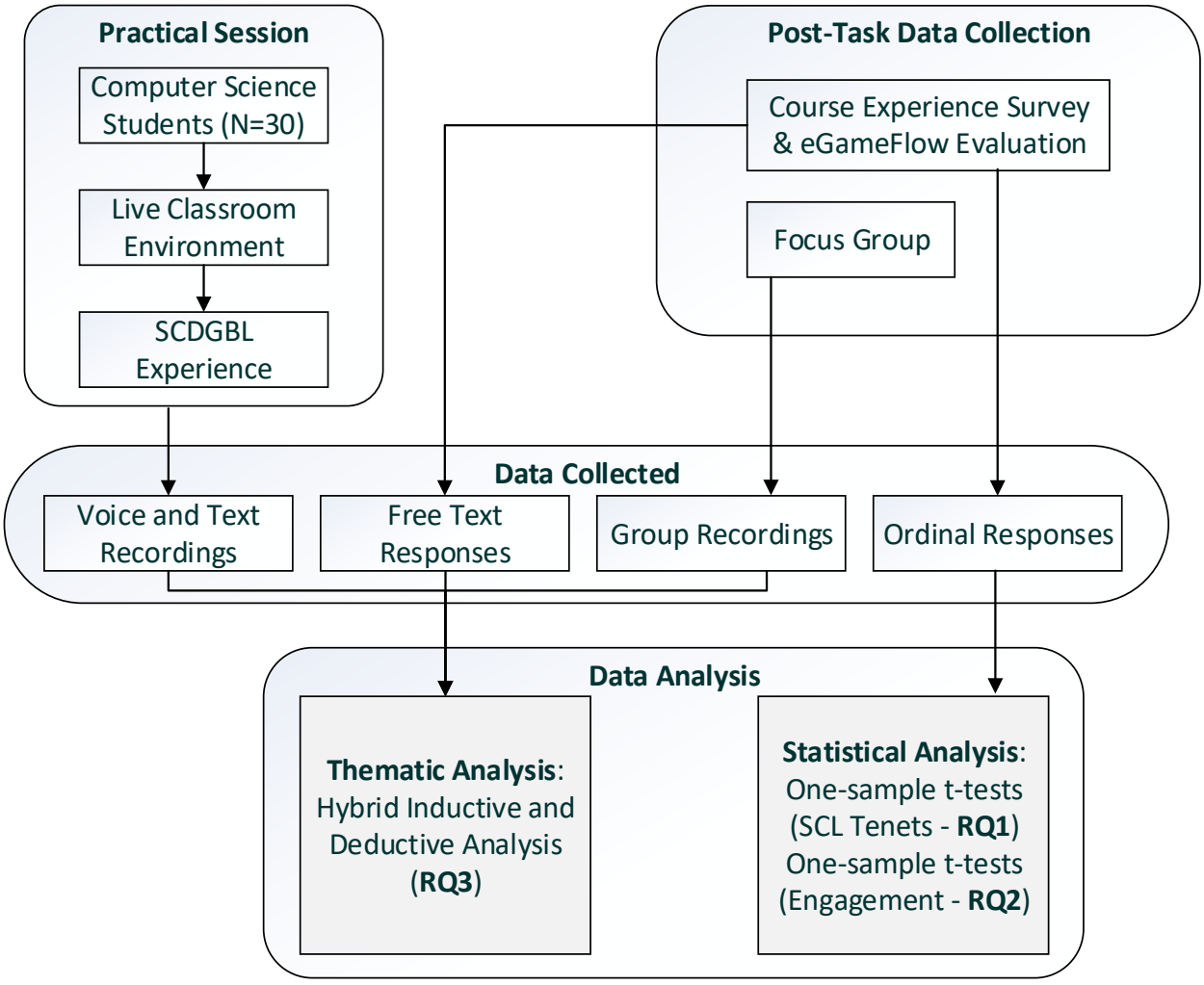

Figure 22. Mixed methods data collection and analysis procedure

5.3.1 Participants

The participants for Experiment 1 were one class of Foundation year computer science students at Brunel University (n=30). A sample of 20-30 participants is recommended for studies involving thematic analysis (Fugard and Potts, 2015), and for statistical analysis, a priori computation using G Power (medium effect size d = 0.5, power = 0.8, p = 0.05, for one-sample one-tailed t-test) indicated a suggested sample size of n = 27. Pragmatic

considerations also included the mixed-methods study design requiring the balancing of manageable sample sizes for qualitative analysis procedures against an optimum sample for meaningful statistical analysis. Foundation year was selected because the foundation course provides a route into bachelor's degrees for students without existing equivalent qualifications, and subsequently delivers content closely tied to A2 level Computing qualification taught within schools and sixth form colleges in the UK, potentially allowing for a wider deployment of the LogicGate System within 16+ education in the future. This allowed identification of Boolean logic as an essential learning concept for this level group. Students were invited to participate through the course, with those who opted out being taught through the same module but being excluded from the data collection process.

The inclusion criteria were that participants: (1) Were on the Foundation course, to give a reasonable approximation of level; (2) Were proficient English speakers, so all members of the class could effectively communicate within the cooperative learning environment. No upper age limits were imposed, as the foundation year course is designed to be accessible to all learners aged 18 and above. The teacher was not included as a research participant within this evaluation as the study was conducted by the researcher in their capacity as demonstrator for the class group – as such they could not objectively participate in the evaluation exercise, and the current study focuses on the student perspective and experience of the LogicGate System.

5.3.2 Outcome measures

Since there are no existing validated instruments that explicitly measure SCL tenets, to identify whether the LogicGate System effectively delivered upon all tenets of Student Centred Learning (**E1RQ1**), it was important to characterise the student perception of teaching and learning when engaging with the LogicGate System through use of appropriate metrics. Further to this, the LogicGate System aimed to deliver upon some of the social aspects of SCL that have been neglected in many SCDGBL offerings to date, including peer-assisted learning, mutual respect and teacher and learner interdependence. Help-seeking behaviour is an important metric for these aspects (Karabenick, 2003, Aleven et al., 2003). The Course Experience Survey (CES) is an evaluation tool for a variety of learning environments (Hyo-Mi, 2018), that explores student perceptions of their learning and taught content. The CES is based upon assessing implementation of the Centre for Research on Education, Diversity and Excellence (CREDE) standards of pedagogy (Tharp, 2018, Dalton, 1998), which share root theory with SCL (Vygotsky, 1997, Dalton, 1998, Tharp, 2018) and exhibit a strong overlap with multiple SCL tenets such as *Active Learning, Deep Learning, Increased Responsibility and Accountability* and *Mutual Respect,* and key concepts associated with Student Centred Learning, such as help-seeking, peer learning, group discussion and teacher/peer

relationships (Lea et al., 2003, Dalton, 1998, Tharp, 2018). This degree of overlap establishes the potential of the CES as an effective tool for evaluating SCL experiences, helping to address **E1RQ1**. In further support of this, Table 9 provides the mapping between the constructs in the Course Experience Survey and eGameFlow survey and the SCL tenets as well as the explanations for the connections explored. The tenets linked to an individual construct are presented in Table 9, where constructs have a secondary linkage for an additional tenet, this tenet is presented in brackets. As can be seen from Table 9, SCL tenets are spoken to by both surveys, therefore the integration of both surveys provides an answer to **E1RQ1**, which pertains to successful delivery of all seven SCL tenets. Each survey construct is marked with the research questions the construct addresses.

The immersion construct is notable as it has no direct link to a SCL tenet. This construct, however, provides a valuable link to user experience metrics which speak to the student's level of engagement with the experience (Garris et al., 2002). Immersion is closely related to flow, explored in 4.2, which establishes that the challenge of the game balanced against the student's increasing ability level and understanding creates conditions whereby the student may enter the flow state, becoming more deeply immersed within the game. While this construct is not a fully featured exploration of flow, it nonetheless provides important data about the student's engagement with their learning experience.

To determine if students were engaged while using the LogicGate System to learn educational content (**E1RQ2**), evaluation of the user experience when playing the game is vital. User experience metrics such as immersion, concentration and clarity of goals can help to establish whether the SCE model has successfully achieved the intention of seamless integration of game design with SCL tenets and pedagogical/assessment requirements (Hamari et al., 2016). The eGameFlow survey (Fu et al., 2009, Chen et al., 2018) was selected from amongst a number of tools for its important inclusion of a 'Social Interaction' (*Mutual Respect*) construct, something that other tools lacked yet is vital for an evaluation that encompasses the key social aspects of SCL. It has been validated within user experience research (Chen et al., 2018) and has been used within educational game evaluation previously (Iten and Petko, 2016, Chen et al., 2012). An optional module for the evaluation of educational content was also utilised (Fu et al., 2009). These outcome measures can be augmented by more qualitative exploration of the student experience when engaging with the LogicGate System. Few studies evaluating recent digital educational games have leveraged qualitative research techniques to explore other aspects of student engagement and the gameplay experience, as demonstrated in the review presented in 4.4.3. Students' views on learning through SCDGBL (**E1RQ3**) were assessed primarily through questions included within the focus group, these questions were designed to capture players' opinions towards engaging in such activities in the future.

5.3.3 Procedures

Upon joining a session, participants would receive explanation on the game, followed by a one hour session using the LogicGate System. Team members sat at numbered computers to ensure they were not seated adjacent, per the design considerations outlined and rationalised in Section 2 above. The session was carried out in the same laboratory which students use for standard classes, the session was supervised and supported by the researcher. All data was collected in November 2018, during the first semester when students in the foundation year class were first introduced to this topic in the existing framework of the course. The experiment took place in a traditional lab setting where students would have normally worked through exercises on this topic.

Following the session, all participants filled out the Course Experience Survey (Appendix 3) assessing their perception of the teaching and learning, help seeking behaviour and experiences (Hyo-Mi, 2018) as well as the eGameFlow questionnaire (Appendix 3) on the LogicGate System itself, addressing the user experience (Chen et al., 2018, Fu et al., 2009). Participants were invited to agree or disagree with statements in both surveys using a 5 point Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree), and were given the opportunity to expand upon these with free text response.

Once questionnaires were completed students were invited to return in a separate session for a short focus group in which discussion was digitally recorded to be transcribed verbatim at a later date. The purpose of this group was to discuss their experiences, providing supporting qualitative data to augment the questionnaires (Canossa et al., 2011). This focus group was conducted in groups of 4 (a recommended sample size for focus groups (Tang and Davis, 1995), although this varies substantially (Carlsen and Glenton, 2011)); focus group topics (Appendix 4) included the challenges of using the LogicGate System, difficulties in group or individual work, and understanding of the topic. Additional qualitative data sources included the voice and text chats between the students during the game sessions and free text responses on both questionnaires.

Table 9: Linkage between Course Experience Survey/eGameFlow constructs and Student Centred Learning tenets

Instrument	Construct	SCL Tenets	Explanation
eGameFlow	Concentration **E1RQ1, E1RQ2**	Active Learning (AL)	Questions within this construct deal with students' active engagement in the task, making this construct a clear fit for the tenet of Active Learning. Further to this, Concentration is an important component of flow within games (Czikszentmihalyi, 1990), representing a key metric of user experience alongside active engagement with learning. (Bober, 2008)
	Goal Clarity **E1RQ1, E1RQ2**	Increased Responsibility and Accountability (IR)	Clear and specific goals are important to allow students to identify what they are expected to achieve, and to provide milestones against which to measure their achievement. Through this student take responsibility for modifying their performance where milestones are not met (Garris et al., 2002) (Whitton, 2014)
	Feedback **E1RQ1, E1RQ2**	Reflexive Approach to Teaching and Learning (RA)	Timely feedback on work done allows a student to learn from their mistakes quickly and improve, showing a Reflexive Approach. (Garris et al., 2002)
	Challenge **E1RQ1, E1RQ2**	Active Learning (AL)	This construct deals with the package of challenge and the support provided to students to overcome this. Using skills to overcome difficulty is an example of Active Learning in action. (Whitton, 2014) Ch 3]
	Autonomy **E1RQ1, E1RQ2**	Sense of Autonomy (SA) (Increased Responsibility and Accountability [IR])	Questions in this construct deal specifically with a student's Sense of Autonomy, making this a natural fit, in addition there is some crossover with Increased Responsibility through the questions on control and impact which are known to interact positively with motivation. (Garris et al., 2002) (Whitton, 2014) Ch 10]
	Immersion **E1RQ2**		The Immersion construct does not directly map to an SCL tenet but provides information on player engagement and user experience. (Garris et al., 2002)
	Social Interaction **E1RQ1, E1RQ2**	Mutual Respect (MR)	Questions addressing student communities and collaboration provide a strong crossover with the tenet of Mutual Respect, as students work together. (Whitton, 2014) Ch 5]
	Knowledge Improvement **E1RQ1, E1RQ2**	Active Learning (AL)	Knowledge improvement is an outcome of Active Learning, engaging in gameplay activity by itself does not constitute effective learning. Through a student's knowledge improvement, an in-game activity can be meaningfully identified as Active Learning. (Annetta, 2010)
Course Experience Survey	Complex Thinking **E1RQ1**	Deep Learning (DL)	Students are asked about their synthesis and application of knowledge, providing a clear demonstration of Deep Learning. (Dalton, 1998)
	Contextualisation **E1RQ1**	Deep Learning (DL)	Contextualisation deals with the application and relation of knowledge to students' everyday lives providing a clear example of Deep Learning. (Dalton, 1998)
	Instructive Conversation **E1RQ1**	Teacher and Learner Interdependence (ID) (Reflexive Approach to Teaching and Learning [RA])	Questions on the relationship between students and teachers naturally fall to Interdependence, this is supported by the standards of effective pedagogy considered to underly this construct, where conducting instruction through conversation allows students to negotiate with teachers and peers to meet their academic and social needs. (Dalton, 1998) (Doherty et al., 2002)
	Joint Productive Activity **E1RQ1**	Mutual Respect (MR) (Active Learning [AL])	This construct asks about how students work together, providing a natural fit for Mutual Respect, particularly as the underlying theoretical foundations for this focus on goal-directed collaboration between students and teachers (Doherty et al., 2002). In addition, Active Learning is identified as a central mechanism by which Joint Productive Activity encourages learning to occur, with Peer Learning and Cooperative Learning in particular forming a key part of this process. (Dalton, 1998)
	Language and Literacy Development **E1RQ1**	Reflexive Approach to Teaching and Learning (RA)	Within this construct, students were asked about feedback and self-improvement, concepts which feature heavily in the tenet of Reflexive Approach to Teaching and Learning. (Hyo-Mi, 2018)

5.3.4 Data Analysis

To answer research questions **E1RQ1** and **E1RQ2**, analysis of the survey responses was performed using IBM SPSS statistics package version 25.0.0. First, five questions which were asked in a negative context had scales inverted, such that 1 always represented the negative and 5 always represented the positive. Cronbach Alpha was performed on each construct within the whole instrument, to assess consistency with the threshold set at 0.6, as is standard for small sample size studies (Churchill Jr, 1979). One sample t-tests were performed on individual questions and the aggregated constructs, comparing participant responses to the neutral point (3). Significance was set at the 0.05 level using one-tailed hypothesis testing, as the nature of the research questions dictates the identification of whether or not there is a skew of student perceptions of their learning experience in a positive direction after exposure to the LogicGate System. As no change or a negative skew are not of interest, this makes a one-tailed test appropriate to use (Jones, 1952).

To answer research question **E1RQ3**, a hybrid approach was taken to thematic analysis, with initial coding undertaken utilising the eGameFlow and Student Experience Survey constructs, as well as Student Centred Learning tenets as deductive themes. This initial coding was expanded upon, identifying further common topics in the discussions and categorising these. The initial codes were examined and emerging themes identified. Using an iterative approach themes were linked, removed and combined leading to a categorisation of themes under overarching themes that describe the content (Braun et al., 2014). This analysis was conducted on the transcribed Focus Group results along with the recorded text/voice chat data from during the task and free text responses from surveys. All coding activities were performed using NVIVO.

5.4 Results

This section presents the results of the analysis of the Course Experience Survey, EGameflow and Focus Group data. Overall 30 participants took part in the experiment.

5.4.1 eGameFlow Evaluation

Research question **E1RQ1** aimed to establish whether the LogicGate System effectively delivered all tenets of SCL for students.

Table 10: eGameFlow results by Construct

Construct	eGameFlow Questions	Mid-Point	Mean	Standard Deviation	Gap score	df	t-value	P-Value	Alpha
Concentration (Active Learning)	***Construct***	**3**	**3.477**	0.945	0.477	29	2.767	**0.005**	0.808
	Stimulating Content	3	3.57						
	Distraction	3	3.23						
	Concentration	3	3.63						

Goal Clarity (Increased Responsibility)	***Construct***	**3**	**3.275**	1.258	0.275	29	1.197	0.120	0.932
	Understanding Goals	3	3.07						
	Goal Clarity	3	3.27						
	Game Progress	3	3.53						
	Event Prediction	3	3.17						
Feedback (Reflexive Approach)	***Construct***	**3**	**2.725**	1.047	-0.275	29	-1.439	0.080	0.904
	Feedback on Progress	3	2.8						
	Immediate feedback	3	2.87						
	Performance Tracking	3	2.83						
	Score Awareness	3	2.4						
Challenge (Active Learning)	***Construct***	**3**	**3.206**	0.951	0.206	29	1.189	0.122	0.858
	Difficulty Suitability	3	3.37						
	Skill Improvement	3	3.17						
	Skill Motivation	3	3.23						
	Well-paced Challenges	3	3.3						
	Levels of Difficulty	3	2.97						
Autonomy (Sense of Autonomy)	***Construct***	**3**	**3.322**	0.964	0.322	29	1.829	**0.037**	0.828
	Control of Movements	3	3.52						
	Control of Interactions.	3	3.31						
	Free use of strategies	3	3.24						
Immersion	***Construct***	**3**	**2.708**	1.125	-0.292	29	-1.419	0.083	0.888
	Losing track of time	3	3.1						
	Losing surroundings	3	2.47						
	Deep Involvement	3	2.97						
	Emotional Involvement	3	2.21						
Social Interaction (Mutual Respect)	***Construct***	**3**	**3.366**	1.029	0.366	29	1.951	**0.030**	0.779
	Social Interaction	3	3.72						
	Community Support	3	3.3						
	Other players help	3	3.17						
Knowledge Improvement (Active Learning)	***Construct***	**3**	**3.46**	1.045	0.460	29	2.41	**0.012**	0.924
	Increase in knowledge	3	3.27						
	Basic Ideas	3	3.4						
	Knowledge application	3	3.55						
	Knowledge Integration	3	3.5						
	Want to learn more	3	3.53						

Six of the eight constructs demonstrated above average results, indicating participants held positive views around these elements of the LogicGate System. Cronbach Alpha values for all constructs were above the minimum reliability threshold of 0.6 used for small sample size studies, demonstrating these results are internally consistent. Analysis showed that the constructs of Concentration (*Active Learning*), Autonomy (*Sense of Autonomy*), Social Interaction (*Mutual Respect*) and Knowledge Improvement (*Active Learning*) achieved mean scores above the midpoint value of 3.00 that were statistically significant on one-sample t-test, with values of 3.477 ($p = 0.005$), 3.322 ($p = 0.039$), 3.366 ($p = 0.030$) and 3.460 ($p = 0.012$) respectively. Further results for the Feedback (*Reflexive Approach to Teaching and Learning*) (2.725, $p = 0.080$) and Immersion (2.709, $p = 0.083$) constructs were approaching significance. Subsequent sections break down results for each construct, augmented by supporting qualitative focus group data that was coded to these constructs during thematic analysis.

5.4.1.1 Concentration

Items within the Concentration (*Active Learning*) construct asked participants to assess their ability to concentrate on the game, ignoring distractions and focusing their attention on playing. The mean score for this construct was higher than the mid-point benchmark, and reached statistical significance (mean = 3.477, t = 2.767, *p = 0.005*). This indicates a perception that participants were able to maintain concentration on the game and focus on their in-game activities.

Some participants expressed a feeling that the game was able to draw them in, while others felt there may be additional work required to improve the LogicGate System to maintain participants' focus, as the engagement with other participants in the team may cause delays, forcing idle periods.

> *S4: "It was more enticing to learn through the game than it is to learn from reading through the internet…. it feels like you'd be able to stick with things better"*

> *S3: "We had gotten through the tutorial part learning the AND gate, the OR gate and stuff, then we had to wait quite a long time for them to figure out the controls."*

5.4.1.2 Goal Clarity

The items within the Goal Clarity (*Increased Responsibility and Accountability*) construct covered participants' understanding of the game's goals and clarity over what they were attempting to do next. The mean score for this construct was higher than the mid-point benchmark but did not approach significance (mean = 3.275, t = 1.197, *p = 0.120*). There were mixed opinions about the clarity of intent, with some participants expressing frustration over a lack of understanding on specific goals and next steps.

> *S13: "I can't even see what we have to do… it's not clear enough what does what"*

S4: "I think it just really wasn't that hard to understand, like it tells you what to do, but then the main problem was that it didn't really emphasise the part that was teamwork"

S13: "I can't even see what we have to do… it's not clear enough what does what"

S4: "I think it just really wasn't that hard to understand, like it tells you what to do, but then the main problem was that it didn't really emphasise the part that was teamwork" presents the findings from the eGameFlow survey completed after exposure to the LogicGate System, to determine the quality of the SCDGBL experience through the lens of a number of constructs.

Each construct is presented with the mean and statistical analysis results (standard deviation, gap score calculated as difference of mean from midpoint, *t*, *df*, *p*, Cronbach's Alpha), while means are presented for each question comprising that construct.

Table 10: eGameFlow results by Construct

Construct	eGameFlow Questions	Mid-Point	Mean	Standard Deviation	Gap score	df	t-value	P-Value	Alpha
Concentration (Active Learning)	***Construct***	**3**	**3.477**	0.945	0.477	29	2.767	**0.005**	0.808
	Stimulating Content	3	3.57						
	Distraction	3	3.23						
	Concentration	3	3.63						
Goal Clarity (Increased Responsibility)	***Construct***	**3**	**3.275**	1.258	0.275	29	1.197	0.120	0.932
	Understanding Goals	3	3.07						
	Goal Clarity	3	3.27						
	Game Progress	3	3.53						
	Event Prediction	3	3.17						
Feedback (Reflexive Approach)	***Construct***	**3**	**2.725**	1.047	-0.275	29	-1.439	0.080	0.904
	Feedback on Progress	3	2.8						
	Immediate feedback	3	2.87						
	Performance Tracking	3	2.83						
	Score Awareness	3	2.4						
Challenge (Active Learning)	***Construct***	**3**	**3.206**	0.951	0.206	29	1.189	0.122	0.858
	Difficulty Suitability	3	3.37						
	Skill Improvement	3	3.17						
	Skill Motivation	3	3.23						
	Well-paced Challenges	3	3.3						
	Levels of Difficulty	3	2.97						
Autonomy (Sense of Autonomy)	***Construct***	**3**	**3.322**	0.964	0.322	29	1.829	**0.037**	0.828
	Control of Movements	3	3.52						
	Control of Interactions.	3	3.31						
	Free use of strategies	3	3.24						
Immersion	***Construct***	**3**	**2.708**	1.125	-0.292	29	-1.419	0.083	0.888
	Losing track of time	3	3.1						
	Losing surroundings	3	2.47						
	Deep Involvement	3	2.97						
	Emotional Involvement	3	2.21						
Social Interaction (Mutual Respect)	***Construct***	**3**	**3.366**	1.029	0.366	29	1.951	**0.030**	0.779
	Social Interaction	3	3.72						
	Community Support	3	3.3						
	Other players help	3	3.17						
Knowledge Improvement (Active Learning)	***Construct***	**3**	**3.46**	1.045	0.460	29	2.41	**0.012**	0.924
	Increase in knowledge	3	3.27						
	Basic Ideas	3	3.4						
	Knowledge application	3	3.55						
	Knowledge Integration	3	3.5						
	Want to learn more	3	3.53						

Six of the eight constructs demonstrated above average results, indicating participants held positive views around these elements of the LogicGate System. Cronbach Alpha values for all constructs were above the minimum reliability threshold of 0.6 used for small sample size studies, demonstrating these results are internally consistent. Analysis showed that the

constructs of Concentration (*Active Learning*), Autonomy (*Sense of Autonomy*), Social Interaction (*Mutual Respect*) and Knowledge Improvement (*Active Learning*) achieved mean scores above the midpoint value of 3.00 that were statistically significant on one-sample t-test, with values of 3.477 (p = 0.005), 3.322 (p = 0.039), 3.366 (p = 0.030) and 3.460 (p = 0.012) respectively. Further results for the Feedback (*Reflexive Approach to Teaching and Learning*) (2.725, p = 0.080) and Immersion (2.709, p = 0.083) constructs were approaching significance. Subsequent sections break down results for each construct, augmented by supporting qualitative focus group data that was coded to these constructs during thematic analysis.

5.4.1.3 Concentration

Items within the Concentration (*Active Learning*) construct asked participants to assess their ability to concentrate on the game, ignoring distractions and focusing their attention on playing. The mean score for this construct was higher than the mid-point benchmark, and reached statistical significance (mean = 3.477, t = 2.767, *p = 0.005*). This indicates a perception that participants were able to maintain concentration on the game and focus on their in-game activities.

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The items within the Goal Clarity (*Increased Responsibility and Accountability*) construct covered participants' understanding of the game's goals and clarity over what they were attempting to do next. The mean score for this construct was higher than the mid-point benchmark but did not approach significance (mean = 3.275, t = 1.197, *p = 0.120*). There were mixed opinions about the clarity of intent, with some participants expressing frustration over a lack of understanding on specific goals and next steps.

> *S13: "I can't even see what we have to do… it's not clear enough what does what"*

S4: "I think it just really wasn't that hard to understand, like it tells you what to do, but then the main problem was that it didn't really emphasise the part that was teamwork"

5.4.1.5 Feedback

The Feedback (*Reflexive Approach to Teaching and Learning*) construct grouped items that asked about participants' perception of and awareness of feedback provided within the game, their understanding of the effects their actions were having and their progression or score. This construct scored below average and was approaching significance (mean = 2.725, t = -1.439, *p = 0.080*). Participants in focus groups noted that feedback on individual actions was good however the lack of a formal score system within the game gave one question "I am always aware of the score of the game" a particularly low response which did pass the threshold for significance (mean 2.40, *p = 0.010*).

S1: "Everything was indicated well, with… with the glass floor indicating what components we needed to activate in the game, the way the leads showed what was lit up"

S4: "as an individual the feedback was done well and was easy to understand, but in a team it wasn't as good. The rat-race thing with everyone going ahead and didn't get that in the task you were supposed to do it as a team"

5.4.1.6 Challenge

The Challenge (*Active Learning*) construct addressed the level of difficulty and skill curve the game provided, participants' perceptions of the increase in difficulty and how appropriate the challenges presented at each stage were. This construct scored above the midpoint, but was not statistically significant (mean = 3.206, t = 1.189, *p = 0.122*). Responses on the difficulty were mixed with some participants feeling they were not fully equipped through the tutorial sections while others found the topic covered or early puzzles to be too simple.

S2: "What I would like to see more is when you have the first gate, like an OR, could you have two more like it? Because what happens is when you do it once, and then you skip to another gate. So if you had the gates two times you'd have to understand it."

S4: "The puzzles weren't that difficult, like they were easy to understand, and even for the stuff that seemed more difficult you had added in the books, so in the inventory you could read and get a better understanding."

5.4.1.7 Autonomy

Autonomy (*Sense of Autonomy*) addressed participants' sense of control over their movements, interactions and strategies within the game. This construct scored significantly above the mid-point benchmark (mean = 3.322, t = 1.829, *p = 0.037*). Participants tended to agree that they had a sense of control over their movements and interactions however some felt the teamwork aspects took away from their sense of control at points.

> *S2: "Well, when the game started I'd never played Minecraft or anything, I didn't know what the controls were or anything. It took me… it took me like two minutes to figure out what do and, like, what not to do, so it was pretty easy."*

> *S4: "Yeah, yeah, however for our group one of the people went on ahead without opening the door for the middle, which was me…"*

5.4.1.8 Immersion

Participants tended to have a negative view of their immersion within the game, scoring this construct below average but not significantly so (mean = 2.708, t = -1.419, *p = 0.083*). Common issues in this area tended towards the nature of the lab environment that participants found drew attention away from the game. Questions on surroundings and emotional involvement in particular did show significance in this area.

> *S4: "(It was) very hard to communicate over voice chat especially with lots of external noise."*

5.4.1.9 Social Interaction

Social Interaction (*Mutual Respect*) was rated broadly positively (mean = 3.366, t = 1.951, *p = 0.030*) that they believed the game promoted interaction between students and supported students as a community. Feelings on the effectiveness of learning through teamwork were more mixed, however the general perception remained positive.

> *S3: "I think a group activity is definitely better, because if you are having trouble someone else in your group may be able to help explain it to you and help you progress, whereas if its' an individual task you might be stuck until you have to do something else like look it up, whereas group activities… you all know you can be better at different aspects of whatever you're doing so working together would be beneficial."*

5.4.1.10 Knowledge Improvement

Participants rated Knowledge Improvement (*Active Learning*) aspects to be significantly above average (mean = 3.460, t = 2.410, *p = 0.012*). Participants broadly felt they did learn from the game and that it was a useful tool for helping push their understanding of the topic. There was some concern over the practicality of the LogicGate System as a revision tool due to the team-based nature of the LogicGate System.

> *S1: "…this would be a good way to propel forward in the module and understanding… what we like and what we don't like, what we need to further extend in and what we have already accomplished in that sort of sense."*

> *S3: "With this game in particular, maybe with games in general it would be different, but with this game in particular it emphasises the potential of working as a team, which is okay when you're learning it but when you're dealing with revision most people do that individually. So this game emphasises the part of working as a team, and I may not have a team to be able to go through it."*

5.4.2 Course Experience Survey Evaluation

Research question **E1RQ2** sought to determine whether the LogicGate System was an engaging method by which to learn the taught concepts. Table 11 displays the by-construct results of the Course Experience survey taken following exposure to the LogicGate System, that explored student perceptions of their learning experience and the way in which they were taught.

Table 11: Course Experience Survey Results by Construct

Construct	Course Experience Survey Questions	Mid-Point	Mean	Standard Deviation	Gap score	df	t-value	P-Value	Alpha
Complex Thinking (Deep Learning)	***Construct***	**3**	**3.583**	0.673	0.583	29	4.744	<0.001	0.687
	Higher order thinking	3	3.600						
	Application of concepts	3	3.570						
	Instructor helps develop solutions	3	3.540						
Contextualisation (Deep Learning)	***Construct***	**3**	**3.310**	0.612	0.175	29	1.566	0.064	0.600
	Teaching relevant to personal life	3	3.170						
	Everyday Experiences	3	3.270						
	Relation to prior experiences	3	3.500						
Instructive Conversation (Interdependence)	***Construct***	**3**	**3.221**	0.837	0.221	29	1.450	0.079	0.863
	Instructor works with small groups	3	3.680						
	Small group discussion	3	3.070						
	Planned Discussions	3	3.100						
	Students contribute to discussion	3	3.130						
	Instructor builds understanding	3	3.130						
	Construct	**3**	**3.366**	0.661	0.366	29	3.036	0.002	0.681

Joint Productive Activity (Mutual Respect)	Regular group discussion	3	3.370						
	Topics have activities	3	4.070						
	Working together on Projects	3	3.790						
	Most activities involve groups	3	2.790						
	Engagement with others	3	2.900						
	Collaboration in and out of class	3	3.200						
Language and Literacy Development (Reflexive Attitude)	***Construct***	**3**	**3.116**	0.767	0.116	29	0.833	0.206	0.711
	Feedback level	3	2.930						
	Encouragement and Support	3	3.570						
	Guidance on writing	3	2.870						

Participants were prompted to answer a number of questions based upon the game-based experience they had just had. All constructs achieved above average results, with Complex Thinking (*Deep Learning*) and Joint Productive Activity (*Mutual Respect*) achieving significance (mean 3.583 and 3.366 with p values of *<0.001* and *0.002* respectively). In addition, both Contextualisation (*Deep Learning*) and Instructional Conversation (*Teacher and Learner Interdependence*) approach significance (mean values of 3.170 and 3.221 with p values *0.064* and *0.079* respectively). Consistency, assessed through the Cronbach Alpha test, was demonstrated in all constructs.

5.4.2.1 Complex Thinking

Participants rated Complex Thinking (*Deep Learning*) completed on the task significantly above average, (mean = 3.583, t = 4.744*, p < 0.001*). Participants felt later levels particularly required understanding of the topic areas and applying that knowledge.

> *S4: "You used the different gates to create the numbers, like when you looked on the floor there were different gates that lead to the wall, that highlighted different parts of the number, so you had to show your knowledge of the gates to highlight certain points of the whole… thing."*

5.4.2.2 Contextualisation

Responses on Contextualisation (*Deep Learning*) were marginally above the mid-point (mean = 3.170, t = 1.566, *p = 0.064*). Within the focus groups participants did not have specific comments to offer on this area. Results from individual questions showed participants reported feeling negatively about making connection between course material and their everyday lives (mean = 2.80) while all other questions individually were above the mid-point (means of 3.17, 3.27 and 3.50).

5.4.2.3 Instructional Conversation

Instructional Conversation (*Teacher and Learner Interdependence*) was narrowly positively received, with overall responses approaching significance (mean = 3.221, t = 1.450, *p = 0.079*). Comments revealed participants felt they were asked to take part in group discussion but that some of the technology used may have got in the way of this discussion.

S4: "We had to go back and forth talking and explaining…"

S2: "So first of all the microphone, the communication to the microphone was not very effective so we had to go to the chat system, and at one point had to get up and talk to them personally instead of the text or the voice."

5.4.2.4 Joint Productive Activity

This Joint Productive Activity (*Mutual Respect*) construct overall was rated positively by participants (mean = 3.366, t = 3.036, *p = 0.002*). Participants felt the group based nature of tasks was not always well communicated leading to difficulty in completing these tasks quickly, but acknowledged that the teamwork elements were present in the tasks.

S3: "I think the teamwork element could have worked well, but because it wasn't emphasised, because we worked individually at the first few tasks, and later on it wasn't emphasised that teamwork was necessary, so everyone rushed forwards as fast as they can and that kind-of detracted from it. But if it was emphasised more that at this point you need to start working together, it could be beneficial."

5.4.2.5 Language and Literacy Development

Participants rated the Language and Literacy Development (*Reflexive Approach to Teaching and Learning*) construct barely above the mid-point of 3.00 (mean = 3.116, t = 0.833, *p = 0.206*). Within this area particularly there was particular divergence between participants' perceptions of their support overall (mean = 3.57) and their support in writing tasks (mean = 2.87). Participants in the focus groups did not offer significant comment on this topic, but it may be necessary to review this item in future usage of this instrument.

5.4.3 Qualitative Analysis

From the qualitative analysis, five overarching themes were found that group the initial themes. These overarching themes are (1) Enhanced Learning, (2) Game Progression, (3) Task Focus, (4) Teamwork and (5) Independence. Figure 23 presents a thematic mind map showing the relationship between these and their respective subthemes. A single emergent theme was added, covering suggested improvements to the games design and layout, while the SCL tenet of Teacher and Learner Interdependence was eliminated as these aspects were not a focus of Experiment 1 and were not addressed in discussion.

Enhanced Learning. Participants reported that the game was a useful way to learn an initial topic, citing that the game was enjoyable and a more fun way to learn compared to traditional laboratory and learning activities.

"If it comes to fun, you're actually forgetting about the learning aspects and playing it for fun, unless there are less distractions in the application and such that you're using." (S1)

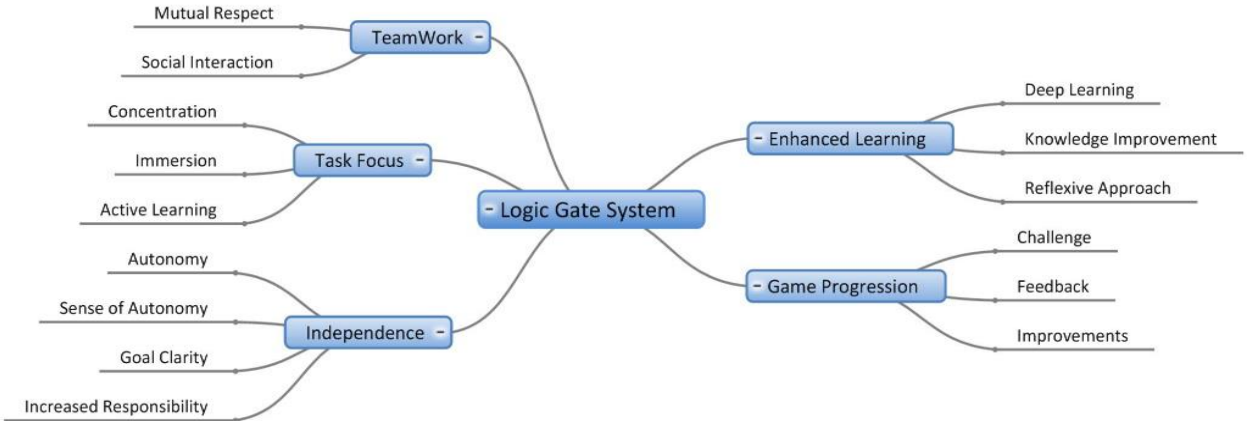


Figure 23: Thematic mind-map of themes and overarching themes.

Some participants expressed concerns over the early tasks simplicity, citing that it may be possible for students to solve early puzzles through trial and error rather than engaging with and understanding the concepts, however the later stages were seen to build upon earlier knowledge and require all participants to be taking part and to understand the task:

"At the end, cos there was a larger number of switches, that means it also required of the previous areas that everyone take part in it. But in some areas, especially the first teamwork area, there's more trial and error as you can just press any number of switches and see if it works." (S3)

Participants expressed some concern over the use of the LogicGate System beyond an initial learning experience, citing the time taken to get a full experience, alongside the ease of traditionally looking up an individual difficult concept. Participants felt that the use as an ongoing revision too may be challenging but could be possible with future refinements:

"With books and online resources being widely available in the library and such, unless the game is as fast as it can be, as efficient as it can be and gives you personalised results as well, like in writing…" (S1)

Participants appreciated being able to look back at earlier tasks, and a common request was for this feature to be expanded further making return to earlier puzzles easier to allow participants to learn from earlier successes and failures by both themselves and their teammates, adapting their approach to new tasks accordingly and demonstrating a reflexive approach to learning:

"What also could have been better is that for each individual to get themselves back and to learn the puzzle again, which teaches the individual

the commands as well, that being their statements for OR, XOR and NOT and such." (S1)

Game Progression. Participants expressed that the level of challenge was acceptable, with later tasks requiring deeper understanding. Some participants felt the topic area presented appeared to be a simple one however others expressed that they had not been able to complete all the tasks in the time allotted. Among all participants there was a sense that the challenges posed were fair and that they were within participants reach to complete:

"The puzzles weren't that difficult, like they were easy to understand, and even for the stuff that seemed more difficult you had added in the books, so in the inventory you could read and get a better understanding." (S4)

"And in the case that some of us were able to complete the final level it does prove that a select amount of people who are able to work together will be able to figure out…" (S1)

Feedback provided on in-game actions was perceived as good, participants expressed that the visual demonstrations of when signals were applied were easy to read and understand:

"Everything was indicated well, with… with the glass floor indicating what components we needed to activate in the game, the way the leads showed what was lit up." (S2)

Participants identified some errors in design, with puzzles allowing one group member to proceed ahead of others and be unable to return to aid their peers:

"A problem for me was that I tried to get through the door and into the next room and it locks behind you. However the problem for me was that it was already locked and I couldn't get in. So I needed someone else to come and let me in." (S2)

Task Focus. Participants expressed mixed views on the ability to concentrate within the game, some participants felt that the enforced waiting times while other students were taking actions caused them to lose focus while others felt that the game was enjoyable enough to hold their attention:

"The third member of our group didn't know how to play, so we… we had gotten through the tutorial part learning the and gate, the or gate and stuff, then we had to wait quite a long time for them to figure out the controls." (S3)

“I’d be invested in similar thing, like games to help learn as it seems like it could be fun. If you’re able to enjoy yourself more and learn more enjoyable skills it feels like you’d be able to stick with things better. I’d love to learn more skills, to give it another go, or a different game.” (S2)

There was a common feeling among participants that the audio caused problems, with participants not being able to use the voice communication aspect properly leading to some participants wanting to leave their seats to try to communicate more effectively:

“So first of all the microphone, the communication to the microphone was not very effective so we had to go to the chat system, and at one point had to get up and talk to them personally instead of the text or the voice.” (S2)

Teamwork. Participants felt there was a definite teamwork basis to the task and that it enhanced their learning experience:

“I think a group activity is definitely better, because if you are having trouble someone else in your group may be able to help explain it to you and help you progress, whereas if it’s an individual task you might be stuck until you have to do something else like look it up, whereas group activities like you all know you can be better at different aspects of whatever you’re doing so working together would be beneficial.” (S3)

Participants had mixed opinions on the execution of the teamwork task, with some feeling that the LogicGate System needed to emphasise the nature of the teamwork required earlier to better ensure participants were prepared for this aspect of the experience:

“I think the teamwork element could have worked well, but because it wasn’t emphasised, because we worked individually at the first few tasks, and later on it wasn’t emphasised that teamwork was necessary, so everyone rushed forwards as fast as they can and that kind-of detracted from it.” (S3)

Participants during the tasks were able to demonstrate mutual respect, building upon each other’s understanding and working together to solve these tasks:

“<BrunelCraft17> right click the two swictches on the side

<BrunelCraft10> ive only got one on the left

<BrunelCraft12> I ONLT GOT ONE ON RIGHT

<BrunelCraft12> AND NOTHING ON THE LEFT

<BrunelCraft10> okay should we try press at the same time?" Excerpt from game conversation, (S10, S12, S17)

Independence. Participants felt they were able to learn to move freely within the game world with ease, however the speed at which other members of their groups were able to reach the same point affected participants own ability to act freely:

"I thankfully was able to get started with ease, the only difficulty I had was with the people I was with, with them trying to, you know, understand where to go in terms of the game when they first entered in. It took them a good 5 minutes for them to realise what to do to start the game, and that was with talking to them over the local area voice chat." (S1)

Participants felt they were able to understand the tasks asked of them through the automated in-game instructions:

"<BrunelCraft22> you guys know what we're trying to do right?

<BrunelCraft26> yh the numbers

<BrunelCraft13> I can't even see what we have to do

[CS0001] Welcome to the final challenge - Use what you have learned to get the display to read "283"!

<BrunelCraft26> oh 283" (S13, S22, S26)

Participants however felt strongly that not enough emphasis was placed upon the teamwork based goals and that they had limited ability to help others to understand this aspect or deal with situations where team-members were not working together:

"Personally I felt it would be better if it were an open teamwork, not a sectioned off teamwork experience. In the fact we were separated off in each room to discover the statement that would then have to access each and everyone's individual gate. Instead I felt like it would have been better if all of us had to work together" (S1)

5.5 Discussion

This study deployed the LogicGate System, a Student Centred Digital Game-Based Learning experience designed to deliver all aspects of Student Centred Learning, in a genuine classroom setting. A total of 30 foundation year students used the LogicGate System as a part

of their regular scheduled laboratory sessions on a module at Brunel University, following a typical introduction to the games subject matter through traditional lecture. Study findings will be discussed with reference to the original research questions outlined at the start of this chapter.

E1RQ1 aimed to establish the extent to which the first iteration of the LogicGate System was able to deliver all tenets of SCL. This was primarily determined by evaluating the student perception of teaching and learning and their user experience when engaging with the LogicGate System, through responses to the Course Experience Survey and eGameFlow, which have been linked to the SCL tenets throughout this work, augmented by findings from the qualitative component of the study.

The analysis of the quantitative questionnaire data from the Course Experience Survey indicated that students rated all aspects of the SCDGBL experience above average. Students rated the promotion and integration of the Complex Thinking (*Deep Learning*) construct significantly above average, indicating that the system can be said to push creative thinking and problem solving abilities within students taking part. Students further rated the Joint Productive Activity (*Mutual Respect*) construct significantly above the midpoint, indicating that use of the LogicGate System successfully stimulated cooperative teamwork within students taking part and that this was positively received by students. The above results were augmented by qualitative data from the focus group and free text responses as well as voice and text logs. This highlighted further areas where the system was successful as well as areas for future development, discussed further in Section 5.3.

Findings from the eGameFlow questionnaire suggested that on the whole, students felt the game was successful in a majority of areas linked to SCL tenets, scoring above average in the areas of Concentration (*Active Learning*), Goal Clarity (*Increased Responsibility and Accountability*), Challenge (*Active Learning*), Autonomy (*Sense of Autonomy, Increased Responsibility and Accountability*), Social Interaction (*Mutual Respect*) and Knowledge Improvement (*Active Learning*). Of these, the Concentration (*Active Learning*) construct proved significant which demonstrated students found the game able to draw and hold their attention for a long period of time while playing. Autonomy (*Sense of Autonomy*) scored significantly above average, indicating that even in a system that heavily emphasised teamwork, participants felt they were given a sufficient degree of control over the LogicGate System and their movements and actions within it, as well as the way in which they could approach and solve in-game tasks.

Social interaction (*Mutual Respect*), scored particularly highly; this indicates a strength in promoting social interaction and a belief by students that the role of peers within the game had

a positive effect on their own skill and learning. Knowledge Improvement (*Active Learning*) was also significantly above the mid-point, showing that students felt able to effectively learn from the LogicGate System and that the game content was well linked with the learning intentions and outcomes. The areas of Feedback (*Reflexive Approach to Teaching and Learning*) and Immersion showed a below average score that was approaching significance. Although the survey findings do not evidence a well-rated implementation of the tenet of *Reflexive Approach to Teaching and Learning* due to the lower rating of the Feedback area within eGameFlow by students, it is present as a theme within the qualitative data. Students expressed that the ability to return to earlier puzzles to explore and learn from their attempts on these was not as robust as desired, showing an appreciation for a *Reflexive Approach to Teaching and Learning* that may be built upon in future.

Overall, the LogicGate System was able to demonstrate the successful inclusion of six of the seven SCL tenets. It was not possible to utilise the embedded support for the seventh tenet (*Teacher and Learner Interdependence*) within the LogicGate System for evaluation in this trial, due to pragmatic considerations necessitating the researcher taking on the role of the facilitator for the SCDGBL experience. This is an area for future work. Showing promise is the focused social aspects of SCL, with demonstrated success in particular in developing students' *Mutual Respect* along with the advanced peer-based aspects of *Active Learning*. Students were able to engage with the puzzles presented being given scope to act both Independently within their own areas, demonstrating a *Sense of Autonomy* and fulfilling a needed role within their teams, showing *Increased Responsibility and Accountability*.

E1RQ2 focused on whether the LogicGate System provided an engaging vehicle by which to learn the taught concepts. This was based on student answers to eGameFlow, supported by qualitative data obtained from the focus groups. Ratings significantly above midpoint for the Concentration (*Active Learning*), Social Interaction (*Mutual Respect*) and Knowledge Improvement (*Active Learning*) areas of eGameFlow indicate that the LogicGate System is perceived by students to hold promise as an effective teaching tool, promoting both academic and social aspects of learning. This was supported by themes of Enhanced Learning, Team Work and Task Focus identified within the qualitative data, which indicated that the LogicGate System was able to hold student attention and improved their knowledge, with the social aspects enhancing their overall learning experience. However, some of these aspects can be improved further, as addressed in Section 5.1.

E1RQ3 explored student receptivity to learning through SCDGBL experiences. This was directly addressed in the focus group topic guide and as such the findings are based upon themes from the qualitative data collected from these focus groups. Within the Team Work

theme, students identified the teamwork basis to the task enhanced their learning experience. Further to this, the Enhanced Learning theme and associated subthemes indicated that students felt the LogicGate System was an effective way to learn the topic, delivering basic knowledge with tasks that enabled students to develop and demonstrate mastery of the concepts. Students felt it required them to consider and analyse the concepts expressed in order to solve the presented problems. This helps to explain the overall finding that students showed interest in using this or similar systems in the future to develop their understanding of other topics, indicating that they are indeed receptive to learning through SCDGBL experiences. The thematic analysis showed that there were some areas for improvement to the LogicGate System, and these themes can be integrated with findings from both the Course Experience Survey and the eGameFlow questionnaire to identify priority areas for future revisions of the LogicGate System. Having answered the research questions, this integration of qualitative and quantitative findings will now be discussed, to identify implications of the research and recommendations for future practice.

5.5.1 Identifying implications and recommendations for future practice

Qualitative data provided additional depth to student responses to the eGameFlow questionnaire and Course Experience Survey. Quantitative and qualitative findings from the analysis were integrated to identify pragmatic areas of focus for future work: The deployment in routine practice of the LogicGate System, and directions for future development of the LogicGate System to improve design and functionality. This integration is summarised in Table 12, which demonstrates, for each area of focus, the key findings from the qualitative and quantitative analysis, and the qualitative themes or survey constructs they originate from. These are subsequently discussed through the lens of the student user experience, to identify whether the LogicGate System has successfully achieved its design intention of incorporating all tenets of SCL, including the social aspects that are the primary emphasis of this SCDGBL offering. Following this, planned improvements to the LogicGate System based on these integrated findings will be discussed.

5.5.1.1 Implications and Recommendations for Deployment in Practice

This focus area can be viewed through themes focusing on student user experience and implementation of the SCL tenets. Students reported that the LogicGate System was an effective way to learn the topic and could explain to others how this learning was related to the puzzles (Knowledge Improvement through *Active Learning*), delivering basic knowledge with tasks that enabled students to develop and demonstrate mastery of the concepts. Students showed interest in using this or similar games in the future to develop their understanding of other topics, showing it was considered an effective way to learn (*Reflexive Approach to Teaching and Learning*). Students felt it required them to consider, analyse and

synthesise the concepts expressed in order to solve the presented problems, and that the integration of learning to experiences outside the course was highlighted to them (Contextualisation and Complex Thinking facilitate *Deep Learning*).

The LogicGate System was perceived as easy to use, with students believing the level of difficulty in the game was appropriate for their level (Challenge enhances *Active Learning*). Students in discussion expressed orientation times for new players of up to a few minutes (Challenge). Students expressed that they were overall aware of their intended goals from the start however there may be scope for improvement in this area (Goal Clarity sets expectations for *Increased Responsibility and Accountability*).

Students expressed that the LogicGate System expected them to work together with others (Joint Productive Activity engenders *Mutual Respect*) and that this co-cooperation was facilitated and supported through the game (Social Interaction develops *Mutual Respect*).

Table 12: Key findings for each area of focus

Area of Focus	Finding	Themes/Constructs	Linked SCL Tenets
Implications and Recommendations for Deployment in Practice	Valuable way to build initial understanding of a topic.	Knowledge Improvement, Reflexive Approach, Complex Thinking	*Active Learning (AL)* *Reflexive Approach to Teaching and Learning (RA)* *Deep Learning (DL)*
	Easy to use game with understandable controls	Challenge, Goal Clarity	*Active Learning (AL)* *Increased Responsibility and Accountability (IR)*
	System encourages positive engagement through the social aspects of Student Centred Learning	Mutual Respect, Social Interaction, Joint Productive Activity	*Mutual Respect (MR)* *Active Learning (AL)*
	Embeds learning deeply into the mechanics of the game world	Deep Learning and Understanding, Knowledge Improvement, Contextualisation, Complex Thinking	*Deep Learning (DL)* *Active Learning (AL)*
	Clear visual design ensuring students are aware of what is happening.	Feedback, Challenge	*Reflexive Approach to Teaching and Learning (RA)* *Active Learning (AL)*
	Ensure students feel they are independently responsible and capable.	Autonomy, Increased Responsibility and Accountability, Sense of Autonomy	*Sense of Autonomy (SA)* *Increased Responsibility and Accountability (IR)*
	Practicality for repeated use.	Reflexive Approach, Knowledge Improvement.	*Reflexive Approach to Teaching and Learning (RA)* *Active Learning (AL)*
Design and Functionality Recommendations	Provide improved orientation description to prepare students for the team-based work.	Feedback, Joint Productive Activity	*Reflexive Approach to Teaching and Learning (RA)* *Mutual Respect (MR)* *Active Learning (AL)*
	Provide a score-system to ensure students are aware of their progress.	Feedback	*Reflexive Approach to Teaching and Learning (RA)*
	Clearer checkpoints to ensure students remain working together and do not separate	Improvements	-
	Further refine communication system to ensure it is appropriate and reliable for all students.	Challenge, Joint Productive Activity, Social Interaction	*Active Learning (AL)* *Mutual Respect (MR)*
	Integrate teachers and demonstrators into the game world	Instructional Conversation	*Teacher and Learner Interdependence (ID)* *Reflexive Approach to Teaching and Learning (RA)*
	Develop a narrative to draw students into their role in the game world.	Immersion	-

Students showed through discussions in and outside of game a sense of responsibility to their team, students were aware of and responded to the need to support their team and communications showed active attempts by students to help others and to improve themselves (Goal Clarity and Autonomy promote *Increased Responsibility and Accountability*). There was a feeling that this aspect of the LogicGate System did enhance students' abilities to complete the game and their understanding of the topic area by promoting positive engagement. Students showed a reliance on others and an ability to turn to and discuss help with other members of their group, and an understanding that their strengths may overlap or differ from those of other group members in different ways, allowing group members to support one another (Joint Productive Activity supports peer-assisted learning processes in *Active Learning*). This demonstrates that the social interactions within the LogicGate System are integral to enhancing the student user experience.

Students were satisfied with their sense of control over the game and the application of strategies (*Sense of Autonomy*). When discussing the potential for reuse of the application for revision purposes, students were unsure as to the teamwork aspect and start-up time and felt that the gentle initial approach may lead to too much time investment compared to revising from more traditional sources (Knowledge Improvement), students expressed a desire to use an application for this purpose but were not convinced about the utility of LogicGate in its current form for this purpose.

5.5.1.2 Design and Functionality Recommendations

This focus area indicates ways in which the LogicGate System may be further developed and refined to better meet the needs of students and provide a more robust Student Centred Digital Game-Based Learning experience. Students felt that the initial orientation area and early puzzles did not provide enough emphasis on the teamwork aspect of the game (Joint Productive Activity), nor did they explain the nature of the teamwork (Feedback) expected in a way that fully prepared students for the group tasks which form the majority of the games content. Solutions suggested to this include a longer orientation area and an (in-game) verbal explanation of the nature of the task.

Students did not feel they were fully aware of their progress within the game, highlighting the lack of a scoring system and uncertainty over when a task was completed and the team could progress (Feedback). Students suggested recurring aspects from the tutorial which involved all members of the team performing the same action at the same time (Improvements) to emphasise that this was a completing activity and they were now able to progress. The addition of a scoring system was highlighted as a potential improvement that would allow students to assess performance numerically and if they desired to compare to other teams.

Scoring systems and progress measures are common features of SCDGBL games, particularly where they are built upon existing games with embedded metrics for game progression (Lin and Lin, 2014, King, 2015). This was not included within the LogicGate System due to it being a cooperative game, and the introduction of individual scores would have produced an unwanted competitive element between players. Further, the use of scoreboards has been evidenced to be damaging to learning experiences in certain situations (Christy and Fox, 2014, Deci et al., 2001). However, this did not take into account the expectations the students had regarding receiving feedback and being able to view performance metrics as part of their learning experience. Traditional teaching techniques integrate such performance metrics as a core aspect, leading students to place a high degree of importance in this being present within a digital learning environment (Bowen et al., 2014).

Students struggled in some instances to lose awareness of aspects outside the game (Immersion), which may be a result of the laboratory environment, there were also indications that emotional involvement was not high, which may be due to the game's lack of a story or other roleplay aspects to help draw participants further into their activities in the game beyond the expectations of their course and team.

Few SCDGBL offerings have included a dedicated narrative (Shafie and Ahmad, 2010, Bowen et al., 2014), and evaluation of the impact of having one is limited in these papers. The existence of a narrative can increase involvement or connection to game content (Bowen et al., 2014), but it can also have unintended effects upon the player's expectations of the game and their interactions with it (Dickey, 2011). Further to this, such games have focused on single player experiences, and another consideration is the challenge posed by the creation of a narrative that a group could engage with on such a level. However, balancing a well-constructed narrative with integrative gameplay could be achieved with future versions of the LogicGate System.

The voice communication system was found to be unreliable by some students, with difficulties in setting this up leading to delays in getting started (Challenge) and to potential frustration while waiting for other students to get set up (Social Interaction). Some students chose to use the text-based chat which was found to be functional and useful for working together (Joint Productive Activity). Solutions suggested include an improved voice system, the use of text chat or moving students to sit near teammates and thereby allowing in-person discussion. With teamwork a significant focus of the LogicGate System this area will be important to iterate upon and improve to provide as few boundaries to peer engagement as possible. The integration of a narrative aspect to the LogicGate System arises from student feedback on emotional involvement within the game (immersion), drawing students further into a role within

the game through a story is a strong candidate method for increasing their emotional involvement in completing the game (Ryan, 2009).

5.5.2 Limitations of current study

This was an exploratory study to establish the feasibility of deploying the LogicGate System within a standard lab environment. While successful, a number of logistical considerations were encountered, such as needing to split the gameplay session from the focus groups due to lab session timetabling and student availability. This primarily impacted the study due to fewer students attending the focus group session, thus only one session could be conducted which limited the richness of the qualitative data gathered. Having a gap between the gameplay experience and focus groups can reduce the immediacy of the gameplay experience and allow it to be tempered by discussion with peers. As such some lesser feedback points may have been missed and instead a more general sense of the gameplay experience may have been gained from the focus group data. In future studies, a longer data collection session would allow focus groups to be conducted more rapidly following students' experiences and the completion of more focus groups to provide further qualitative data. The communication system will be redesigned to allow students to get set up more quickly while improved tutorials will be produced to smooth this setup process. The application will be redeveloped to improve on some points, ensuring game flow is clearer and students concerns expressed through this work are met.

No validated instruments existed for explicit measurement of successful implementation of SCL tenets within an educational game that seeks to create a SCDGBL experience. For this reason it was necessary to utilise the Course Experience Survey which exhibits significant overlap with SCL tenets due to shared theoretical roots (Lea et al., 2003, Dalton, 1998). Cronbach's alpha values for both surveys indicated good levels of consistency within constructs overall. However, some considerations arose from the use of these surveys to achieve the research aims. For the Course Experience Survey, some students found it difficult to answer questions that appear intended for module evaluation rather than a specific learning experience within a module, finding them too general. This was mitigated by instructing students to answer all questions as if they related to the learning experience they'd just engaged in. For future usage of the Course Experience Survey in the evaluation of SCDGBL experiences, some explanation from the researcher to support the approach to these questions may be necessary. This may potentially improve the consistency of some constructs such as Contextualisation (*Deep Learning*), which had a lower Cronbach Alpha score potentially driven by a difference in perception between connections the students were asked to make to their everyday lives, versus connections the instructor highlighted.

During analysis, it proved difficult to draw targeted improvement points for the LogicGate System from the eGameFlow questionnaire without the supporting qualitative data. While questions spoke well to their constructs, which in turn addressed many common issues e.g. immersion, individual game experiences that students may encounter, both good and bad, are not brought out. For example, reduced immersion scores may be difficult to attribute to whether the student was immersed in the first place, or to a particular point in the game where immersion had been broken. This emphasises the utility of a mixed methods approach to address such limitations when using this evaluation tool.

Some pacing issues were also identified during data collection, attributed to the use of the revised eGameFlow questionnaire (Chen et al., 2018) for the bulk of the instrument and then following on with the Educational construct from the original eGameFlow questionnaire (Fu et al., 2009), as this had not been updated as part of the revision process (Chen et al., 2018). The revised questions were tighter and more focused by contrast to those in the original questionnaire, leading to a marked disparity in the number and relevancy of the questions between the Educational construct and the rest of the instrument as used within this study. However, all participants completed this one-off questionnaire, and there were no obvious indicators of survey fatigue such as satisficing, as negative questions where the Likert scale was flipped were answered appropriately (Krosnick, 1991).

Lastly, this was not a comparative study in its aims, and therefore a control group was not included within the study design. However, having established the viability and acceptability of the LogicGate System within a live teaching environment, the next step is to demonstrate that it is at a minimum comparable to traditional teaching techniques for the effective delivery of the selected learning concepts.

5.6 Conclusion

This study investigated the deployment of LogicGate, a Student Centred Digital Game-Based Learning experience designed using the Student Centred Experience framework. The study deployed the LogicGate System in a genuine classroom environment and assessed its ability to deliver a comprehensive student centred experience. Overall students were positive about a majority of aspects of the application, believing the LogicGate System was engaging and effectively delivered the content students sought to learn. In answer to the research questions **E1RQ1:** In its current form the LogicGate System is able to deliver on a majority of aspects of SCL as assessed through the surveys, the tenets of Interdependence and Reflexive Approach form particular areas for development which may be addressed through tighter teacher integration. To answer **E1RQ2:** Students felt the learning was delivered in an effective and engaging manner, a majority were able to complete all puzzles, demonstrating an

understanding of the subject matter through the game elements. Results for the construct of Immersion demonstrates an area for further development, where additional revisions should look towards maintaining students focus on the game. For **E1RQ3:** Students were positive about exploring the use of video games as learning tools in future, including greater emphasis on the team-based nature of an SCDGBL intervention. As part of the Design Science Research process, further work on the LogicGate System is needed before the next deployment, which can establish if improvements intended to address the shortcomings in Feedback and Immersion yield greater effects. For the Student Centred Experience framework, it is clear from the current study that social interaction comprised an important part of the enhanced learning experience for students using the LogicGate System, this aspect was not explicitly represented which may form an area for improvement within the framework. In addition, this initial study can now inform the design of further studies which may directly compare between methods of learning to establish a comparative benchmark for the LogicGate System.

Chapter 6. Experiment 2

6.1 Introduction

Based on the literature review conducted in Chapter 2, a need was established for research into a comprehensive deployment of Student Centred Learning concepts. Chapter 4 then describes the design of the Student Centred Experience (SCE) model for educational game design, which is utilised in Chapter 5 for the design of the LogicGate System, along with its deployment in a live classroom environment. The practice of Design Science Research sets out both a process and a need for multiple iterations of the design, demonstration and evaluation stage (Peffers et al., 2007, Hevner, 2007). Following on from the initial testing detailed in Chapter 5, a number of aspects of the LogicGate System were identified for improvement and revision in a second iteration, drawn from the quantitative survey data and the qualitative focus group process with students who had participated in Experiment 1.

The issues in the LogicGate System identified by participants included: A weaker introduction to the teamwork aspect of the game in the early stages of playing, which led participants to feel they were not fully prepared for the reliance upon team mates in later stages. It is anticipated that solving this issue would lead students to work together more easily, easing pain points in early teamwork exercises while developing further the group-work focused sections of Student Centred Learning (Bishop and Verleger, 2013). Participants did not feel they were sufficiently aware of their progress through the game, highlighting issues with identifying where a task was completed and knowing how far they were through the game. Solving this issue is anticipated to increase engagement by allowing students to see their progress towards their goal and through reducing opportunities for frustration that might lead to breaks in immersion and concentration. Difficulties remaining immersed in the game were highlighted as a concern, particularly as regards the environment and emotional involvement. Solving this should provide more encouragement to students to complete the game and potentially encourage deeper engagement and learning. The voice communication system had some issues, with this unreliability preventing participants communicating effectively and presenting an issue in affecting students' concentration on the task and teamwork. Solving this issue is anticipated to ease cooperation, particularly as students get started within the game world and as teams get used to working together.

This chapter is structured as follows: Section 6.2 presents the redesign of the LogicGate System, named LogicGate-R, taking into account the user feedback gathered. This section includes a walkthrough of the changes made along with explanations of the design process to bring about these changes, to solve the issues highlighted above. Section 6.3 details the methods used to evaluate the LogicGate-R System, leading to Section 6.4 which presents the

results from this evaluation. Section 6.5 then provides a discussion of the results in context. Finally Section 6.6 offers a summary of the chapter and conclusory comments.

6.2 Redesigning the LogicGate System

LogicGate-R takes into account issues highlighted during the previous design, demonstration and evaluation cycle, including: (1) The need for greater levels of immersion during the experience. (2) A need for more feedback on student performance and goals. (3) A more well-paced experience that eases pain points in group-work.

6.2.1 Refining the Student Centred Experience framework

The initial version of the LogicGate System was developed utilising the Student Centred Experience (SCE) framework. As the process of Design Science stresses the need to revise an artefact through multiple iterations, so the process of Design Thinking encourages revision and improvement of a problem solving approach. With this in mind it is important to revisit the SCE framework and identify not just shortcomings in the implementation of the framework but also areas the framework did not cover, and improvements to these areas. Having implemented a game developed utilising the SCE framework in Chapter 5, one observed absence was the representation within the framework of social engagement. Qualitative data from Experiment 1, performed in Chapter 5, indicated that the students felt the social elements of the LogicGate System enhanced their learning. The MDA framework, upon which the SCE framework is based, includes an aesthetic dimension of Fellowship, described as fun gained from the use of the game as a social framework, which relates closely to this theme. This dimension was not explored within the original version of the SCE framework and has been explored and integrated into a revised framework, to identify areas where implementation of a principle offers opportunities to build this into the experience (Hunicke et al., 2004). Figure 24 presents the revised SCE framework including the added dimension of Fellowship.

Within the principle of *Skills as Strategies*, Fellowship arises as students have the possibility to employ social skills as a part of progression. Students taking on leadership or other roles are able to put these skills into practice to help their team advance while students who do not take on these leadership roles are able to respond and work with others to contribute to the progression.

Co-Design promotes Fellowship as players decisions may be reflected and viewable by other players. This offered greater recognition of player decisions as players can see not just the effects of their own actions but also those of others. It offers the opportunity to have a collective effect on the world and thus build a shared experience.

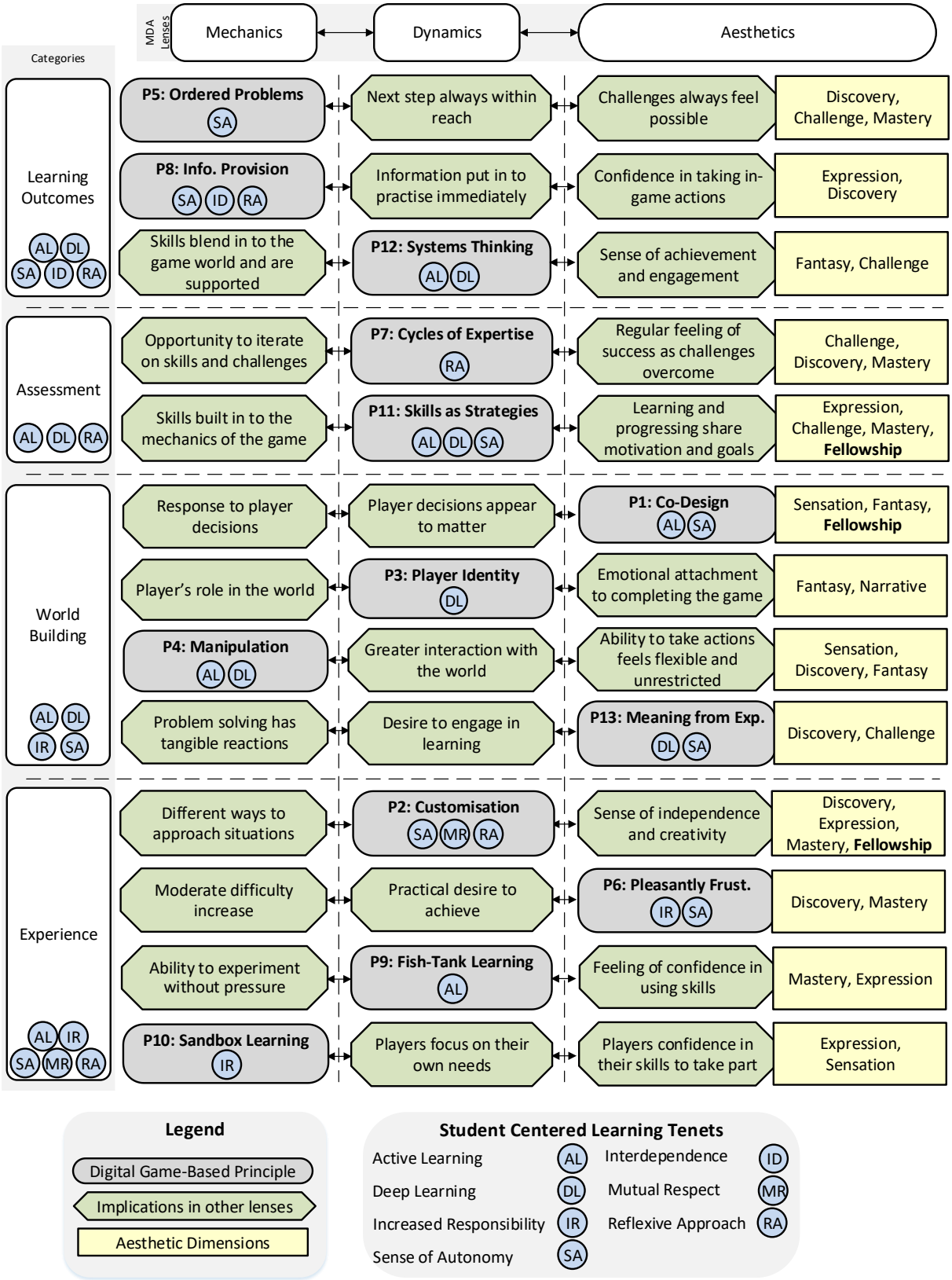


Figure 24: The Revised Student Centred Experience framework including the dimension of Fellowship

Customisation may give rise to the aesthetic dimension of Fellowship as students are able to discuss and share approaches to solving in-game problems. The social aspect also adds to

the number of approaches and strategies available to a player, opening up strategies using multiple players to achieve a goal.

This additional dimension, drawn from the original MDA framework, recognises the opportunities to incorporate social engagement within a game to the benefit of student learning (as found in Chapter 5), and highlights where this may have beneficial effects within the design of a game (Hunicke et al., 2004).

6.2.2 Design Focuses

The LogicGate-R System offers a number of major improvements based upon qualitative feedback and quantitative survey data from the initial study. A number of issues were identified with the previous version, where the LogicGate-R System could provide improvements. These issues and improvements, as well as related SCL tenets these improvements may impact upon, are shown in Table 13.

Table 13: Issues in the original LogicGate System and Improvements made in the LogicGate-R System

Issue	**Improvement**	**SCL Tenets**
Noisy Environment	Increased use of communication tools.	*Mutual Respect*
Lack of Emotional Involvement	Integration of storyline to provide additional reasons for engagement.	*Deep Learning* *Increased Responsibility and Accountability*
Concentration Easily Broken	Increased Voice Over IP reliability. Group-work improvements to clarity.	*Teacher and Learner Interdependence* *Mutual Respect*
Insufficient Feedback on Performance	Introduction of a time-based score.	*Active Learning* *Reflexive Approach to Teaching and Learning*
Difficulties Tracking Goals	Voice track providing goal information. Clearer sound and visual elements.	*Sense of Autonomy* *Active Learning*
Clarity of Teamwork Focus	Improved initial messaging. Signposting of group work elements.	*Mutual Respect* *Sense of Autonomy*
Group Members not Remaining in Parallel	Staging areas to provide clarity on when to progress and ensure all students are ready.	*Increased Responsibility and Accountability* *Mutual Respect*

For each of these issues the SCE framework was used to guide the redevelopment of the LogicGate-R System. Each issue identified was examined and its relationship to SCDGBL was explored, this led to understanding of the aesthetic dimensions and implications, and enabled the redevelopment to focus on these areas. Each of the three key issues and areas of improvement are presented below, including the problems and solutions.

6.2.2.1 Levels of Immersion

Students reported through the initial study that their immersion was affected by several factors, these included: A noisy laboratory environment which made concentration and losing track of

surroundings more difficult. The lack of a story was brought up through the data collected in surveys, which impacts on the emotional involvement in the game. Finally the Voice Over IP communication system had some initial issues, which led to students having difficulty settling into play, as they could not effectively talk to their team mates. These three issues formed the core of the improvements in immersion.

The laboratory environment formed the first challenge and a number of solutions were envisaged to help students maintain focus on the game process. A technological solution presented itself in the use of noise cancelling headphones to block out or reduce the noise from outside sources. This offered a potential solution but utilises technology which may put the cost outside the reach of a number of institutions, limiting the practical applicability of the research. Utilising a different environment was examined as a potential solution, as a significantly smaller room and number of people would offer a generally reduced noise level. This solution was not undertaken as reducing participation too much would damage the fidelity of the simulated classroom environment, laboratory sessions typically being run in labs. Increased use of the communication tools was chosen as the solution, ensuring participants were performing both the traditional and SCDGBL task using the voice communication system would help participants communicate clearly and without having to raise voices, reducing overall noise while ensuring the simulated laboratory environment was maintained for all participants.

To combat a lack of immersion and emotional involvement within students, a greater ongoing storyline was introduced to the game. Other possible solutions that add emotional involvement include adding real-world relevant elements to the individual participants to offer linked emotional involvement. This was not chosen as the breadth of participants' backgrounds makes such elements challenging to create in a way that would engage all students (Stuckey et al., 2013). This story was designed to provide an additional focus for students, providing emotional reasons for achieving the goals of the game and so driving students to maintain concentration and complete the experience (Wolf, 2014, Wouters et al., 2009). The storyline chosen related to the topic area, casting students as a team from the future being sent back into Charles Babbage's Difference Engine to fix sabotage and ensure his demonstration is a success, thereby safeguarding the history of computing. The storyline was presented through recorded messages, put to students as communications from their mission control in the future. These messages served a double function presenting not just the storyline but also an additional tutorial and explanation through which students can learn to understand the game world (Gee, 2005). The messages were embedded within in-game objects, which further helped maintain immersion as students were given reasons why the messages were playing and offered triggers by which they could set or re-set them off.

Further to this the voice over IP setup was improved, ensuring students had an easier time engaging in group communication and reducing opportunities for students to lose concentration due to external noise in the laboratory (Kiili, 2005). Improvements to the group work section also served to reduce opportunities for students to become bored if they are unable to understand how to progress, thereby increasing continued engagement and immersion (Kiili et al., 2012).

Maintaining engagement was considered to be an important element of the game's design, as it impacts upon a number of SCL tenets including *Deep Learning* and *Active Learning*, and forms an important part of the DGBL principles (Gee, 2005). Therefore, a number of other design choices in following focuses were made with reflection upon this need.

6.2.2.2 Feedback on Student Performance

Participants in the first study indicated the feedback available on student performance was not satisfactory. Students did not understand how well they were performing, potentially due to the lack of a scoring system. Students also did not feel the LogicGate System made good use of the immediate feedback on actions, which may have led to students not seeing the results of their in-game actions.

To allow students to see how they were progressing a time-based score component was introduced. This is a whole group score, not individually associated with any student, and was not presented on a leader board but was used for the group to judge their performance. This allows students to judge their progress in the game as they were offered sample scores to achieve and compare against, while not placing their measurement of success on a competition between students which may take away from the collaborative nature of the game (Plass et al., 2013). The decision to develop the score this way was taken to address some of the issues associated with including an individual in-game score which can have detrimental effects on some students' motivation and dampen excitement to engage (Hanus and Fox, 2015). Overall, the intent of this score is to meet student expectations of being able to view some kind of performance metric, while also avoiding introduction of a within-group competitive element which may work against the collaborative elements of the game (Hanus and Fox, 2015).

To address other concerns, prompts such as sounds and visual elements were made clearer, making the volume on relevant sounds, such as doors opening, louder to allow students to more easily identify that something important has changed in the world as a result of their actions.

Additional messages, both written and spoken let students know where they were in their progress towards the stories overall goal and reinforced the goal students were seeking to

achieve. The use of in-game messages here ties into the immersion points in section 2.2.1 while also offering the game a consistent look and feel when messages are all received through the same channel and in the same style.

6.2.2.3 Group-work and Pacing

Participants had felt that the nature of the original LogicGate System as a teamwork focused task was not made clear sufficiently early within the session. Participants also noted through focus groups that they were not sure when they should be progressing and when they needed to wait for and assist others within their group, leading to feelings of frustration where students felt they should be progressing but were unable to do so, as progress required their team mates to catch up.

At the beginning of the game, in keeping with the voice prompts used for storyline and progress tracking, the first recorded message was created to make clear the importance of teamwork to the task undertaken. Keeping this in the game and delivering the information on teamwork alongside that of how to play was intended to present the collaborative aspect as a fundamental part of the game. To enhance group work, additional 'staging' sections were included, requiring students to get all three group members together to proceed. These staging sections allowed students to see clearly when they had progressed to the end of a string of puzzles, and who of their group was also ready to proceed. This allowed groups to see who they needed to help and therefore to know if they needed to return to guide them. The intention of this change is to avoid the "rat race" mentality reported by some participants during the initial trial in Chapter 5, creating natural breaking points where the students may feel encouraged to pause and support their team mates if they have not yet made it to the space. Improvements made to the voice communications system would also affect this area, allowing easier communication between group members. The improved Voice Over IP was selected over moving participants to sit next to one another as a further aid to maintaining concentration, and to maintain students' sense of autonomy, as there are more significant barriers to another member of their group completing the task for them using their keyboard and mouse. These reasons remain unchanged from Chapter 5 but were re-examined in the context of communication issues. Text chat was made available as a backup or additional communication possibility and would in future be available for any students suffering hearing related issues.

6.2.3 Game Map and Walkthrough

This section presents a map of the game world, Figure 25, highlighting significant features within the LogicGate-R System. Participants begin in the upper section (Sandbox Learning Area) and proceed from top to bottom, encountering challenges along the way.

Sandbox Learning Area
P1: Co Design, P3: Player Identity, P10: Sandbox Learning
Provides an opportunity to get comfortable with the game controls and world.

Individual Tutorial Tasks
P4: Manipulation, P5: Ordered Problems, P8 Information Provision
Completed to ensure players understand basic concepts. Time based scoring starts while students can call upon others in the group to help via voice communications.

Initial Group Task
P2: Customisation, P4: Manipulation
Students must work together to help all group members progress

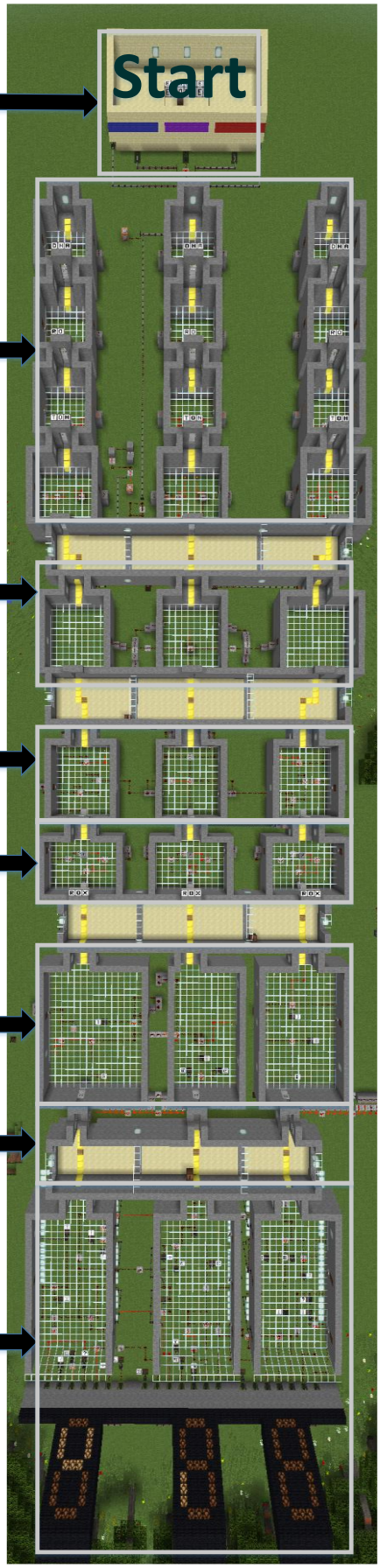
Early Group Tasks
P6: Pleasantly Frustrating, P11: Skills as Strategies, P12: Systems Thinking
Students deploy teamwork and subject specific skills to proceed

Intermediate training
P7: Cycles of Expertise
Students learn an extension of the skills deployed.

Intermediate Group Tasks
P9: Fish Tank Learning
Students face additional challenge to complete subject specific tasks.

Staging/Rest Area
P3: Player Identity, P8: Information Provision
Students must all join up before progressing to the next task.

Advanced Final Task
P3: Player Identity, P13: Meaning from Experience
Brings together knowledge from throughout the game to make a major change on the game world



Introductory audio, explains basic game concepts and sets up the story and goals.

Audio cues used to let students know when aspects of the game world change. Group discussion continues while players are separated.

Audio reinforces teamwork focus. Participants discuss what can be seen and changes.

Players continue working together, utilising learned skills. Further story progression

Story indicates increased challenge and importance as players progress towards the conclusion.

Story presents the final task explaining the challenge and difference from previous tasks. Students continue to work together to achieve success.

Figure 25: Annotated map of the game world within the LogicGate-R System.

A number of areas on the game map show updates from the original LogicGate System. The use of audio to create in-game cues, provide guidance and instruction, present the storyline and introduce elements is indicated with a speaker icon. Expected and prompted student discussions are also presented alongside this icon. The remainder of this section explores the parts of the game-world in detail, identifying changes and improvements as well as the utilisation of DGBL principles as drawn from the SCE framework.

6.2.3.1 Sandbox Learning Area

The Sandbox Learning Area is where students first find themselves upon joining the game. In this area students are free to experiment with controls and get used to moving within the game world, making use of the area's namesake **P10: Sandbox Learning**. Figure 26 shows the Sandbox Learning Area, featuring the media player as well as part of the introductory message to students.

Figure 26: The Sandbox Learning Area showing in game information storage and media player

Students receive an in-game "information storage" item, shown in Figure 26 on the lower right, which when used progresses the story and provides further instruction as to how to proceed to the next stage, as well as introducing the teamwork aspects of the game. Students are in the same area at this point, further reinforcing the multiplayer nature of the game. This area in particular seeks to deliver upon **P1: Co-Design** as students can decide which path to send

each team member down, **P3: Player Identity** as their roles mechanically and in story are introduced, and **P4: Manipulation**, as students get used to affecting the world around them.

6.2.3.2 Individual Tutorial Tasks

This sequence of four small sections provides students with an individual tutorial section, where each student is gradually introduced to the basic logic gates: AND, OR and NOT and asked to use and interact with these in the world. As they do so the student is given information on the use of that gate which they can return to and refer to in future. Figure 27 shows one of these Tutorial Areas including the switches a user can interact with and the exit/goal.

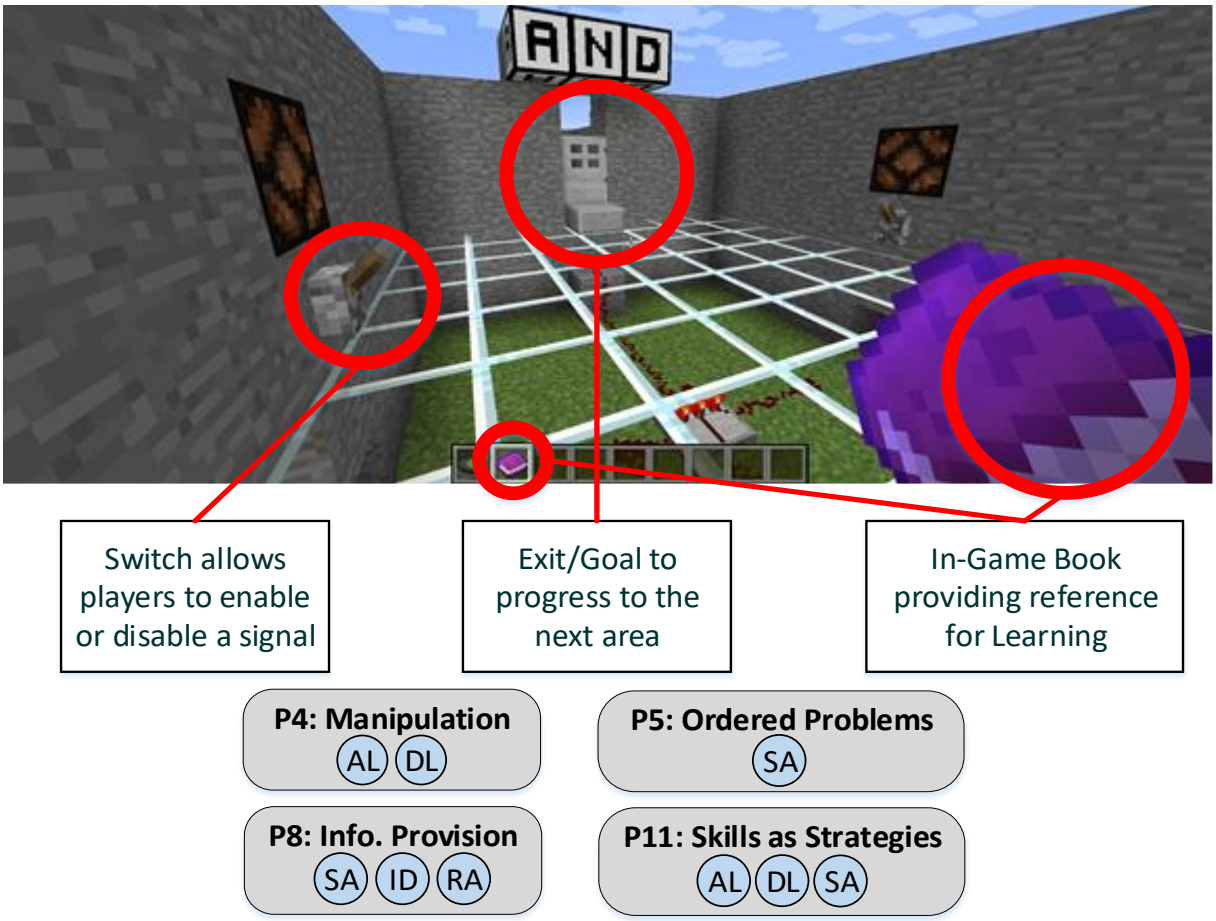


Figure 27: Introductory tutorial task area for one student teaching the basic use of AND Gates

While each student must complete these tasks, the communication system remains active throughout and students are encouraged to seek and offer help from and to other members of their team. At the beginning of this section the time-based scoring is introduced, offering students a further incentive to proceed through the game. Throughout this section, students are introduced to the audio-visual cues that their actions have changed something within the game world, most particularly a distinctive effect was used to indicate the door opening and prompt students that they had successfully solved the puzzle (Collins, 2008). Within each room students are provided with an in-game reference containing information on the logic

concept the room is addressing, which can be stored and referred to at will throughout the experience. This serves as timely and lasting **P8: Information Provision**, as students are taught new skills as they are put into practice to proceed. The final room within this section offers a challenge utilising all three types of gate, this offers an increase in difficulty over the single gate challenges while remaining approachable. Over this section several aspects in particular are delivered upon, including **P4: Manipulation** as the puzzles and world respond to the students; **P5: Ordered Problems** as students face first the single gate then combination challenges; and **P11: Skills as Strategies** as students' logic abilities come to be used to progress faster. Towards the end of the section, students receive a further in-game "information storage" item with which to unlock the next part of the story and receive further instruction.

6.2.3.3 Staging/Rest Area

A number of these areas are found through the game. These areas, decorated as the Sandbox Learning Area, serve a number of purposes: They provide an area for students to further experiment, if desired, with some of the game mechanics outside of the puzzle areas. Figure 28 shows one of these Staging/Rest Areas, depicting a further media player as well as the areas participants must stand on.

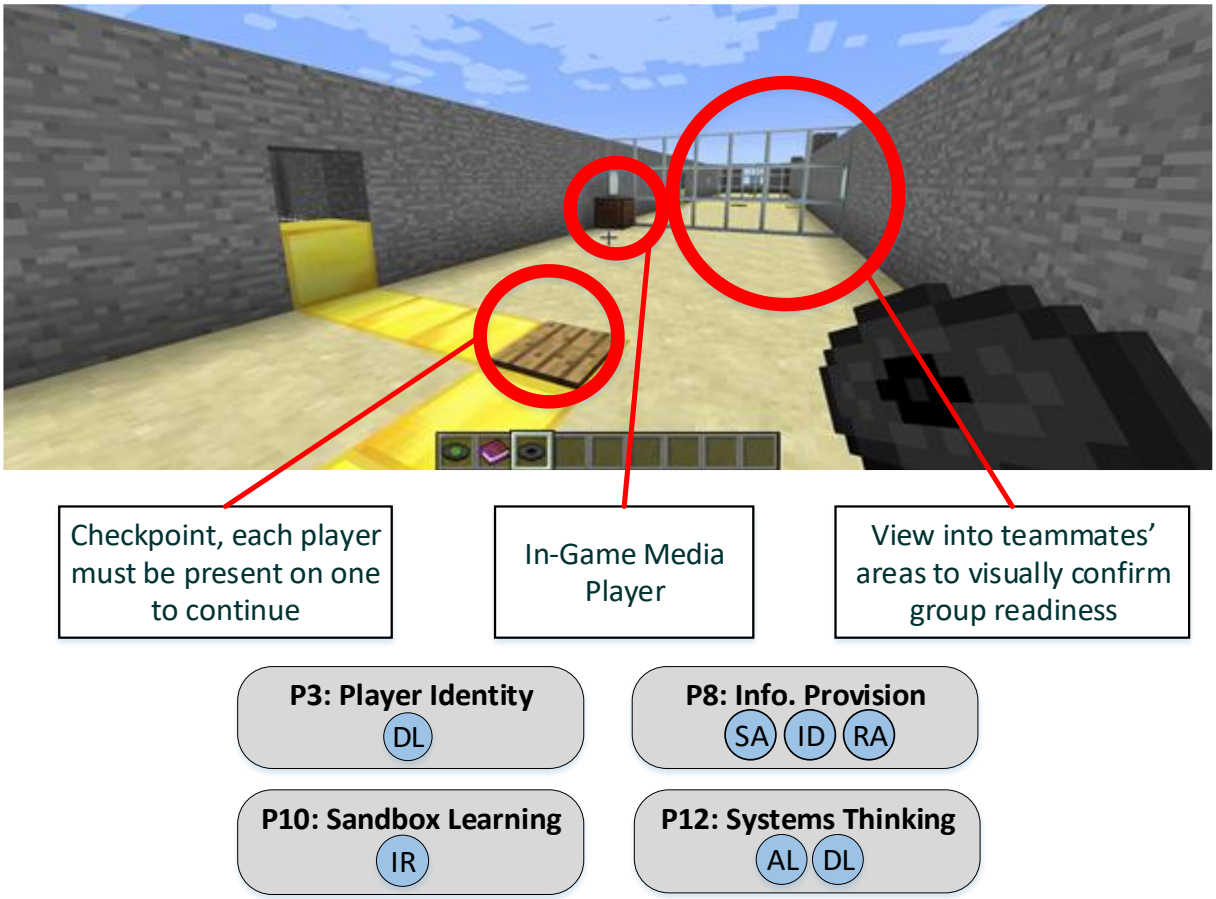


Figure 28: Staging/Rest Area

These areas require all members of a group to be present to progress, forming a checkpoint to prompt students who get there before their peers to help their groups out through discussion and in some cases through returning to the earlier rooms to make changes to the puzzle. The rooms feature the in-game media players which allow students to play and re-play story elements if desired. These areas focus on **P8: Information Provision** allowing students to review media; **P3: Player Identity** as story sections reinforce the student's role and motivation; **P12: Systems Thinking** as the skills are given in-game meaning; and **P10: Sandbox Learning** as students can further experiment with their skills.

6.2.3.4 Initial Group Task

This first group task asks participants to work together to solve a simple puzzle. This task does not lean heavily on the subject specific knowledge but instead focuses on the team discussing and working together to progress. Figure 29 shows the initial group task viewed from the air, each participant has access to one of the rooms and must cooperate in order to open the three doors shown above.

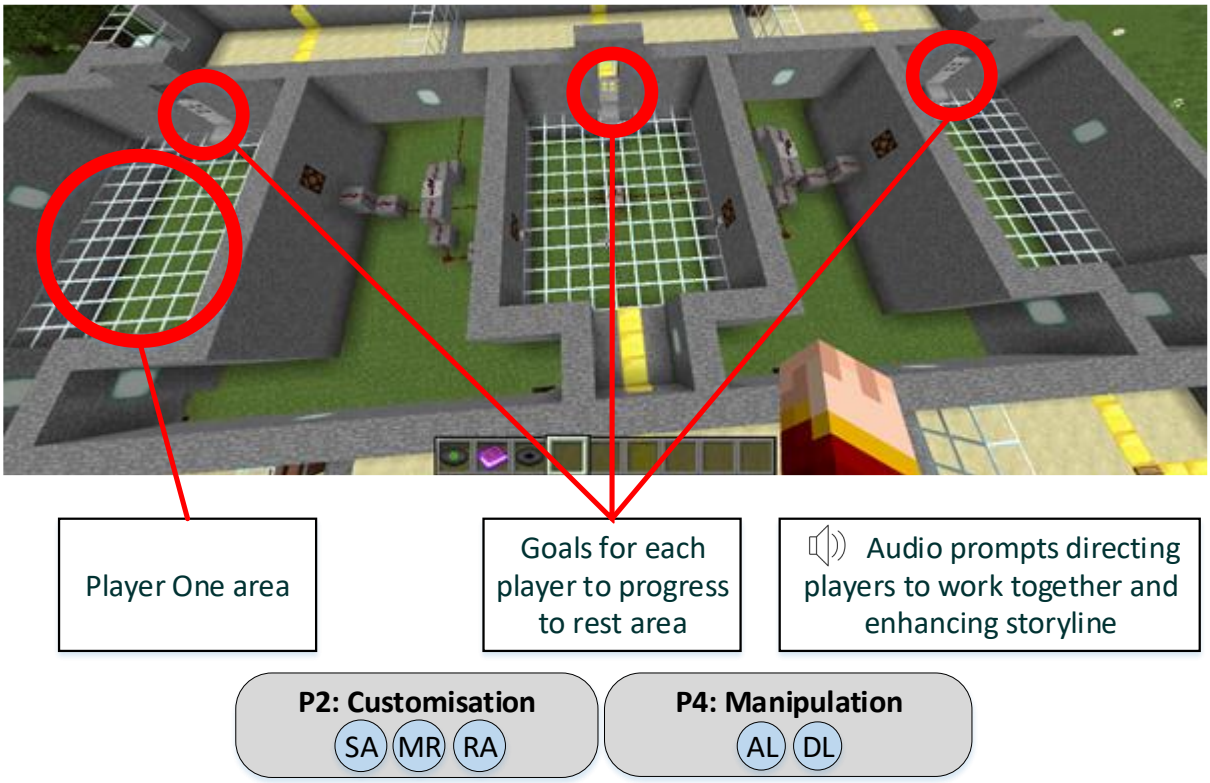


Figure 29: Arial view of the Initial group task showing three parallel rooms, one for each participant

The task provides an introduction to the major teamwork focus and forms the first point where a puzzle cannot be completed without help from team mates. The area seeks to operationalise the principles of **P4: Manipulation**, as students' actions have effects on not just their but other students' visible rooms, and of **P2: Customisation**, as students can choose how to handle

the teamwork and how they experiment. This area is followed by another rest area for participants to catch up.

6.2.3.5 Early Group Tasks

The early group tasks ask participants to work together, utilising the skills gained from the Tutorial Tasks and the teamwork skills gained from the Initial Group Task. Figure 30 shows the first circuit participants are tasked to complete, indicating the areas individual students have access to see and interact with.

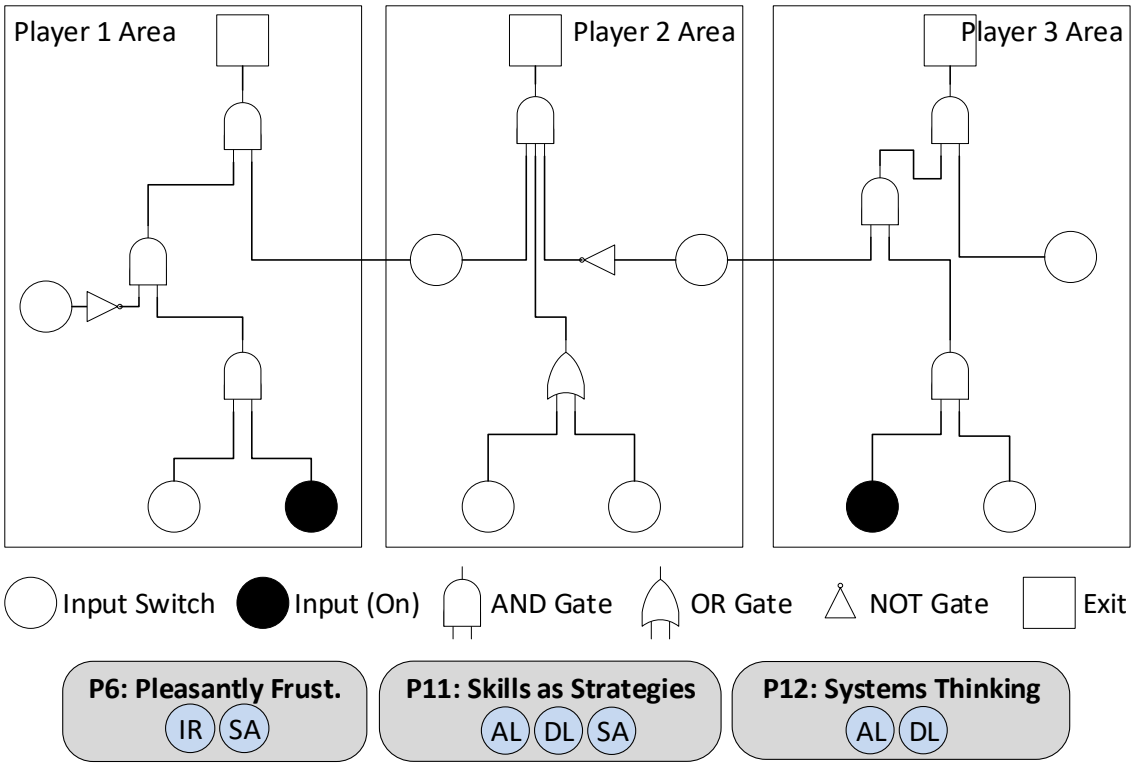


Figure 30: Circuit Diagram for the first subject specific group task

Participants use their subject knowledge to solve group puzzles and allow themselves and their team mates to progress. This area particularly focuses on **P11: Skills as Strategies**, where the learned logic skills are applied as strategies to complete the puzzles, **P12: Systems Thinking** as the concepts of Logic introduced form a fundamental and interact able part of the game world, and **P6: Pleasantly Frustrating** as the challenges step up. The teamwork component of the game promotes stronger students helping weaker ones, while weaker students have easy access to the help of peers to progress.

6.2.3.6 Intermediate Training

During this section, students are introduced to further subject specific content in the form of more advanced XOR gates. This takes the form of an individual puzzle as seen in the Introductory Tutorial Tasks section, where students have access to support through the voice

communication system. In addition to the principles utilised in the Initial Training, this area puts into practice **P7: Cycles of Expertise**. Having navigated the tasks utilising the initial logic gates, the skill of solving puzzles is advanced through the introduction of additional gates, providing a further challenge and extending the breadth of possible puzzles and solutions for students to explore.

6.2.3.7 Intermediate Group Tasks

Integrating students' understanding from Early Group Tasks with the new skills gained in the Intermediate Training, this area provides further challenge to students as they progress. Figure 31 displays a section of an intermediate level task, showing a part of the circuit.

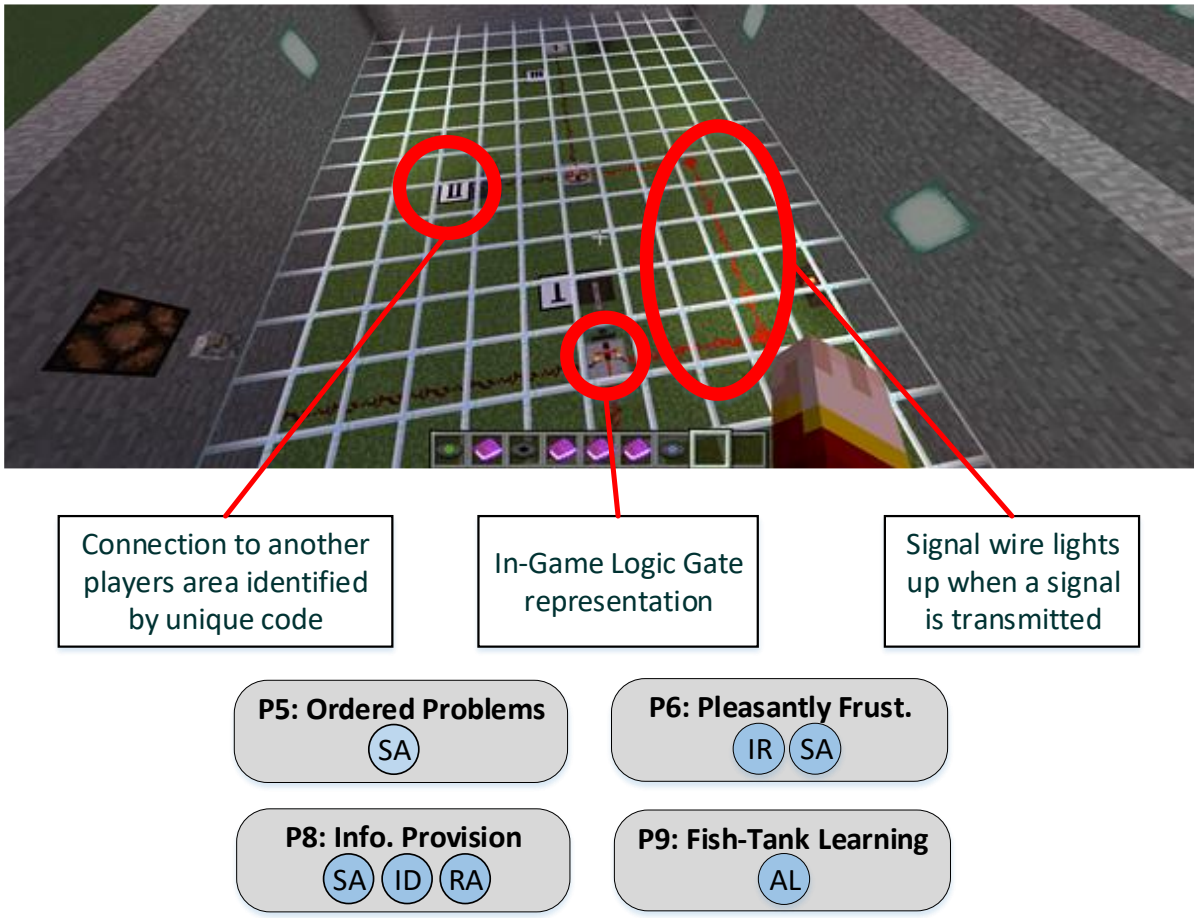


Figure 31: A section of an Intermediate Subject Specific Task area viewed from above

The storyline reinforces students' continued success while the difficulty of puzzles is increased. **P9: Fish Tank Learning** is in evidence here, as these tasks are designed to allow students to make, identify, and correct mistakes without significant consequence, encouraging experimentation to refine understanding. The area provides additional instantiation of **P5: Ordered Problems**, supporting students learning with a new set of challenges taking a step up in difficulty; **P6: Pleasantly Frustrating** as the challenges faced are more difficult but

remain within a student's reach; and **P8: Information Provision** as students put into practice the knowledge just gained on new logic gates.

6.2.3.8 Advanced Final Task

The final task is set up both through storyline and visually to present a more impressive area for students. Figure 32 shows the entrance to this task, including part of the text prompt.

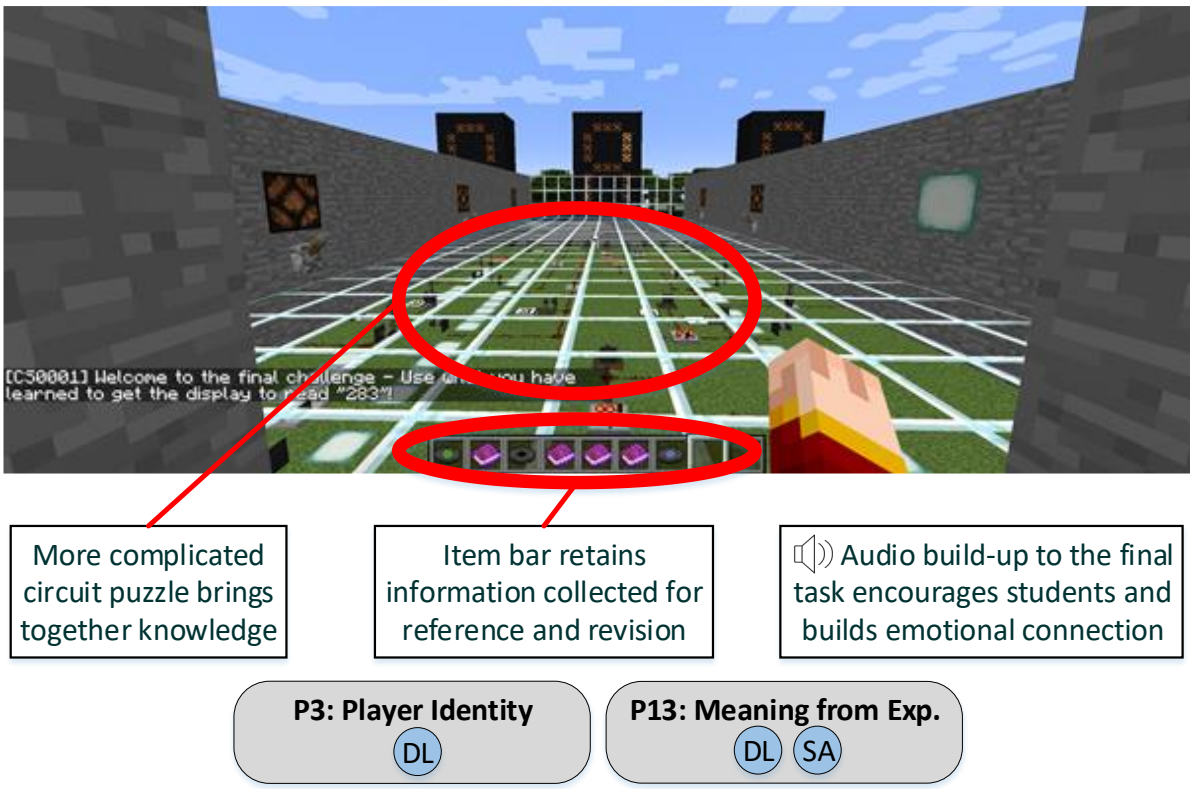


Figure 32: The entrance to the final task as viewed by student 2

This final challenge provides a major conclusion and the culmination of the storyline goal presented through the audio overlay. Students must work together and utilise knowledge from all previous sections to solve the challenge and complete the storyline. In particular this area provides for **P3: Player Identity** as the culmination of both the students' learning and of the ongoing story that the students are exploring, this area offers a conclusion to the SCDGBL experience, identifying to players that they have mastered the topics at hand and have achieved their goal. **P13: Meaning from Experience** is then fulfilled as students are able to reflect upon their experience with the game and with each other and to associate this with their learning. In addition to these principles, a number of other principles are carried forwards from previous group tasks as established game elements continue to be present in the way students are accustomed to.

The next section looks at how the design of the study was formulated and updated to accurately test the LogicGate-R System.

6.3 Study Design Changes

A number of difficulties with the study design were identified in Chapter 5, accordingly targeted improvements have been made for this next round of evaluation. A within-groups counterbalanced study design was adopted to gather comparative data from a control condition. This control condition was a traditional SCL based task already in use at Brunel University, designed to teach the course topic and to last approximately the same length of time as the LogicGate-R System. Participants were randomly assigned to either group A or group B. Group A were exposed to the Traditional task first, followed by the LogicGate-R System, while Group B experienced the LogicGate-R System first, followed by the Traditional task. This would offer comparative data with the Traditional task while controlling for any order of exposure effects through whole group analysis.

In order to assess knowledge acquisition and to compare the effect upon learning of the LogicGate-R System, an online test was used to assessed students' understanding of key concepts taught. Such testing procedures are used regularly with Brunel students, providing a consistency with students' expectations of assessment to maintain the authenticity of the learning environment. A longer session was utilised to ensure time was available to conduct focus groups immediately following exposure to the LogicGate-R System. This approach helped avoid difficulty experienced in earlier studies recruiting for focus groups while also ensuring richer recall of participants' experiences as they are more recent (Manzanero et al., 2009). This technique ensured more accurate, precise and relevant feedback points were gathered.

6.4 Research Methods

This section offers details of the data collection methods, participants and analysis techniques utilised to fulfil the research aims of this study.

6.4.1 Research Questions

This study forms a follow-up to the initial LogicGate System study, exploring the implementation of SCDGBL through the LogicGate-R System. The study focused on delivering an effective SCDGBL experience, assessing the improvements made to the LogicGate-R System as a result of the first study, and comparing this experience to a traditional student centred classroom task that delivered the same learning outcomes on a number of parameters, including engagement, student experience and knowledge improvement. The review presented in 4.4.3, which sought to frame the LogicGate System in the context of other recent digital educational games deployed and evaluated in formal education environments, suggests that few recent offerings were evaluated on a comparative basis against traditional classroom activities. Thus the current focus enables a robust

evaluation approach for the LogicGate-R System. As such, the following research questions take form for Experiment 2:

E2RQ1: To what extent does the LogicGate-R System more effectively deliver all seven tenets of Student Centred Learning in comparison to a traditional, paper-based student centred classroom task?

E2RQ2: To what extent does the LogicGate-R System provide a more engaging gameplay and learning experience in comparison to a traditional, paper-based student centred classroom task?

E2RQ3: To what extent does the LogicGate-R System improve student knowledge in comparison to traditional learning experiences?

E2RQ4: What are students' views on SCDGBL as a vehicle for their learning?

6.4.2 Outcome Measures

In keeping with the initial study, to measure how effectively the LogicGate-R System delivered an SCDGBL experience (**E2RQ1**) a combination of two validated surveys was utilised. The Course Experience Survey is an evaluation tool designed to fit a number of learning environments that addresses many of the core concepts of Student Centred Learning (Hyo-Mi, 2018). It addresses features such as student-teacher relationships, group discussions, student responsibility and offers a view into students perceptions of their learning experience around these topics (Hyo-Mi, 2018). The eGameFlow survey provides further information on a number of Student Centred Learning tenets, addressing particularly students' *Sense of Autonomy*, *Increased Responsibility and Accountability*, *Mutual Respect* and *Active Learning* (Fu et al., 2009, Chen et al., 2018). eGameFlow has been used before in education, as well as within wider user experience research, and includes an optional module, utilised during this study, for use in assessing educational content (Fu et al., 2009, Chen et al., 2018). For the mapping between the constructs included within the Course Experience Survey and eGameFlow survey and the SCL tenets, as well as an explanation for these connections and establishment of the role of the Immersion construct in evaluating learner experience, please see 5.3.2.

The use of eGameFlow is also vital in the evaluation of students' engagement with the learning experience (**E2RQ2**) where supported user experience metrics such as Goal Clarity, Immersion and Feedback allow an understanding of where the experience is best delivering, and identification of areas for improvement (Chen et al., 2018). Both surveys performed well in the initial study and the data captured through these surveys allowed for the development of the LogicGate-R System. As the research questions posed are similar, these surveys have

been retained, allowing for an iterative approach to development to be maintained. A class test was devised based upon knowledge tests used routinely within the undergraduate course to assess the extent of knowledge improvement (**E2RQ3**). A knowledge test administered pre- and post-learning experience is frequently deployed to identify knowledge improvement when evaluating educational games, as demonstrated within the review presented in 4.4.3. When comparing between learning experiences, expressing an individual's knowledge gain as a gap score for pre versus post learning intervention can mitigate the impact of individual differences in baseline topic knowledge (Theobald and Freeman, 2014). Students' views of SCDGBL experiences as a vehicle for their learning are explored through focus groups (**E2RQ4**); the outcome measures within the surveys were augmented with data from these focus group sections to provide valuable contextual information for survey findings and a more nuanced perspective of the student learning and gameplay experience (**E2RQ1, E2RQ2**). Again, the review in 4.4.3 suggested a mixed methods evaluation approach was under-utilised despite the valuable information this provides. Figure 33 presents the participant data collection and analysis procedure for this mixed methods study.

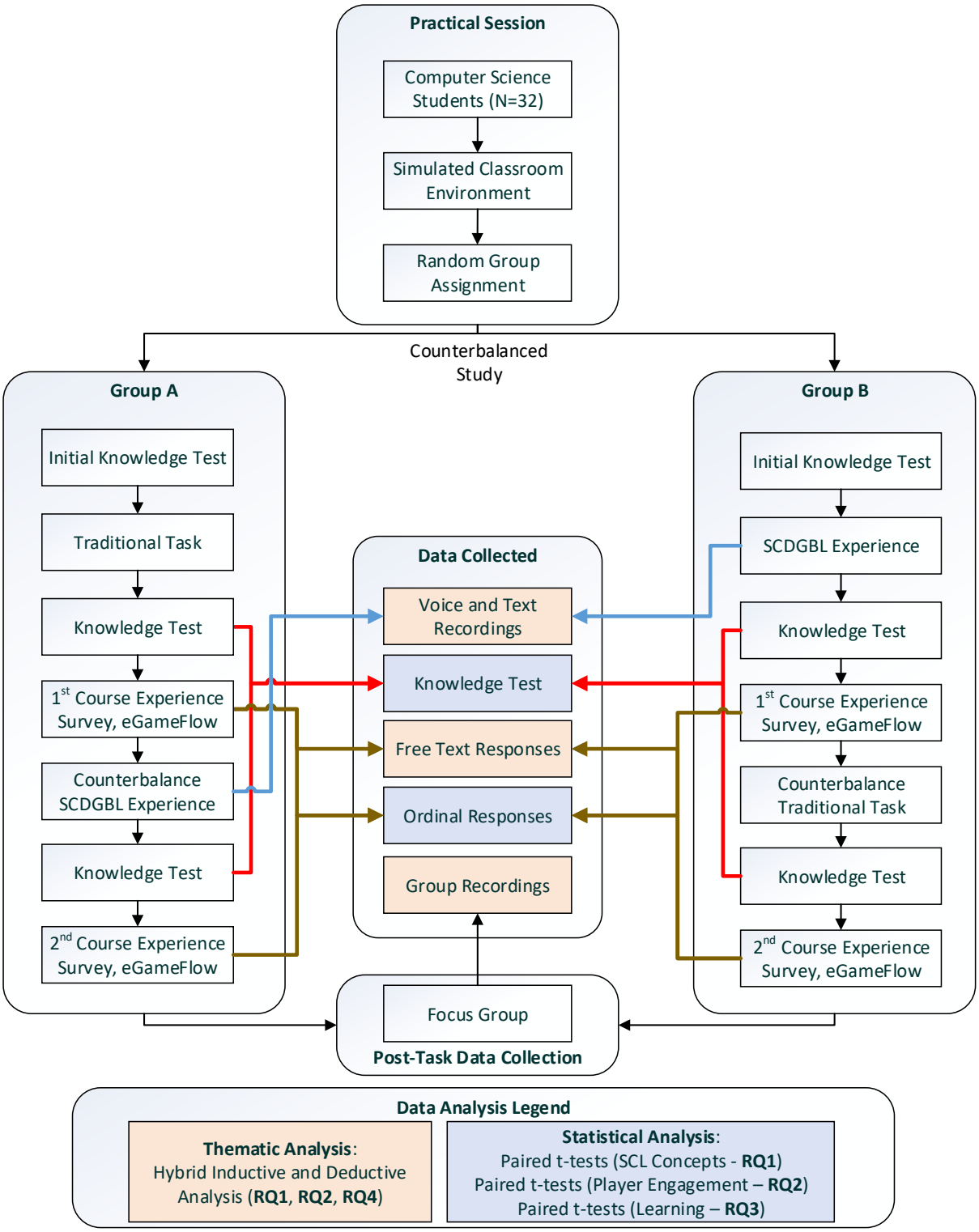


Figure 33: Counterbalanced mixed methods data collection and analysis procedure

6.4.3 Sample

The participants for this follow up study were students studying Computer Science, Business Computing and Multimedia Computing courses at Brunel University (n=32), primarily those in first year. This is congruent with established practice on sample size for studies involving thematic analysis (Fugard and Potts, 2015). The courses (Computer Science, Business

Computing, Multimedia Computing) were selected as they involve the use of Boolean logic, being the core of the learning intentions of the LogicGate-R System. This selection of courses ensured the course content was aligned with content delivered to students through the game. Participants were recruited through email and through their weekly group tutoring sessions, where they were invited to participate in the study as an additional learning and revision session teaching concepts used in their courses, which students were aware would be included as a topic of assessment in upcoming examinations.

The inclusion criteria for participants was: (1) Participants should be on one of the above courses to ensure their knowledge was comparable. (2) Participants were proficient English speakers to allow all members of a group to contribute in the cooperative, teamwork based learning tasks. No age limits were applied as the courses are designed to be accessible to students from 18+ and it was decided it was appropriate for this to be represented in the study. As a simulated classroom environment, the researcher took on the role of teacher for this study and therefore there was no teacher present to objectively evaluate the LogicGate-R System from that perspective. For this reason the teachers' perspective and experience is not reflected within the study.

6.4.4 Study Design and Procedures

This mixed-methods study utilised a counterbalanced, within subjects design which allows the effective comparison of the LogicGate-R System to a traditional student centred task utilised within the classroom. The study took place within Brunel University from March to April 2019, using a computer laboratory used by students at the university in regular practical teaching sessions, this laboratory environment was prepared and reset between each session to ensure the hardware and software required remained functional and students had the same onboarding experience. Upon arrival at a session, participants were randomly assigned to either Group A or Group B using an online coin flip generator. Participants were then asked to log on as normal in a laboratory session and provided with a verbal explanation and an instruction sheet outlining the activities they were to undertake. All participants would take a short knowledge test before joining their groups in using the voice communication software. Those in Group A would first engage with a paper-based student centred classroom task (Traditional task), working in their groups to solve a series of logic puzzles, distributing the work between themselves to come to a final group solution. Those in Group B would use the LogicGate-R System, working in groups to complete the puzzles in-game. Following this all students would fill out the Course Experience Survey (Hyo-Mi, 2018) and eGameFlow survey (Fu et al., 2009, Chen et al., 2018), rated using a 5-point Likert scale, and fill out a knowledge test (Appendix 5). Participants would then engage in a second iteration of the trial using the alternative task, followed by filling out the surveys and test again. This counterbalanced design

allows the identification of and control for order effects, particularly as relates to learning with both tasks covering the same topic area. When both learning experiences had been completed and the surveys filled out, participants were invited to take part in a focus group containing members of both experimental groups where the learning experiences, challenges and intentions were discussed along with the possibilities for future improvements and deployment in routine practice. These focus groups were recorded and transcribed verbatim.

6.4.5 Data Analysis

6.4.5.1 Quantitative Data Analysis

Analysis of the Course Experience Survey and eGameFlow survey responses along with knowledge test data was performed using IBM SPSS statistics package version 25.0.0. For both surveys, descriptive statistics (mean, standard deviation) and gap scores (difference between post-LogicGate-R System value and post-traditional value) were calculated per construct, aggregated from the relevant items per the previous study. Cronbach alpha for scale reliability was reported for each construct.

Two-tailed paired t-tests were used to test for whole-group differences in construct scores between the post-LogicGate-R System and post-Traditional learning experiences (**E2RQ1, E2RQ2**). A two-tailed analysis was selected because the gap score had the potential to be positive (favouring the LogicGate-R System) or negative (favouring the Traditional task). Significance was set at the 0.05 level for all tests – no corrections were required as the analyses to be performed were defined at the start by the research questions and each comparison was only performed once due to the use of two learning experiences.

To assess the degree of knowledge improvement (**E2RQ3**) occurring after each learning experience, one-tailed paired t-tests were performed to compare pre-experience and post-experience raw test scores(Udovic et al., 2002). To compare the size of the change in raw test scores between learning experiences, a one-tailed paired t-test was performed on the gap score (calculated as the difference in test scores between pre-experience and post-experience). A one-tailed test was selected because the research question is assessing the difference in improvement of student knowledge of this topic between learning experiences.

Reliability was calculated at a construct level, initially utilising Cronbach Alpha. It has been identified that for constructs with a small number of questions, such as those utilised in the Course Experience Survey and eGameFlow survey, Cronbach Alpha can report erroneously small values (Tavakol and Dennick, 2011, Streiner, 2003). In such situations it is recommended that Mean Inter-Item Correlation can be utilised to provide reliability information (DeVellis, 2003). This was calculated for all constructs within both surveys, using recommended acceptability values between 0.15 and 0.7, with values over 0.5 indicating a

potential overlap in some questions (Clark and Watson, 1995, DeVellis, 2003). Where necessary, questions that with an inter-item correlation under 0.15 and whose removal would increase the Mean Inter-Item Correlation were removed to increase reliability and validity.

Post hoc, correlational analysis (Pearson) was performed to explore the relationship between baseline raw test scores and gap scores representing knowledge improvement post-experience.

6.4.5.2 Qualitative Data Analysis

As in the previous study, thematic analysis was employed for the qualitative data to obtain contextual information regarding the student perspective of their SCDGBL experience with the LogicGate-R System. This analysis was performed to augment survey findings (**E2RQ1**), and explore the impact of changes made to the game upon the learning and gameplay experience (**E2RQ2**). Qualitative data included in the analysis were transcripts from the seven focus groups, alongside the recorded voice and text communications from the gameplay and the free text responses from surveys. A hybrid approach was adopted, utilising deductive a priori themes, taken from qualitative data analysed in the previous study, as a basis for initial coding. This approach was taken because the topic guide for the focus groups was identical to that used in the previous study and allows the impact of changes made to the game, identified from the previous data analysis and implemented in the current study, to be assessed. From this analysis a number of themes and subthemes were identified, which group both the initial themes and those additional themes identified during the inductive analysis process.

6.5 Results

Presented below are the results from the analysis of the Course Experience Survey, eGameFlow Survey and thematic analysis of the qualitative data. A total of 32 participants took part in the experiment.

6.5.1 Course Experience Survey Evaluation

The Course Experience Survey was used to assess many of the Student Centred Learning elements of the LogicGate-R System. The findings from the Course Experience Survey, taken both after exposure to the Traditional task and after exposure to the LogicGate-R System may be found below. Results are presented by construct and by question in Table 14 for all participants. Statistical analysis for each construct is presented including mean and standard deviation for the post-LogicGate-R System and post-Traditional tasks, comparative statistics are included comprising gap score (calculated as post-LogicGate-R System value – post-Traditional value), *t*, *df*, *p*. In addition mean values and standard deviation are presented per question.

Of the five constructs in the Course Experience Survey, four of the five presented positive gap scores within Table 14 indicating participants held positive views on the LogicGate-R System as compared to the Traditional task. Analysis showed the construct of Joint Productive Activity achieved an improvement over the Traditional task that was statistically significant, demonstrating a gap score of 0.245 ($p = 0.018$). The constructs of Complex Thinking (*Deep Learning*), Contextualisation (*Deep Learning*), Instructive Conversation (*Teacher and Learner Interdependence*) and Language and Literacy Development (*Reflexive Approach to Teaching and Learning*) did not achieve significance in either direction, presenting respective gap scores of 0.042 ($p = 0.745$), -0.018 ($p = 0.865$), 0.081 ($p = 0.629$) and 0.146 ($p = 0.372$). Mean Inter-Item Correlations were within the acceptable range for all constructs indicating reliability. Subsequent sections provide detailed results and analysis, broken down by construct and by experimental group.

Students rated Complex Thinking (*Deep Learning*) in the LogicGate-R System above that of the Traditional task, but this did not reach significance with a gap score of 0.042 (t = 0.329, t = 0.329, $p = 0.745$). Results for all groups demonstrate a mean of 3.885, compared to the Traditional Task mean of 3.844. This indicates that both tasks were perceived to require the understanding and application of knowledge about the topic area.

Contextualisation (*Deep Learning*) was the only CES construct which showed a zero gap score, t = 0.000, $p = 1.000$. Mean results for both the Traditional and LogicGate-R System learning experiences were below the mid-point of 3, at 2.854. One question within this construct was excluded from the construct level results to bring the Mean Inter-Item Correlation into acceptable bounds. The results for this construct indicate connections may not be effectively made to students' everyday experiences.

Participants rated the Instructive Conversation (*Teacher and Learner Interdependence*) construct marginally positively with a gap score of 0.081, t = 0.489, $p = 0.629$. This indicates that students did not find the teachers presence within the game and engagements with the students through this medium to distance them and that this may form an avenue through which to build deeper *Teacher and Learner Interdependence*.

Within the construct of Joint Productive Activity (*Mutual Respect*) participants rated the LogicGate-R System favourably demonstrating a gap score of 0.258, t = 2.494, $p = 0.018$, being the only construct to achieve significance overall. This indicates students felt the LogicGate-R System enabled them to work more collaboratively compared to the traditional task and that it more effectively delivered on the tenet of *Mutual Respect*.

Table 14: Course Experience Survey results by construct and questions, comparing Logic Gate R system experience and Traditional task experience.

Construct	Course Experience Survey Questions	LogicGate-R System		Traditional task		Comparison Statistics			
		Mean	Standard Deviation	Mean	Standard Deviation	Gap score	df	t-value	P-Value
Complex Thinking (Deep Learning)	***Construct***	**3.885**	**0.675**	**3.844**	**0.672**	0.042	31	0.329	0.745
	Higher order thinking	3.906	0.928	4.031	0.933				
	Application of concepts	4.188	0.780	3.969	0.933				
	Instructor helps develop solutions	3.563	0.948	3.531	0.950				
Contextualisation (Deep Learning)	***Construct***	**2.854**	**0.742**	**2.854**	**0.798**	0.000	31	0.000	1.000
	Personal Connections	2.500	1.047	2.387	1.022				
	Teaching relevant to personal life	2.938	0.948	3.000	1.000				
	Everyday Experiences	2.906	1.058	2.903	1.076				
	Relation to prior experiences	3.156	1.110	3.226	1.055				
Instructive Conversation (Interdependence)**Joint**	***Construct***	**3.625**	**0.837**	**3.544**	**0.604**	0.081	31	0.489	0.629
	Instructor works with small groups	3.875	0.907	3.656	1.066				
	Small group discussion	3.781	1.099	3.719	1.023				
	Planned Discussions	3.438	1.105	3.438	0.982				
	Students contribute to discussion	3.500	1.164	3.500	1.107				
	Instructor builds understanding	3.531	1.047	3.406	0.979				
Productive Activity (Mutual Respect)	***Construct***	**3.737**	**0.530**	**3.479**	**0.675**	**0.258**	31.000	2.494	**0.018***
	Regular group discussion	3.844	0.884	3.531	0.915				
	Topics have activities	3.656	0.865	3.469	0.879				
	Working together on Projects	4.125	0.751	3.906	0.995				
	Most activities involve groups	3.094	1.279	3.313	1.230				
	Engagement with others	3.656	1.310	3.000	1.320				
	Collaboration in and out of class	3.969	0.822	3.656	0.827				
Language and Literacy Development (Reflexive Attitude)	***Construct***	**3.593**	**0.723**	**3.297**	**0.868**	0.297	31	1.605	0.119
	Feedback level	3.344	0.971	3.250	1.244				
	Encouragement and Support	3.844	0.847	3.344	1.125				
	Guidance on writing	2.781	1.237	2.938	1.318				

* Statistically significant at the 0.05 level; Gap score is difference between post-Traditional and post-Game scores for construct - positive gap scores favour LogicGate-R System

Students rated Language and Literacy Development (*Reflexive Approach to Teaching and Learning*) for the LogicGate-R System above that of the Traditional task however this did not achieve significance with a gap score of 0.297, t = 1.605, $p = 0.119$. One question within this construct was excluded to bring the overall construct within reliability bounds. The results for this construct indicate that students were provided with feedback and were able to utilise this to improve, but that any improvements were not significant over the traditional task.

6.5.2 eGameFlow Evaluation

The eGameFlow survey was used to assess the effectiveness of the LogicGate-R System as a Digital Game-Based Learning experience. Participants completed this survey after undertaking both the game-based task and the gamified Traditional task. The results of this survey were analysed at a question and construct level for the entire cohort. Statistical analysis for each construct is presented including mean and standard deviation for the LogicGate-R System and Traditional tasks, comparative statistics are included comprising gap score (calculated as LogicGate-R System value – Traditional value), *t*, *df*, *p*. In addition to these calculations, in Table 15 mean values are presented per question.

Five of the eight constructs in the eGameFlow survey demonstrated positive gap scores, indicating users felt the game-based task was an improvement over the Traditional task. The constructs of Feedback (*Reflexive Approach to Teaching and Learning*), Autonomy (*Sense of Autonomy*) and Social Interaction (*Mutual Respect*) achieved gap scores which were statistically significant with gap scores of 0.641 (t = 3.715, *p = 0.001*), 0.375 (t = 2.958, *p = 0.006*), 0.385 (t = 2.713, *p = 0.011*) respectively. No constructs demonstrating negative gap scores achieved significance nor were approaching significance. Mean Inter-Item Correlation was within the acceptable levels of 0.15-0.7, with a majority of constructs falling within the 0.3-0.5 bound, indicating acceptable consistency within constructs. Subsequent sections break down the results by construct providing additional information.

Participants rated the Concentration (*Active Learning*) construct narrowly positively, indicating a minor but not significant preference for the LogicGate-R System over the Traditional task (gap-score = 0.156, t = 1.039, *p=0.307*). This indicates students were actively engaged within the task and that *Active Learning* was effectively integrated, though that significant benefits were not perceived by students over the traditional task.

The Goal Clarity (*Increased Responsibility and Accountability*) construct was rated slightly negatively (gap score = -0.203, t = -1.187, *p = 0.244*) but did not achieve significance. This indicates that despite improvements and additional explanation provided in-game, the specific goals and milestones students were intended to achieve within the LogicGate-R System were approximately as clear as those to be achieved in the traditional task.

Participants rated the Feedback (*Reflexive Approach to Teaching and Learning*) construct positively (gap score = 0.641*,* t = 3.715*, p = 0.001*), with this achieving significance. This demonstrates that the feedback on learning and actions was felt to be a marked improvement over that in the traditional learning task. This positive Feedback result for the LogicGate-R System shows the implementation of a *Reflexive Approach to Teaching and Learnin*g is more effective than that within the traditional task.

Table 15: eGameFlow Survey results by construct and individual questions, comparing Logic Gate-R system experience and Traditional task experience

Construct	eGameFlow Survey Questions	LogicGate-R System		Traditional task		Comparison Statistics			
		Mean	Standard Deviation	Mean	Standard Deviation	Gap score	df	t-value	P-Value
Concentration (Active Learning)	***Construct***	**4.083**	**0.825**	**3.927**	**0.702**	0.156	31	1.039	0.307
	Stimulates attention	4.031	1.031	3.813	0.78				
	Do not get distracted	4.031	0.897	3.875	0.907				
	Able to concentrate	4.188	0.859	4.094	0.856				
Goal Clarity (Increased Responsibility)	***Construct***	**3.727**	**0.925**	**3.93**	**0.821**	-0.203	31	-1.187	0.244
	Understand goals from the start	3.656	1.260	4.000	0.984				
	Overall goals clear	3.813	1.176	3.938	1.105				
	Understand overall progress	4.125	0.942	4.125	0.907				
	Know what will happen next	3.313	1.176	3.656	1.035				
Feedback (Reflexive Approach)	***Construct***	**3.781**	**0.805**	**3.141**	**1.116**	**0.641**	31	3.715	**0.001***
	Receive feedback on progress	3.844	0.987	3.156	1.167				
	Feedback on actions	4.094	0.928	3.188	1.203				
	Feedback on game performance	3.969	1.031	3.156	1.322				
	Aware of score in game	3.219	1.289	3.063	1.39				
Challenge (Active Learning)	***Construct***	**3.794**	**0.667**	**3.963**	**0.707**	-0.169	31	-1.494	0.145
	Difficulty level suitable	4.031	1.000	4.000	1.016				
	Skills gradually improve	3.719	1.023	3.969	0.897				
	Motivated by improvement	3.688	0.859	3.938	0.84				
	Pace of Challenges	3.938	0.914	4.094	0.818				
	Different levels of challenge	3.594	0.946	3.813	0.965				
Autonomy (Sense of Autonomy)	***Construct***	**3.833**	**0.803**	**3.458**	**0.949**	**0.375**	31	2.958	**0.006***
	Control over movements	3.969	0.967	3.438	1.190				
	Sense of control	3.938	0.914	3.719	0.991				
	Strategies can be used freely	3.594	1.043	3.219	1.128				
Immersion	***Construct***	**3.227**	**1.113**	**2.93**	**1.078**	0.297	31	1.516	0.14
	Forget about passage of time	3.594	1.341	3.129	1.231				
	Unaware of surroundings	3.125	1.212	2.774	1.309				
	Can become deeply involved	3.438	1.343	2.903	1.221				
	Feel emotionally involved	2.750	1.368	2.774	1.383				
Social Interaction (Mutual Respect)	***Construct***	**4.167**	**0.661**	**3.781**	**0.746**	**0.385**	31	2.713	**0.011***
	Social interaction	4.438	0.669	3.938	0.840				
	Communities supported	4.094	0.856	3.563	0.982				
	Other players improve my skills	3.969	0.933	3.844	1.019				
Knowledge Improvement (Active Learning)	***Construct***	**3.994**	**0.809**	**3.969**	**0.614**	0.025	31	0.222	0.826
	Game increases my knowledge	3.656	1.153	3.844	0.884				
	Caught basic ideas	4.125	0.907	4.031	0.647				
	Try to apply knowledge in game	4.031	0.933	4.063	0.840				
	Integrate taught knowledge	4.219	0.870	4.094	0.689				
	Want to know more	3.938	0.840	3.813	0.896				

* Statistically significant at the 0.05 level; Gap score is difference between post-Traditional and post-Game scores for construct - positive gap scores favour LogicGate-R System

Within the construct of Challenge (*Active Learning*), participants rated the LogicGate-R System slightly negatively (gap score = -0.169, t = -1.494 *p = 0.145*) but this did not achieve significance. This demonstrates that the difficulty of the challenges presented and the scaling of this difficulty was not significantly improved or detracted in the LogicGate-R System compared to the traditional task.

Autonomy (*Sense of Autonomy*) was one of the constructs participants rated as significantly improved in the LogicGate-R System (gap score = 0.375, t = 2.958, *p = 0.006*) showing a major improvement over the gamified Traditional task. This demonstrates that as both tasks were collaborative, students felt the LogicGate-R System gave them a greater *Sense of Autonomy* as students felt they had a greater ability to act on their own and were able to creatively apply solutions to problems.

The Immersion construct was rated positively but did not achieve significance (gap score = 0.297, t = 1.516, *p = 0.140*). This indicates that while students were able to become immersed in the ongoing experience, this did not offer a significant improvement from the traditional student centred task.

Social Interaction (*Mutual Respect*) was rated positively and achieved significance (gap score = 0.385, t = 2.713, *p = 0.011*) showing participants felt the LogicGate-R System to provide enhanced social interaction opportunities and skills as compared to the Traditional task. This indicates students felt that the LogicGate-R System provided opportunities for social interaction and peer learning and that the tenet of *Mutual Respect* was more successfully integrated into the LogicGate-R System.

Students rated the Knowledge Improvement (*Active Learning*) construct marginally positively (gap score = 0.025, t = 0.222, *p = 0.826*), however this did not achieve significance. This indicates that students felt both experiences allowed them to learn as effectively and were equivalently able to deliver and encourage the active use of knowledge and techniques.

6.5.3 Qualitative Analysis of Focus Group and Free Text/Voice Chat Data

Qualitative analysis identified five major themes, these are (1) Social Interaction, (2) Knowledge Improvement, (3) Game Design, (4) Perception and (5) Increased Responsibility. Figure 34 shows these themes and relevant subthemes in a thematic mind map. Emergent themes were added, from inductive analysis, comprising Game Design, Information Provision, Perception, Motivation and Aesthetic. One theme was dropped, that of Reflexive Approach; while appearing in the previous paper the theme was rarely discussed by participants using the LogicGate-R System and discussion that did arise was in the context of revisiting puzzles to help other students, and as such the contents of this theme have been merged with that of Mutual Respect.

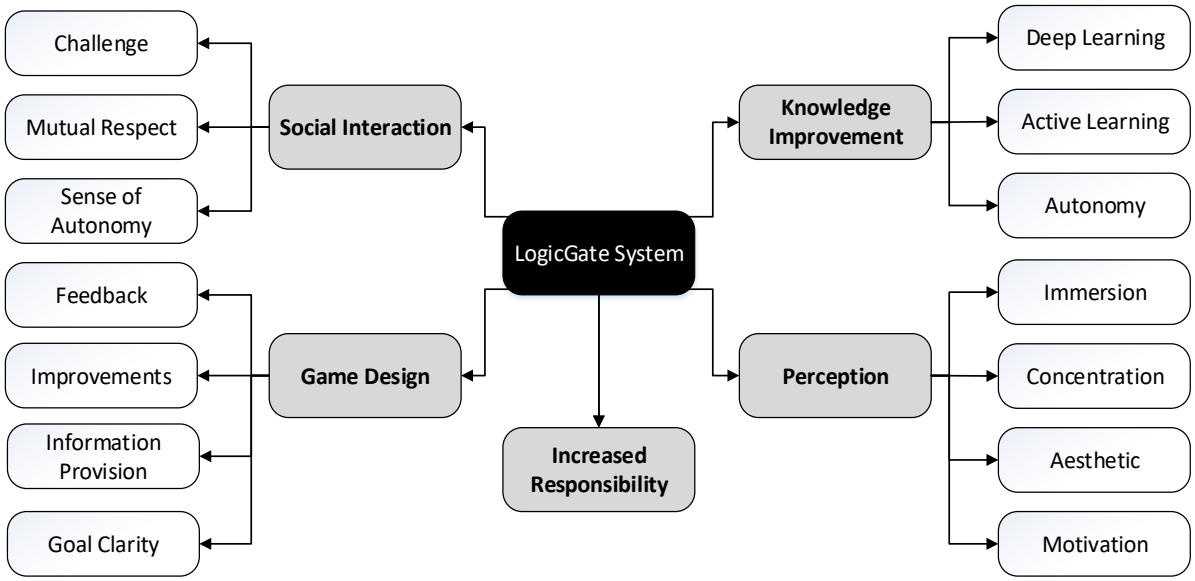


Figure 34: Thematic mind-map of themes and subthemes.

6.5.3.1 Social Interaction

The Social Interaction theme draws identity from the eGameFlow construct of the same name, it deals with concepts such as cooperation and desire to cooperate between peers, along with support for community building in and outside the game. It includes a number of subthemes which relate to it and to each other, these are addressed within this subsection.

Participants expressed support for working with others, and found that when successful the social interactions helped boost their enjoyment of the game, with some groups citing it as one of the highlights of the experience.

> *"It's just more engaging when you're working with other people… so when you apply that to the game, I think it just amplifies that."*

Concerns were expressed about the time taken to start the task, as participants felt getting started talking to and working with team mates was a slow process. Some students expressed a worry that being asked to work with people they did not know could be an issue, however no students cited this as an issue they had come across directly. Overall, reception to the social interaction aspects was positive, with some participants specifically noting the voice communication as a boon, as it did not require time taken away from the tasks to type.

6.5.3.1.1 Challenge

The Challenge theme was developed from the Challenge eGameFlow construct, and explores difficulties students faced in engaging with and completing the game, as well as discussion around progression or completion speed.

This subtheme appeared under the theme of Social Interaction through two common threads: Participants expressed that the initial orientation to group work was challenging, getting others

in their group to communicate and to understand the team-based nature of the tasks. The second thread was participants discussing how having team mates and requiring their input made the game easier or harder. Participants suggested that the difficulty may have increased too fast, leaving some people stranded and requiring a lot of support from their teams to progress.

6.5.3.1.2 Mutual Respect

Mutual Respect is one of the deductive themes taken from the tenets of Student Centred Learning, it primarily deals with the respect students build from each other. As a team-based exercise this has significant crossover with the theme of Social Interaction, with the primary method of building mutual respect being the group-based work.

Participants were often surprised at how much others would learn over the course of the session, with students who appeared weaker at the start gaining confidence and ability.

> *"I just helped him with the first few rooms, and then he just kind of took over."*

Participants appreciated the ability to learn from others, though expressed some concern about the reliance upon the team's 'weakest link' and the feeling that may generate in a student placed in that role.

6.5.3.1.3 Sense of Autonomy

Sense of Autonomy is developed from the Student Centred Learning tenet of the same name and covers a student's belief in their own ability to progress based upon their strength. A majority of the discussion in this theme centred on the relationships to other people in their team and how much the individual was able to contribute, placing it as a contributor to the theme of Social Interaction.

> *"It felt like each of us had a different difficulty, at some point. Like each one of us got stuck, whereas the others kept going nicely. Each one of the others got stuck, so we had to sort of chip in and help. It was very interesting. "*

Participants had concerns where sometimes their progression was hindered by something another student had to do, but once teams were able to cooperate well, participants felt their individual contribution was an important part of their group's success.

6.5.3.2 Knowledge Improvement

The theme of Knowledge Improvement deals with how participants learn, and how they feel they learn. A number of subthemes were explored, covering different types of learning and ability to engage with the learning process.

Participants were broadly positive about the ability to learn from the game, however some expressed reservations about how much knowledge they would like to go in with, and about if they could learn content as quickly through the game.

> *"I think as long as it doesn't hinder what you've learnt otherwise, and it still covers everything, I think it would still be fine even if it took a bit longer."*

Discussion came up on the initial orientation period, where students felt they had to get to familiarise themselves with the game's mechanics before engaging more fully with the educational content.

6.5.3.2.1 Deep Learning

Deep Learning draws from the Student Centred Learning tenets, this theme covers the investment of meaning into learning to associate the facts and understanding with personal experiences.

Students felt the application of their learning in a practical sense was effective and appreciated being able to see the effect.

> *"And then, probably trying to apply the circuit logic in real life for the first time ever. When I was first learning about it, I was like: Oh, I will never need it in my life…. and it is in video games."*

A recurring idea was the use of games to back-up or build upon previous learning, though other participants expressed the view that they learned significantly through the course of playing.

6.5.3.2.2 Active Learning

Active Learning is a widely explored Student Centred Learning tenet in video games, as a theme it covers engaging with learning through practical activity. It forms a subtheme of Knowledge Improvement as it deals with a method of learning.

> *"It's kind of cool, the real-life application. You see that you cannot go if the circuit is open or the circuit is closed. So, you see that it's really straight forward and relating to the logic gates. I've never seen these educational games I think, only the children's videos for alphabet."*

Participants discussed the effectiveness of making changes and seeing the effects immediately, appreciating the ability to experiment and work out the effects. Recurring comments highlighted the game as a more 'fun' way to learn.

6.5.3.2.3 Autonomy

The theme of Autonomy comes from the eGameFlow construct of the same name. It covers students' ability to control their activities, use strategies and make or recover from errors. This theme frequently dealt with the ability to progress through learning and to employ educational knowledge as a strategy, situating it as a subtheme of Knowledge Improvement. Some participants expressed a concern that their lack of ability to progress individually was slowing their own learning on more complex ideas, while others appreciated the ability to work forward or backward through problems.

6.5.3.3 Game Design

The theme of Game Design was an emergent theme within the data, it covers the discussion of mechanical game elements separate to the educational content. Discussion within this theme addressed a number of areas of game design, with common discussions covering a number of subthemes.

6.5.3.3.1 Feedback

Feedback as a theme arises from an eGameFlow construct, it addresses the game's responses to student actions and the way students are able to understand and improve on their solution and progress. Participants expressed a strong approval for this aspect of the game, particularly bringing up the instant feedback on solutions and the visual and audio cues offered in response to in-game actions.

> *"If there was a group one that we played in class, I would play it definitely, because the feedback is instant and as long as there is communication, everything will go well."*

6.5.3.3.2 Improvements

The theme of Improvements covers students' desired betterments to the game, ideas for ways to make the game more effective and enjoyable fell under this theme. Common student requests included a more detailed tutorial in the early game, particularly to cover the game mechanics. Other common requests were greater indication of what team mates were seeing or doing, and a system that offered a reward or punishment for students based on the number of changes or guesses they made within a section.

6.5.3.3.3 Information Provision

The theme of Information Provision emerged through inductive analysis. It covers the presentation of information to students at appropriate times and in a way that is accessible.

> *"I also liked when you can hear the person talking. It's a lot easier to follow than reading it off the screen, I think."*

Participants had mixed feelings on the information provision within the game: some participants made use of the library functions to access information on the game, while others were unaware of or forgot how to access this information and proceeded regardless. Participants felt the audio tracks delivered the story and would have appreciated more information presented this way, such as that provided through the library books.

6.5.3.3.4 Goal Clarity

Participants expressed mixed feelings on the subtheme of Goal Clarity, which covers students' understanding of both their short and long term goals during their use of the LogicGate-R System. Discussion here covered some good and bad points, with participants again showing concern over the introductory areas and wishing for greater orientation and practice at these points. The overall goals were felt to be very clear, with the theme of opening the doors and escaping from the rooms having resonance with participants.

> *"Actually playing the game wasn't complicated. It was reasonably informative, so you weren't getting confused as to where you were supposed to go, it was more, what do I need to do? Not, where do I need to go to continue?"*

Some discussions were over the later stages, where the goal changed, with students sometimes missing the text cue and looking for a door as in previous sections.

6.5.3.4 Perception

The theme of Perception covers the aspects of the experience that coloured participants' view of the game. Within this theme participants discussed factors that affected their Immersion, Concentration, appreciation for visual design, participants' desire to play and reasons for doing so. Participants shared a wide range of views on these issues, which are explored in more detail through the subthemes below.

6.5.3.4.1 Immersion

The subtheme of Immersion covers students' engagement with the LogicGate-R System, Immersion is particularly the ability to lose track of external factors and to feel deeply involved in the game. Within this subtheme, participants discussed an ability to lose track of time as the game felt enjoyable. Participants noted the emotional involvement and commitment in later puzzles leading to a sense of achievement and release when they succeeded.

> *"Maybe, it was really exciting to escape after in the doors really long and you just feel this relief and you're like: Oh, yes, I did it."*

Participants did express some concern that the difficulty level could lead to a break in immersion when students were confused as to their next step if they were unaware why a solution was not working.

6.5.3.4.2 Concentration

Concentration as a subtheme covers participants' ability to focus on the LogicGate-R System. In particular participants discussed the ability to remain engaged with the game, citing enjoyment as a factor in this.

> *"So, if… I'm enjoying it, say, which I probably would a game, I'd be far more willing to spend the extra half hour doing that as opposed to sitting there, pen and paper, working through a sheet."*

Further discussion covered the multi-player nature of the LogicGate-R System as a factor that encouraged participants to remain committed to playing.

6.5.3.4.3 Aesthetic

The emergent subtheme of Aesthetic addressed the look and feel of the game. Participants expressed appreciation for environmental features of the game, with weather effects and the day night cycle serving to enhance students' enjoyment.

> *"Every room was really mysterious, and the lights were cool and the graphics, like the… the rain falling down.*

Participants did express concern over the simple aesthetic style presented, feeling that perhaps the style of Minecraft could lead people to think the game to be childish.

6.5.3.4.4 Motivation

The subtheme of Motivation addresses aspects of the game that encouraged students to play or to continue playing. Particular reference was made to the enjoyment of the game, with participants wanting to continue playing through enjoyment as well as to learn. Rewards given out were felt to keep them encouraged, and participants cited a feeling of satisfaction when a section was completed, that encouraged them to continue on to the next section.

> *"…every time you have unlocked a door, you feel the progress. It's like your goal is achieved and you feel more motivated to keep going. It's very small competition task that you have to complete, which is exciting."*

Feeding into this, the checkpoints where teams reunited were felt to contribute to the sense of success, offering a chance to see the rest of the group in-game and know the group was going forward together.

6.5.3.5 Increased Responsibility

Increased Responsibility is one theme arising from the Student Centred Learning tenets, while appearing in discussion this theme did not have distinct overlap with any other themes, and as such is presented as a theme on its own without subdivision. It covers students' perceptions of their own responsibility for completing the tasks and accountability for the success or failure.

Participants discussed having others rely upon them and the nature of progression. Some participants felt they held a responsibility for leading or supporting their team, while others felt they could concentrate on individual aspects.

> *"I'm just waiting for everybody else to do it. As long as I did it properly, the door was going to open. As long as they all open, as long as everybody does their part the door will open. "*

Broadly participants expressed the idea that they were responsible for their performance in the game and that despite the group-based work, they had to contribute to succeed.

6.5.4 Knowledge Test Performance

All students completed the 5-question knowledge test prior to their learning experiences, and repeated this test following each learning experience. Table 16 presents their mean scores pre-experience and post-experience. Although test scores in the sample at baseline skewed higher (baseline skewness = -0.711), gap score skewness was lower (baseline vs post-LogicGate-R System = 0.572, baseline vs post-Traditional = 0.504). The paired t-test is considered robust against minor departures from normality provided the underlying distribution of the populations being compared is similar (Thode, 2002, Ghasemi and Zahediasl, 2012). As the assumptions for the paired t-test apply to the distribution of the differences between pre and post-experience test scores, visual inspection of gap score histograms for symmetry and weight of tails was performed, which is a common method for assessing normality in sample sizes above 30, where Shapiro-Wilk testing for normality can produce statistically significant findings even with a very small deviation (Ghasemi and Zahediasl, 2012). As the gap score histograms presented a more normal distribution with lower skewness, it was considered appropriate to proceed with a paired t-test to assess changes in knowledge improvement within the group.

A statistically significant increase in test score was identified after both learning experiences from baseline (post-LogicGate-R System gap score = 0.38, *one-tailed p = 0.036*, post-Traditional gap score = 0.44, *one-tailed p = 0.014*), but the level of improvement, identified through the gap score, was not significantly different between the two learning experiences.

This demonstrates that both the Traditional learning experience and the LogicGate-R System improved test scores by similar amounts.

Table 16: Statistical Analysis of Knowledge Test scores

	Mean Score (SD)	Gap Score (Experience - Pre-Experience	t	p-value
Pre-Experience	3.03 (1.68)	-		
Post-LogicGate-R System	3.41 (1.27)*	0.380		0.036
Post-Traditional	3.47 (1.41)*	0.440		0.014

*Statistically significant improvement from baseline at 0.05 level with one-tailed test

Post hoc, moderate to strong negative correlations were identified between baseline raw test score and gap score for each learning experience (post-LogicGate-R System R = -0.654, $p < 0.001$; post-Traditional R = -0.545, $p = 0.001$), indicating that higher baseline raw test scores were correlated with lower gap scores. There were no statistically significant differences in baseline raw test scores or gap scores for either learning experience between the group that completed the Traditional learning experience first, and the group that completed the LogicGate-R System experience first, showing that randomisation appears to have ensured student equivalence in baseline knowledge and learning ability between these groups.

6.6 Discussion

This study deployed the LogicGate-R System, a Student Centred Digital Game Based Learning experience, in a simulated classroom environment. A total of 32 Brunel University students used the LogicGate-R System in additional revision sessions to augment the study of the subject matter undertaken during their existing course. First the research questions will be addressed based upon the results presented in Section 6.5, this then leads to Implications and Recommendations for Deployment in Practice in Section 6.6.1 followed by an acknowledgement of the limitations upon this study in Section 6.6.2.

E2RQ1 sought to determine the extent to which the LogicGate-R System more effectively delivered all seven tenets of Student Centred Learning in comparison to a traditional, paper-based student centred classroom task. Analysis of the quantitative questionnaire data from the Course Experience Survey and eGameFlow survey indicated that students felt the LogicGate-R System delivers a comparable or superior experience to the Traditional exercise in all areas. Particular benefits were identified by students over the Traditional task in the tenet-linked constructs of Joint Productive Activity (*Mutual Respect, Active Learnin*g), Social Interaction (*Mutual Respect*) Autonomy (*Sense of Autonomy*, *Increased Responsibility and Accountability*), and Feedback (*Reflexive Approach to Teaching and Learning*). The LogicGate-R System is therefore capable of delivering a comprehensive student-centred learning experience and is able to improve upon traditional student centred techniques in a

number of key areas identified in the previous study. Further depth relating to extent of SCL tenet delivery can be provided through an examination of the qualitative data.

During thematic analysis of the qualitative data, support for the Reflexive Approach theme present in the previous study was not found within the current study. Groups partaking in the previous study had discussed lack of perceived opportunity to revisit what they had done, which had been addressed in the revised system by making it easier for students to return to earlier areas in the game. This may be a potential explanation for why this theme was not evident in the qualitative data obtained in this study. This is supported by quantitative findings which indicated that students rated the LogicGate-R System more highly than the Traditional task on the Feedback (*Reflexive Approach to Teaching and Learning*) construct within the eGameFlow survey in Table 15. In contrast, while the constructs of Complex Thinking (*Deep Learning and Understanding*) and Contextualisation (*Deep Learning and Understanding*) did not show significant improvement over the traditional task, qualitative analysis showed participants were associating learning with in-game experiences and found that they were actively utilising knowledge gained through play and through previous experience, demonstrating the successful integration of Deep Learning.

The Goal Clarity (*Increased Responsibility and Accountability*) construct was also associated with a negative gap score, although not statistically significant. The Goal Clarity theme presents clearly the key reasons for this perception on part of the students, as their difficulties with anticipating changing goals as the game progressed can be tied to responses on the Event Prediction, Game Progress and Goal Clarity components of this construct. Although the overarching goals of the game were considered clear, the qualitative findings indicate that clarity was lacking with regard to per-room and per-area individual and group goals, for example, identifying instances where an uncompleted goal for a teammate was impeding the team's overall goal progress.

However, delivery of this SCL tenet is supported by findings for the Autonomy (*Sense of Autonomy, Increased Responsibility and Accountability*) construct which was scored highly for the LogicGate-R System by students, over the Traditional task. This may be explained within the qualitative themes of Autonomy and Increased Responsibility, where students felt able to work forwards or backwards through problems individually as well as adopting a team leader role where they wished. Aspects within the Autonomy construct included questions on control of interactions and movements which are spoken to within **P4: Manipulation**, as well as on the free use of strategies related to **P2: Customisation**. The LogicGate-R System is designed to grant agency through implementing these DGBL principles, so that each individual's progress contributes to team progress, reducing situations where students are taking over and

completing the work for the whole team. This is reflected accordingly within the themes, as students felt their autonomy was enabled within the game and this gave them a sense of responsibility towards other students.

E2RQ2 explored the gameplay experience with the LogicGate-R System and whether students found it a more engaging learning experience in comparison to a traditional, paper-based student centred classroom task. The survey findings indicate the LogicGate-R System was rated more highly than the Traditional task for the Feedback (*Reflexive Approach to Teaching and Learning*) construct, identified as being an important user experience metric for student engagement earlier in this chapter. However for other user experience metrics such as Goal Clarity and Immersion, the LogicGate-R System was deemed by students to be equivalent to the Traditional task. With this in mind, it may be concluded that the LogicGate-R System is capable of providing an engaging learning experience, however the extent to which it delivers in all areas cannot be concluded from quantitative data alone. These findings can be explored and augmented further by examining survey reliability statistics and qualitative data.

Reliability statistics scores for the eGameFlow survey comfortably achieved the minimum threshold of 0.15-0.7 for all constructs, however mean Inter-Item Correlation for the Course Experience Survey was less consistent. This is in contrast to the previous study which showed acceptable reliability values when asking students to complete the Course Experience Survey to evaluate the LogicGate-R System in isolation. These findings would suggest that repeating the Course Experience Survey for different learning experiences may make it more difficult for the students to interpret certain questions within particular constructs. Two questions, one each from Contextualisation (*Deep Learning*) and Language and Literacy Development (*Reflexive Approach to Teaching and Learning*) were excluded to bring the construct score into acceptable bounds. The findings from both surveys may therefore benefit from being further augmented with qualitative data, to address some improvements not reflected within the survey findings and further explore the impact of improvements upon construct scores.

Students responded positively to changes to the LogicGate-R System's feedback approach, manifesting as a higher rating for the LogicGate-R System on the Feedback (*Reflexive Approach to Teaching and Learning*) construct. This is supported by the Feedback theme within the qualitative data, but can also be linked to the Motivation theme: feedback mechanisms such as doors opening and checkpoints where they were reunited with their team mates motivated student progression through the game. This can feed into questions on performance tracking and feedback on progress within the Feedback construct. A link may also be made to the Active Learning theme, within which students reported that the immediate

feedback from their activities was pleasing, another question within the Feedback construct. The topic of score did not arise within the qualitative data, in contrast to the previous study where feedback about the lack of a score in the qualitative data and the score awareness component of the Feedback construct led to the implementation of one in the revised system. It is possible that the presence of a score is a fundamental expectation of the students as part of the gameplay loop, thus more likely to attract comment by its absence rather than its presence as part of the background of a DGBL engagement.

For the theme of Concentration, participants reported finding the LogicGate-R System enjoyable and fun to learn through, making it easier for them to stay engaged, while multiplayer elements kept them committed. While quantitative data supports the role of the LogicGate-R System in promoting Joint Productive Activity (*Mutual Respect*) and Social Interaction (*Mutual Respect*), more so than the Traditional task, such effects were not noted for the Concentration (*Active Learning*) construct, at odds with the qualitative findings. Issues such as a noisy learning environment that arose in the previous study were not brought up by participants in the current study. Although not apparent within this theme, it is possible that survey questions within the Concentration construct may have been interpreted by students as asking about their ability to stay on task, with instances where they encountered a rest area or needed to support another student potentially representing a break in concentration. This may explain the mismatch between findings from the survey construct and qualitative data for this theme.

The theme of Challenge helps to explain the negative gap scores associated with this construct within the eGameFlow survey. Two clear components to this theme are apparent: the difficulty level increase was perceived by some students to be too fast, and students experienced challenge during initial orientation to the strong team-based elements of the LogicGate-R System, with this team-based working impacting perceived ease or difficulty in game progression. The former component relates to the content of the game and therefore contribution to delivery of the *Active Learning* SCL tenet, while the latter relates to the learning experience as a whole. Questions within the Challenge (*Active Learning*) construct ask about skills, pacing and difficulty, but the qualitative theme of Challenge sits under the Social Interaction subtheme because students perceived team working as one of the more challenging aspects of progressing through the game. Although positively received overall, it can be argued that the team-based elements of the LogicGate-R System may have interacted with student perception of the concept of ‘Challenge’, leading to the negative gap scores for this construct. While pacing of task difficulty levels also arose as an area for improvement related to the Active Learning theme, this is more easily addressed in future revisions of the LogicGate-R System, for example by adjusting the difficulty curve through additional easy and

intermediate challenges to aid students in further developing their mastery before the next evolution of the skills involved. It is important to bear this in mind when interpreting this result.

Overall, these integrated findings demonstrate that the LogicGate-R System was able to deliver all aspects of SCL to some degree (**E2RQ1**), and is capable of providing an engaging gameplay and learning experience over a traditional task (**E2RQ2**).

E2RQ3 sought to determine the extent of student knowledge improvement after exposure to the LogicGate-R System in comparison to a traditional learning experience, to answer this the test scores from pre and post exposure to each learning experience were examined. Knowledge test scores identified that both experiences provided an equivalent boost to test scores and delivered roughly the same impact on learning outcomes. This is supported by the eGameFlow survey construct of Knowledge Improvement, which showed little difference between the LogicGate-R System and the Traditional task. This indicates that the LogicGate-R System produces at least a comparable knowledge improvement to the traditional learning experience, while more comprehensively delivering upon the tenets of Student Centred Learning. It is particularly notable that the average initial test scores were high, with a mean of 61%, potentially due to the deployment of the LogicGate-R System being presented within a revision session. As gap scores were used to identify the improvement to these scores it is possible the initially high scores mask the extent of the learning experience. The use of gap scores in this way is established to control for students starting from differing baseline knowledge levels, however it does not control for this ceiling effect on higher scoring students who have little to no room to improve further (Theobald and Freeman, 2014). This existence of this effect is supported by the strong negative correlation between baseline test scores and gap scores, with lower scoring students achieving higher gap scores. The need for an effective method to assess the impact of a learning intervention is an area of ongoing work within the field of education. The study design selected provided a practical limit to the depth of knowledge testing that could be used, however more in-depth testing of knowledge improvement may form an area for future work upon the LogicGate-R System. The use of randomisation in this cross-over study controls for the impact of differing student characteristics between groups within the sample, such as baseline knowledge level and ability to learn the content, which could potentially affect test scores (Theobald and Freeman, 2014). Post-hoc independent t-tests indicated no statistically significant differences in baseline test scores or gap scores between the group that completed the Traditional experience first or the LogicGate-R System first, demonstrating that randomisation achieved student equivalence between groups. The similarity in test score improvement following experience with the LogicGate-R System and the Traditional task cannot therefore be attributed to differences in academic ability between students. Taking into account the success of the randomised control,

it appears that the LogicGate-R System is demonstrably equivalent to a Traditional task in terms of achieving learning outcomes, answering research question **E2RQ3**.

E2RQ4, which explored students' views on SCDGBL as a vehicle for their learning, can be answered through the thematic analysis of qualitative data. Overall, students were keen on the use of SCDGBL experiences within their learning, with this being particularly evident within the themes of Social Interaction and its subthemes Mutual Respect and Sense of Autonomy; Knowledge Improvement and subthemes Active Learning and Deep Learning; the Game Design subtheme of Feedback; and Perception subthemes of Concentration and Motivation. Students were broadly receptive to the idea of SCDGBL experiences within future courses and viewed the LogicGate-R System as an enjoyable way to learn. They were aware of their learning throughout the game and valued important aspects within the Game Design theme that facilitated their learning, such as instant feedback on changes they made within the game and whether they yielded solutions. The cooperative learning experience at the heart of the LogicGate-R System was viewed positively by the students, who contrasted it to other group-based exercises that they had done in class, but they also perceived this to be a core source of much of the challenge of the game. They were supportive of working with others and felt the SCDGBL experience also changed their view of learning with their peers through seeing them respond to challenges and taking on increased responsibility to lead or support others in their group. However, the Perception theme did raise an issue relating to the perception of learning through games potentially not being perceived as serious or mature, depending on the aesthetic. This may be something future games delivering SCDGBL experiences must work to overcome, to achieve wider acceptance within a variety of learning environments. Future studies may seek to establish the degree of acceptance in students at different educational levels, potentially utilising established acceptance metrics alongside the qualitative approach adopted in the current study.

In response to feedback gained from the initial testing of the LogicGate System in Chapter 5, a number of improvements were made. These were as follows: (1) The need for greater levels of immersion during the experience. (2) A need for more feedback on student performance and goals. (3) A more well-paced experience that eases pain-points in group-work. The quantitative data provides evidence for the achievement of some of these goals, which are explored below.

To achieve (1), a storyline was added to improve immersion. The Immersion construct explored through the eGameFlow survey demonstrated an improvement approaching significance over the Traditional task. This construct was notably rated much higher by students within group A, who had undertaken the Traditional task first. This may indicate that,

comparatively, the changes made to the game offer a more immersive experience than traditional learning, but are insufficient in isolation for participants playing the game first to rate it highly in this area. This is one of a number of areas where the analysis showed that the order of learning experiences mattered, and that despite instruction to evaluate based on the experience they just had, a comparative effect does seem to exist. The cross-over design of this study allows for the control over this variable, however as a result it is possible that some comparative benefits of the LogicGate-R System over the Traditional task are masked, with this effect on immersion being a key example. Further aspects of story and immersion are addressed within the qualitative analysis.

The improvements made to the presentation of Feedback and to Goal Clarity met with mixed results. Participants expressed that the overall Feedback (*Reflexive Approach to Teaching and Learning*) construct within eGameFlow was significantly improved over the Traditional task, however the Goal Clarity (*Increased Responsibility and Accountability*) construct showed a decrease from the Traditional task which did not achieve significance. This indicates that the improvements were effective, but that there is still further to go in the realisation of Goal Clarity, important in easing students into the game and in maintaining effective flow within the game.

Having evaluated this deployment of the LogicGate-R System, and its role as an exemplar of SCDGBL experiences within the classroom, a number of more generalisable implications for wider deployment arise. These implications will now be discussed alongside recommendations for the deployment of this and future SCDGBL experiences in teaching and learning practice.

6.6.1 Implications and Recommendations for Design, Development and Deployment in Practice

The deployment of the LogicGate-R System, as detailed within this chapter, including the testing and evaluation performed, give rise to some recommendations and implications that can be offered for the design, development and deployment of this and other games that create SCDGBL experiences in practice. These implications and recommendations are summarised in Table 17 which demonstrates for the findings the two areas of focus, associated qualitative themes and survey constructs, and the linked SCL tenets.

Table 17: Implications and Recommendations for Deployment in Practice

Area of Focus	Finding	Themes/Constructs	Linked SCL Tenets
Implications and Recommendations for Deployment in Practice	Importance of team-work should be emphasised to students from the introduction of the exercise to clarify goals	Goal Clarity, Challenge, Increased Responsibility	*Teacher and Learner Interdependence (ID)*
			Increased Responsibility and Accountability (IR)
			Mutual Respect (MR)
	Multiplayer experiences offer important social benefits	Social Interaction, Concentration	*Active Learning (AL)*
			Mutual Respect (MR)
	Students supportive of the use of SCDGBL Games to augment learning	Deep Learning, Contextualisation	*Deep Learning (DL)*
	Deployment outside of an evaluative research project may result in deeper student engagement	Immersion	-
	The value of student feedback is important in deploying the experience	Improvements	*Reflexive Approach to Teaching and Learning (RA)*
Design and Functionality Recommendations	Provide improved orientation and onboarding process to prepare students for the team-based work.	Social Interaction, Challenge, Joint Productive Activity	*Mutual Respect (MR)*
			Active Learning (AL)
	Delivery of knowledge through multiple channels to suit individual students	Information Provision	*Sense of Autonomy (SA)*
	Maintaining rapid feedback enhances student attention	Feedback, Immersion	*Sense of Autonomy (SA)*
	Deeper tutorial section to introduce game mechanics and taught concepts at a slower pace	Knowledge Improvement, Goal Clarity	*Active Learning (AL)*
			Deep Learning (DL
	Increased awareness of peers' activities may help students direct peer support more effectively	Increased Responsibility, Immersion, Social Engagement	*Active Learning (AL)*
			Increased Responsibility and Accountability (IR)

6.6.1.1 Implications and Recommendations for Deployment in Practice

This focus area covers identified recommendations that may inform and direct wider deployment of the LogicGate-R System in routine teaching and learning practice. Each of the identified implications and recommendations are discussed along with the themes and constructs that informed them and how they may serve to enhance the delivery of any associated SCL tenets.

While increased attention and emphasis has been placed on the team work components in the LogicGate-R System, based on student feedback obtained in Chapter 5, qualitative findings relating to the themes of Goal Clarity, Challenge and Increased Responsibility indicate that still more needs to be done to clarify to students that this is an integral aspect to group success and progress. When using the LogicGate-R System in practice, it is therefore recommended that additional information is delivered to the students by the teacher or demonstrator (*Teacher and Learner Interdependence*) before engagement with the activity to set expectations among students (*Increased Responsibility and Accountability*). This may include explicit mention of team work as a learning outcome (*Mutual Respect*).

Students were positive about the multiplayer aspects of the game as a whole, recognising that important social benefits were offered by this SCDGBL experience, in particular students expressed surprise over the speed at which others in the group were able to pick up on concepts as they were explained through peer learning, a technique within *Active Learning* and the contribution this *Mutual Respect* made to deepen their engagement, as shown in the themes of Social Interaction and Concentration. This in turn demonstrates the implication that students appreciate and valued learning through this multiplayer SCDGBL experience.

The use of SCDGBL experiences within a standard curriculum was welcomed by students, as was the positive overall reception to the LogicGate-R System. However, students expressed concerns over their initial exposure to an area, topic or concept being within a game-based experience. In contrast, students were very open to the idea of utilising games to further develop and reinforce their understanding of a topic area following an initial experience through a lecture or teacher-led explanation (*Deep Learning*), reflected in the Contextualisation and Deep Learning themes/constructs. Practitioners may wish to establish and bear in mind these preferences within their students when deciding the appropriate time to make this experience available, although it is possible that such preferences may change as students become more familiar with the use of SCDGBL experiences in a classroom environment

While this study indicates strong potential for the practical usage of the LogicGate-R System within a standard curriculum, it should be noted that there are inherent differences in an experimental study such as that within this paper as opposed to a standard classroom or laboratory session which goal remains exclusively the education and learning of the students. In particular the repeated tests and surveys utilised to gain an understanding of student opinion and performance form breakpoints in students' concentration, and may detract from their engagement with the tasks at hand, as shown in the Immersion theme and construct. It

is possible that this may be naturally corrected when deployed within a standard classroom or laboratory environment.

The LogicGate-R System presented within this chapter forms a natural successor to the LogicGate System previously evaluated in Chapter 5. Within practice, the LogicGate-R System has been designed such that practitioners may make modifications and adjustments to suit the needs of their own classes and students, as reflected in the Improvements theme. While the collection of feedback is expected within a research trial as part of the evaluation process, it is recommended that practitioners also engage in gathering student feedback with a view to adjusting their application of the LogicGate-R System reflexively to meet the needs of their students (*Reflexive Approach to Teaching and Learning*).

6.6.1.2 Design and Functionality Recommendations

A key recommendation emerging from the qualitative data relates to the orientation and onboarding process within the LogicGate-R System that prepares students for the team-based work. This is reflected in the Social Interaction, Challenge and Joint Productive Activity themes. While modifications were made to this area including delivering information on the teamwork focus of the experience through audio as well as text cues, students expressed concern that they were not fully prepared for the depth of peer interaction required within the experience. Future iterations of the LogicGate System may seek to resolve this through introducing students to the team-based nature of the experience before introducing the early curriculum content, thereby ensuring the first activities student engage in within the game involve a high degree of peer-based cooperation (*Active Learning*), thus setting expectations for the remainder of the exercise (*Mutual Respect*).

Students expressed approval for the audio delivery of story and events as well as the referable library of text-based information, represented in the Information Provision theme. However, a number of students only engaged with one or other source and therefore missed information contained exclusively within one form of media. Students felt this impacted their ability to progress at points within the experience as they did not have the appropriate information to fully understand the task at hand (*Sense of Autonomy*). In order to tackle this issue in future revisions of the LogicGate System, it is recommended that all information be provided in both audio and text format to suit a learner's preferred method of engaging with such information. This approach may also offer benefits for students who suffer from sensory impairment or specific learning difficulties who would otherwise have been unable to engage with this information.

On the topic of in-game feedback, students expressed a high level of approval for the speed at which they were able to see if a solution had succeeded, allowing them to quickly iterate to

find solutions to problems and solve ongoing issues (*Sense of Autonomy*). This rapid response to feedback was noted to help keep students engaged within the game as they were not waiting for responses and were immediately able to continue their learning without pause. This finding is demonstrated within the Feedback and Immersion themes. For this reason, it is recommended that future iterations of the LogicGate System and other games designed for SCDGBL experiences incorporate the immediate presentation of feedback to students within the design as an effective tool to maintain engagement and promote effective learning. This includes redesigning puzzles where the response to an action is hidden to include more obvious responses to alert a player that a change has been made and potentially to indicate which peer within the team may be affected.

A number of students felt that the introductory and tutorial areas of the game offered a brief explanation and introduction the game's mechanics and early taught concepts (*Active Learning*). Some students felt that this introduction did not sufficiently explain the game mechanics in a way that allowed them to fully participate in early team-based tasks, while others, notably many of those familiar with the basic Minecraft game, were able to import this understanding and therefore engage faster. This issue is represented within the Knowledge Improvement and Goal Clarity themes/constructs. This creates a disparity in learning paces between students, which is in part ameliorated by the peer-based nature of the task, allowing those experienced students to pass on their understanding, but which nonetheless must be acknowledged. Future iterations of the LogicGate System may seek to avoid these issues through the inclusion of an extended introduction and tutorial area. This tutorial area should focus not just on the educational content but also explore the game mechanics and with which students will engage at a slower pace (*Deep Learning*) presenting these to allow students to learn to interact with them alongside and intermixed with the academic content. Such a tutorial section may be designed with the opportunity for the experienced students to bypass this area, however it is important to provide such students with engaging and relevant activities to pursue while their peers engage in these tutorials to ensure engagement is maintained.

In response to previous student feedback in Chapter 5, checkpoint areas were introduced which offered a clear opportunity for students to see when their group was all ready to proceed to a further challenge. Students responded positively to these changes, feeling that they offered a shared sense of achievement (*Increased Responsibility and Accountability*), however students felt that at other points it was not clear where their group members were and what activities they were currently engaged with. This could lead to a break in immersion as students felt the game did not provide them with the necessary tools to understand the impediment to progress their team mate was facing, and therefore felt unable to effectively render assistance (*Active Learning*). These issues were highlighted across the themes of

Increased Responsibility, Immersion and Social Engagement. Students requested to have access to all parts of a puzzle, such that they could fully direct other group members, however the removal of this hidden information aspect of the game is likely to impact on student learning as it would reintroduce one of the common flaws of group learning in allowing a single student to complete the puzzle for the entire group, and therefore would not be recommended. Recommendations to address this issue in future iterations include incorporating a visible indicator within each puzzle for which students were ready to progress such as a sequence of traffic lights indicating which doors are currently open. This indicator would help students understand where assistance may be offered and which students were in a position to offer assistance without interrupting a task. Alternatively, a greater visibility of player position may be integrated through enhanced player position indicators or the addition of a mini-map showing player position, such that a student could see if a group member was within the same area and engaging with the same task.

6.6.1.3 Further Revision to the SCE Framework

The study presented within this section evaluates a game developed utilising the SCE Framework. It is desirable to further develop and iterate upon this framework to ensure its is accessible, applicable and that it delivers upon its goal of enabling teaching and game design professionals to design games that integrate all seven tenets of SCL. This study however does not present a comprehensive evaluation of the SCE framework to ensure it is effectively meeting those goals. In order to ensure that future revisions of the SCE framework continue to build towards effective delivery of these goals it is recommended that a more targeted study looks to evaluate the framework in isolation, looking at how professionals from within these fields are able to make use of it and using this to shape future revisions. Potential areas for investigation may include the accessibility, in particular clarity on how the different aesthetic dimensions can be identified and incorporated. Further improvements may include the use of exemplars to showcase successful realisation of DGBL principles and clearly identify where this has improved the learning experience for players through the alternative lenses. This forms an area of future work that would take the form of an additional research study.

6.6.2 Limitations of Current Study

This study evaluated the LogicGate-R System as deployed within a simulated laboratory environment. Although the deployment was successful and revealed some significant gains over both the Traditional task and the previous system, some limitations were encountered which may impact the breadth of the study, and which may be overcome in future studies.

This study utilised a simulated classroom environment, this environment was designed to recreate a laboratory setting as experienced by students through their course, but by necessity

such recreation is not perfect, as students are aware that the session they are entering is not a standard laboratory experience. While the session was presented as a revision session, to minimise the effect of this and retain a connection to the students' course, it was nonetheless notably different due to the presence of research elements such as consent forms and information sheets, and this may colour students' perception, thus a research participation or 'Hawthorne' effect cannot be ruled out, although the degree of impact of such effects is extremely difficult to capture (McCambridge et al., 2014). In addition the recruitment required students to volunteer to take part in this session, such self-selecting groups may skew participants towards those who are more interested and invested in the course or in research. This may be fixed in future through deployment in a live classroom environment which surrenders some environmental control in favour of a broader recruitment base.

Reliability scores for the Course Experience Survey were less consistent compared to the previous study, indicating findings for this particular instrument should be interpreted with caution within this study. Qualitative data helps to support Course Experience Survey findings, increasing validity, but exploring alternative measures that are perhaps more suited for comparison of learning experiences may be warranted for future comparative work.

Assessment of Knowledge Improvement was limited by time constraints and the test chosen. Participants showed a good understanding of concepts coming in and a ceiling effect may disguise the results of exposure to the two experiences. This may be remedied by more in depth testing to capture more subtle misconceptions, but must be measured against students' willingness to undertake such and against the respondent fatigue that repeated quizzing or longer questionnaires may induce (Ben-Nun, 2008). Further options include assessing knowledge improvement directly through the tasks however this has issues as the separate knowledge improvement assessment is common to both the traditional task and the LogicGate-R System, therefore removing this shifts the focus to the student's ability to negotiate the method of assessment, rather than their performance on the assessment itself.

The retention of knowledge was not assessed over time, as students took part in the study and were assessed before returning to their normal learning experiences. The conduct of longitudinal studies may offer opportunities to understand if there is a long term effect on knowledge retention through the use of the LogicGate-R System which can support not only the realisation of educational goals but also demonstrate further the effective implementation of Deep Learning (Darland and Carmichael, 2012).

Test scores were not linked back to areas of the game students can revisit to learn more about areas where they scored poorly. This sort of integration would flow naturally from the SCE

model and could offer a future improvement through moving the testing inside the LogicGate-R System (Biggs and Tang, 2015).

Goal Clarity remains an area for further improvement. It is important to build in further ways for students to identify their next steps in ways that do not significantly increase gameplay time. Opportunities for this may include further matching of progression between participants, and user interface indications as to peer progress, such as a mini-map.

6.7 Conclusion

This study deployed and evaluated the LogicGate-R System, a Student Centred Digital Game-Based Learning experience within a simulated classroom environment in comparison to a traditional Student Centred task. The study compared the two tasks and assessed how effectively the LogicGate-R System was able to deliver on all aspects of Student Centred Digital Game-Based Learning and how effectively it delivered the learning outcomes. In answer to the research questions: **E2RQ1**: The LogicGate-R System does deliver all aspects of Student Centred Learning as assessed through the Course Experience Survey and eGameFlow survey and supported through the focus groups. The tenets of *Active Learning*, *Mutual Respect*, *Sense of Autonomy*, *Increased Responsibility and Accountability* and *Reflexive Approach to Teaching and Learning* in particular demonstrated notable improvements over the Traditional task showing that the LogicGate-R System can form an effective part of a student centred classroom. In answer to **E2RQ2**: Participants felt the game was engaging and provided an interactive experience that made good use of peer engagement. Students remained positive about the deployment of games in educational situations and were supportive of the utilisation of cooperative and collaborative experiences in game-based learning. There remain improvements to be made as demonstrated by the constructs of Challenge, Immersion and Contextualisation which show areas where future revisions and future games should look to focus. In answer to **E2RQ3**: The LogicGate-R System demonstrated an equivalent performance to the Traditional task in knowledge improvement, showing that it is an effective way to deliver learning and can deliver the learning outcomes set out for the task and topic area. Future work on the LogicGate-R System may seek to establish the long term effectiveness of use of the LogicGate-R System particularly with regard to knowledge retention. Improvements to the game may include extending the game to allow a slower learning curve, and integrating testing into the LogicGate-R System to further develop the reflexive learning aspect of the game. Finally the improved system may be deployed in a wider context to assess its practicality outside of close support by the researcher and to gather wider participation data. Such improvements may be addressed in a future revision of the LogicGate-R System and wider deployment evaluated in future studies.

Chapter 7. Conclusions, Recommendations and Future Work

7.1 Introduction

This final chapter provides a summary of the overall work completed in this thesis; it discusses and concludes the findings of the research in the context of the objectives outlined in Chapter 1. This is accompanied by a description of the final contributions made to the research domain. Section 7.2 provides an overview of each chapter in the thesis. Section 7.3 addresses the key research findings drawn from each chapter and presented in relation to the overall research objectives outlined in Chapter 1. Section 7.4 sets out the contributions made through this research to both the academic study of this area and to the wider practice of education. Section 7.5 then establishes the limitations of this research and sets out a number of recommendations and areas of future work to be undertaken to further understanding.

Returning to Chapter 1, the research aim guiding the work undertaken was as follows:

> *To develop and evaluate a novel game-based educational artefact that fully realises all aspects of Student Centred Learning in delivering an engaging and effective educational experience.*

This objective informed the work documented in this thesis and provided direction as the individual research stages were undertaken. These research stages are documented below.

7.2 Thesis summary

7.2.1 Chapter 1

Chapter 1 introduced the research aim, presented above, which would form the justification for the work undertaken and research reported within this thesis. An overview of the domain of Student Centred Digital Game-Based Learning was provided, including the need for greater integration of the techniques within Student Centred Learning within digital games. While a number of areas for future work had been identified within the literature review, the most pressing of these were selected to form the focus of this research and formed the research aims presented. A description of the research approaches follows, identifying the methods through which the research was to be undertaken. The expected contributions of the research were outlined, followed by a roadmap for the thesis chapters.

7.2.2 Chapter 2

Chapter 2 presented a comprehensive and systematic literature review, identifying the state of the art in SCDGBL and including a conceptual framework derived from and used to categorise the range of games that seek to create SCDGBL experiences and studies available. Components in the framework were then utilised to discuss the literature domain

and explore the findings associated with each component. The findings from this were explained, and the identified gaps provided the basis for recommendations for future work within the field. These gaps included the lack of attention during the game design process to several key tenets of SCL, including particularly provision for the tenets of *Teacher and Learner Interdependence*, *Mutual Respect* and a *Reflexive Approach to Teaching and Learning.* The identified gaps and associated recommendations provided the basis for the further research undertaken and reported within subsequent chapters.

7.2.3 Chapter 3

Chapter 3 sets out the research approach utilised to achieve the research aims and objectives identified. This research approach, using the design science research process was explained, along with its integration with the design thinking framework utilised alongside it. The data analysis techniques were presented including the nature of the mixed-methods approach to data collection and analysis utilising qualitative and quantitative data. The general and ethical considerations which guided and were followed by the work were discussed. A conclusion section then presents a summary of the chapter.

7.2.4 Chapter 4

Chapter 4 presents the game design framework which would guide the design of a game that creates a comprehensive SCDGBL experience, with this framework used and evaluated in subsequent chapters. The need for a framework for game design is laid out, followed by an exploration of current game design frameworks and their suitability for the purpose of designing a game according to the research aim. Following this the steps undertaken to develop a SCDGBL framework are laid out according to the stages of the design thinking process utilised to accomplish this task. The theoretical underpinnings and components and their integration is explored, and the developed framework then presented. The utilisation of this framework is discussed and the chapter ends with a conclusion identifying the need for further cycles of revision, which is undertaken in subsequent experimental chapters.

7.2.5 Chapter 5

Chapter 5 reports Experiment 1, undertaken with foundation year students at Brunel University to assess the effectiveness of the LogicGate System at delivering the tenets of SCL and at maintaining student engagement. The design of the LogicGate System was guided by the framework presented in Chapter 4. The design and system architecture of the game are presented. This is followed by a walkthrough of the game stepping through each stage and identifying the principles drawn from the framework presented in Chapter 4, and their integration into the game environment. The outcome measures, participants and procedures are laid out including the participation requirements and environment utilised. The qualitative

and quantitative results are then stepped through, identifying areas of strength and weakness in the game. These areas are discussed and feedback from participants is utilised to identify areas for improvement. Results showed that while the multiplayer nature of the game was appreciated, the integration of the tenets of *Teacher and Learner Interdependence* and *Reflexive Approach to Teaching and Learning* were areas to improve. Implications and recommendations for further practice and for further revision of the application are presented and form the chapters' conclusions.

7.2.6 Chapter 6

Chapter 6 presents Experiment 2, undertaken using first year students at Brunel University to compare the SCDGBL experience created from deploying the LogicGate-R System to traditional SCL experiences, at both delivering the tenets of SCL and at enhancing student understanding. The re-design of the LogicGate System is presented, including the revisions to the framework developed in Chapter 4 to reflect social needs within the game. A walkthrough of the revised application details the changes undertaken and the theoretical underpinning that supports these changes. The study design is presented including the participant information, outcome measures and data analysis techniques employed. Results from the qualitative and quantitative data collected are set out. The findings highlighted that LogicGate-R System was able to deliver all tenets of SCL and to achieve equivalent educational outcomes to traditional tasks. Future work was identified to further improve the LogicGate-R System and to assess its effectiveness in a wider context.

7.3 Overall research findings and the meeting of objectives

RO1. Identify gaps in the state of the art through a survey of the literature in this domain, and develop a conceptual model of that domain from which aspects of those systems can be classified and explored.

In order to identify gaps in the research area, a systematic survey of the SCDGBL domain was undertaken. This survey is presented within Chapter 2, which also proposes a conceptual framework for the classification of literature within this domain, linking the tenets of SCL with the principles of DGBL. A number of recommendations arose from the classification of the literature using this framework, a selection of these recommendations would inform the research foci which guide this work:

- Deeper integration of peer-based *Active Learning* techniques to promote the social aspects of SCL, in particular *Teacher and Learner Interdependence* and *Mutual Respect.*
- Greater involvement of teachers within game environments in an active role, to further facilitate *Teacher and Learner Interdependence* and *Mutual Respect.*

- Provision of games that allow for modification and adaptation of the created SCDGBL experience by teacher-practitioners without requirement for deep programming or graphic design skills, to enable teachers in their *Reflexive Approach to Teaching and Learning.*
- Provision of opportunities for role reversal, in which skilled students take on a demonstrating or leadership role within cooperative gameplay, to build *Mutual Respect.*
- Support theoretical work with studies to implement and evaluate the ideas explored.
- Provide learners with a role to play within the SCDGBL experience to personalise learning to the individual, developing *Deep Learning and Understanding*
- Deeper integration of Learning Outcomes into World Building at an early stage to associate game progression with subject learning and understanding.

The findings from this review of the state of the art in SCDGBL identified that current SCDGBL offerings do not appear to tap into all areas of SCL, with the Social Aspects (Section 5.1.2) in particular being neglected due to the preponderance of single player experiences. This informed both the need for a focused game design framework that incorporated all aspects of SCDGBL, to provide a comprehensive Student Centred experience (the Student Centred Experience framework presented in Chapter 4), and the decision to focus on designing a multiplayer, collaborative game guided by the SCE framework to deliver a SCDGBL experience (the LogicGate System presented in Chapter 5, and the LogicGate-R System in Chapter 6).

RO2. Design and develop a conceptual approach to delivering the gaps in Student Centred Digital Game-Based Learning identified above and explore the practicality of applying this approach.

Based on the literature review, it was established that there are a number of frequently missing tenets of Student Centred Learning. This systematic absence suggested that designing a game which incorporates all aspects of Student Centred Learning presented a challenge which was as yet unaddressed. Such a design should utilise good practice in both SCL and in Game Design, which includes following a design framework to ensure the integration takes place in a systematic way. In order to ensure this game artefact is effectively designed the research followed a Design Science Research approach utilising two iterations of the research cycle and incorporated a mixed methods approach to feedback and data analysis.

DSR is a well-established paradigm used in projects where the creation and refinement of artefacts is a core output integrated with the refinement of knowledge and understanding. In this case, the artefacts produced would form the Student Centred Experience framework, the

LogicGate System and its successor, the LogicGate-R System. This approach would be coupled with further techniques, most notably the Design Thinking framework, to develop innovative solutions.

RO3. Develop a framework to enable and assist with the design of games delivering Student Centred Digital Game-Based Learning experiences.

Within the first iteration of the DSR approach, it was clear that best practice in games design stressed the importance of developing a framework which would assist and guide the design process to ensure the game created incorporated all tenets of SCL. A number of existing frameworks for game design were identified and evaluated, however they did not suitably address the need for the integration of SCL at the initial design stage leading to the need to create such a framework to support development. Within the *Define* stage of DT, a problem statement was formulated to guide the nature of the framework to be developed. Within the *Ideate* stage, the frameworks were examined and the MDA framework was selected as the basis for adaptation, being a generic framework and so open to adjustment and being well respected and utilised within the academic and industry communities. The existing combination of SCL tenets and DGBL principles established in Chapter 2 was identified as the basis for this SCDGBL framework. This theoretical backing was coupled with additional SCL and game design theory identifying the need to consider aspects of World Building, Player Experience, clearly defined Learning Outcomes and appropriate Assessment. The theory identified would be coupled with the MDA framework to produce the first iteration of the Student Centred Experience framework, which would guide the development of the game-based educational artefact in Objective D.

Following the application of the SCE framework in Chapter 5, some revisions were made to adapt the framework and improve areas that were not addressed, the dimension of Fellowship was incorporated and other implications were adapted to reflect the opportunities and needs to integrate social aspects into the games design.

RO4. Develop a game-based educational artefact based upon the above conceptual design that implements the identified aspects of Student Centred Learning.

Two iterations of the DSR approach cover the development, testing, deployment and evaluation of the game-based educational artefact designed utilising the SCE framework to ensure a comprehensive SCDGBL experience.

Artefact development based on the SCE framework

The LogicGate System offers a multiplayer, student centred experience that teaches students Boolean logic through interactive group-based puzzles. The use of Minecraft as a framework

to base the game on allows for easy adaption and modification by teachers and lecturers while providing an adaptable but unified look and feel throughout the experience. Through the use of voice communication systems and limiting the provision of information and access to actions students must work collaboratively in a team to progress. Teachers are offered the opportunity to join in both in game and in the voice communication software with the students to interact with and assist students and to play on a similar level. Student experience learning through a series of puzzles which integrate game progress and strategies with subject based learning outcomes to deliver deeper learning and understanding associated with the application of skills. Through these methods, the LogicGate System integrates all tenets of SCL from the design stage and uses this to deliver an effective and engaging learning experience.

The revised system, LogicGate-R, builds upon the LogicGate System by integrating in-game story to offer students emotional reasons to progress, while adding additional elements to make tracking team progress easier and incorporating a time-based scoring system which further encourages students to attempt to finish the game.

Implementation of SCL tenets within the artefact

E1RQ1: Within Experiment 1, RQ1 sought to establish *"To what extent does the LogicGate System deliver all tenets of Student Centred Learning?"* This was assessed through the use of the Course Experience Survey and eGameFlow survey. Through these instruments, participants indicated that the tenets of *Active Learning*, *Deep Learning*, *Sense of Autonomy* and *Mutual Respect* were significantly improved over the baseline. No tenet was assessed as being below the baseline. These results indicated that the tenets of SCL were all integrated to some level within the game, while identifying areas for further improvement.

E2RQ1: Experiment 2, included within Chapter 6, sought to establish "*To what extent does the LogicGate-R System deliver all aspects of Student Centred Learning in comparison to a traditional, paper-based student centred classroom task?"* This research question was evaluated through the use of the Course Experience Survey and eGameFlow survey which were administered following both the LogicGate-R System and traditional task. The tenets of *Active Learning*, *Mutual Respect*, *Sense of Autonomy*, *Increased Responsibility and Accountability* and *Reflexive Approach to Teaching and Learning* were particularly highly rated by participants with the remaining two tenets achieving equivalence with the traditional student centred task. This indicates that the LogicGate-R System is able to offer a full Student Centred Learning experience that incorporates all tenets.

RO5. Evaluate the developed artefact through appropriate means to assess both the educational effectiveness as a tool for learning alongside the acceptability and usability for users.

Acceptability and Usability

E1RQ2: This research question in Experiment 1 sought to identify "*Does the LogicGate System provide an engaging method to learn the taught concepts?*" This research question was addressed through the constructs of Immersion and Concentration within the eGameFlow survey, and through the qualitative data collected from focus groups. Results from the construct of Immersion identified this as an area for improvement, this was augmented by focus group data where participants indicated that elements of the setting and game were distracting, though students felt that the learning was enjoyable and engaging. This identifies engagement as an area for improvement with revisions seeking to build students focus on the game and reduce opportunities for distraction.

E1RQ3: Further assessment of acceptability within Chapter 5 was made using the question "*Are students receptive to learning through Student Centred Digital Game-Based Learning?*" This research question was evaluated through the Focus Group process in Experiment 1. Participants expressed positive reception to the use of SCDGBL experiences in future and were positive about further collaborative experience. A number of pain points were identified which inhibited teamwork and collaborative experience which formed areas of improvement in later revisions.

E2RQ2: Within Chapter 6, the following research question was addressed "*Does the LogicGate-R System provide a more engaging gameplay and learning experience in comparison to a traditional, paper-based student centred classroom task?*" This was assessed primarily through the qualitative data from focus groups. Participants expressed positive reactions to the feedback provided by the game, and to the motivating factors that encouraged students to engage with and progress further in their game and learning. Further issues were identified in the clarity of reading some game components and further improvements in immersion were identified which form areas for future work. Overall it can be said that while the LogicGate-R System achieves this aim, there are areas further revisions and future games could seek to improve upon.

Educational effectiveness

E2RQ3: The educational effectiveness of the LogicGate-R System was established within Chapter 6 through the research question "*To what extent does the LogicGate-R System improve student knowledge in comparison to traditional learning experiences?*" This was assessed through the knowledge test conducted before and after both the traditional and SCDGBL experiences. Both experiences demonstrated an improvement in knowledge, with the improvement being equivalent within both experiences. This indicates that the LogicGate-

R System is as efficient at delivering learning outcomes as the traditional task and thus offers promise for deployment in the standard curriculum as a part of a student centred course.

7.4 Key contributions of the research

Through this work, a number of key contributions to the research sphere of SCDGBL have been developed. These contributions may be identified and summarised as:

- A conceptual framework to guide the evaluation of the Student Centred Digital Game-Based Learning research domain, based upon a systematic literature survey on the area.
- A framework for the design of Student Centred Digital Game-Based Learning experiences to guide and enable their development and use.
- An artefact, being a novel implementation of a SCDGBL system that delivers on all seven tenets of Student Centred Learning.
- Implications and recommendations for research and practice which provide key learning points from this work to inform researchers and practitioners when designing and deploying SCDGBL experiences.

Each of these contributions will now be discussed.

7.4.1 A conceptual framework to guide the evaluation of the Student Centred Digital Game-Based Learning research domain, based upon a literature survey on the area

Many literature reviews cover the area of Digital Game-Based Learning, looking at games used for educational purposes (Abdul Jabbar and Felicia, 2015). This is also true for the area of Student Centred Learning, where surveys exist which cover the discussion of SCL experiences and theory (Rocca, 2010, Din and Wheatley, 2007). To the best knowledge of the researcher no surveys existed which evaluated SCDGBL as an area, looking at the deployment of SCL techniques within DGBL experiences. Within this area there was little attempt at the categorisation of experiences to provide an understanding of the subdomains within SCDGBL. To provide this information, a comprehensive and systematic review of the literature was conducted in Chapter 2 which sought to categorise the papers where SCL theory and techniques have informed DGBL experiences. The systematic approach allowed the literature search to be reproducible with all search terms and databases utilised documented. Figure 4 presents the conceptual framework developed to categorise the range of SCDGBL papers, based upon the novel theoretical mapping of DGBL principles to SCL tenets carried out in this work. This framework allows for the categorisation of SCDGBL papers according to

a number of key factors, including the role and design of the game, nature of player engagement and the DGBL Principles and SCL tenets incorporated within.

A survey of the state of the art in SCDGBL literature is presented utilising this framework to organise and understand the research domain. A number of gaps in the literature were identified, and recommendations presented to address these through research work. Within these recommendations, the need to design games which implement all tenets of SCL was the primary driver for the research undertaken. The survey and framework contribute to the research domain by offering potential directions for future research work based upon systematic and reproducible work. It enables future work in this area to be systematic by offering the conceptual framework as a method by which to categorise the research landscape, and assists researchers with conceptualising and understanding the potential areas where new developments may be placed.

7.4.2 A framework for the design of Student Centred Digital Game-Based Learning experiences to guide and enable their development and use

In order to design and implement a game that fully implements all tenets of SCL, it was necessary to utilise a game design framework. While many frameworks exist for game design, with a number designed for the development of educational games, no framework could be identified with a particular focus on the tenets of SCL. Having established in Chapter 2 that current SCDGBL offerings do not deliver effectively on all tenets of SCL, the absence of a game design framework with an SCL focus was argued to be a likely contributor to this finding. To address this absence, and ensure the design of a SCDGBL game integrated SCL tenets from the early stages, a framework was designed and developed. This contribution, the Student Centred Experience framework, is presented as an artefact in Chapter 4 and revised in Chapter 6, based on the evaluation by students of an artefact designed with guidance of the framework (Experiment 1, Chapter 5).

The SCE framework forms a novel tool to use in the design of SCDGBL games, to guide and assist both game designers and teachers. The SCE framework utilises the MDA framework as a basis, along with the unique mapping from DGBL principles to SCL tenets performed in this work (Section 2.2.1), and other important components of education and game design theory. It allows the identification of the primary areas in which a particular principle of DGBL may be implemented, and subsequently changes to the Mechanics, expected behaviour (Dynamics) and emotional responses (Aesthetics) which may give rise to or indicate the successful integration of the associated SCL tenets.

The SCE framework is a generic framework allowing for the design of games of any genres and is subject agnostic allowing for its utilisation with any academic subject and associated

learning outcomes. This provides versatility in future usage at a variety of educational levels. To summarise, the SCE framework is an artefact which contributes to the research domain by providing guidance for future work in SCDGBL, its benefits include:

- Providing information to game designers on where and how tenets of SCL may be realised
- Guiding educational professionals on the integration of learning into games at a deeper level
- Clearly defined areas of enjoyment, identifying the ways incorporating DGBL principles can enhance player fun
- A subject and genre agnostic design allowing its use with different game styles and learning outcomes

The SCE framework was utilised in the design of the LogicGate and LogicGate-R Systems, it has the potential to be used in a number of further areas, this is explored further in Section 7.5.

7.4.3 An artefact, being a novel implementation of a SCDGBL system that delivers on all aspects of Student Centred Learning

This significant contribution of this work is designed, implemented and evaluated in Chapter 5 and Chapter 6 through Experiment 1 and 2, utilising the framework developed in Chapter 4. The artefact takes the form of a game, the LogicGate System, designed to teach Boolean logic through collaborative learning in teams of three. This artefact was designed to implement all tenets of SCL from the design stage, with a particular focus on the Social Aspects of SCL (Section 5.1.1). This design focus was to address the limited implementation of the Social Aspects of SCL within current SCDGBL offerings as identified in Chapter 2, while maintaining suitable representation of the other SCL tenets to deliver a comprehensive SCDGBL experience for students. This represents a novel implementation of a game-based educational artefact, which in its revised form (Chapter 6) was found to deliver effectively on all of the SCL tenets, in a way that improved knowledge and was well rated by students after deployment in a classroom environment. This was established in Chapter 6 through a robust and rigorous mixed methods evaluation process that compared the SCDGBL experience created by deploying the LogicGate-R System to a traditional classroom-based SCL task.

This unique game-based educational artefact offers a number of benefits to students and teachers over a traditional SCL task, while delivering equivalent learning and subsequent knowledge improvement:

- More engaging and effective integration of the Social Aspects of SCL, through the multiplayer focus and the involvement of the teacher within the learning experience of the students.
- Enhanced student autonomy through use of individual access to sections of the problem they can engage with and information provision that delivers relevant information to students that can be referred to as and when required.
- Greater responsibility/accountability encouraged amongst students through the team-based learning areas that require input from each student to succeed, as each student must participate for the group as a whole to achieve success.
- Promote a more reflexive approach to teaching and learning through allowing students to revisit solutions and confirm understanding, thereby refamiliarising themselves with concepts to iterate upon them again.

This contributes to the research field a comprehensive implementation of all tenets of SCL which has been compared and tested against a traditional SCL task. This demonstrates that the incorporation of all tenets of SCL through a digital game within the classroom is an achievable goal through use of the SCE framework, and can offer measurable improvements in the student experience over traditional SCL activities. In addition to these comparative benefits, this artefact also offers opportunity for revision and adaptation by practitioners without a programming or game development background, through the in-game tools and utilising a wealth of publicly available extensions and modifications that could be integrated by a practitioner. This offers an important opportunity to implement the SCL tenet of *Reflexive Approach to Teaching and Learning* from the practitioner's perspective, allowing tailoring of the SCDGBL experience to the needs of individual cohorts. The LogicGate-R System provides a novel game-based educational artefact within the SCDGBL field that highlights opportunities to move forward in the design of future games that create comprehensive SCDGBL experiences.

7.4.4 Implications and recommendations for SCDGBL games design and teaching practice

The primary artefact produced through this research is the LogicGate System, discussed in 7.4.3. This game-based educational artefact represents a proof of concept for a game explicitly designed to deliver all 7 tenets of SCL for a comprehensive SCDGBL experience. Through the evaluation performed upon this during Experiments 1 and 2, it is identified that the creation of such SCDGBL experiences forms an effective way to deliver the techniques of SCL and that the deployment of such games offers a SCDGBL experience for students to learn taught concepts that is at least equivalent with traditional methods of teaching and learning. In

addition to the delivery of taught concepts, it has been demonstrated that SCDGBL learning experiences can offer greater opportunity in terms of social engagement, immediacy of feedback and that these effects can carry over into increased student engagement with the learning task and increased motivation. Taken together, these findings may direct practitioners to the deployment of games to create SCDGBL experiences within classroom environments and should help assuage any potential concerns that such experiences may not be an effective vehicle for the learning they seek to impart, using robust and rigorous research.

DGBL experiences must be specifically designed with a view to their usage in their intended learning environment. When designing an educational game, many of the benefits to be realised come from the integration of curricular content into the core game mechanics, and from the adjustment of the experience to suit both the individual practitioners deploying the experience and the individual learners taking part. Such customisation comes in two stages, firstly the integration of game mechanics and learning outcomes must be undertaken at a design stage, which requires either the utilisation of an open and highly customisable game platform, such as the utilisation of Minecraft in the design of the LogicGate System. This integration is critical to the implementation of SCL tenets, most particularly *Deep Learning and Understanding*, as regardless of whether a student is motivated by a desire to learn or a desire to complete the game, this integration ties these elements together, presenting the game and the game world as a unified whole where learning is achieved through participation. Secondly, the flexibility to adapt the experience is important as it allows practitioners to tailor the experience as best suits their cohort of learners. The tenet of *Reflexive Approach to Teaching and Learning* requires not just that the student look back at their own learning and establish what works well for them, but also that the practitioner is able to evaluate and adapt, then adjust the experiences they offer learners.

During the creation of the LogicGate System, a framework was utilised to guide the game design process. This framework was specifically created to facilitate the design of games that integrate all seven tenets of SCL. Previous SCDGBL offerings using game design frameworks that were not focused on SCL were found in this work to not deliver on all tenets of SCL, particularly the social aspects of *Active Learning*, *Teacher and Learner Interdependence* and *Mutual Respect*. It is therefore recommended that designers and practitioners wishing to create SCDGBL experiences through games seek to utilise a game design framework with an appropriate focus on the SCL tenets. The use of such a framework, for example, the SCE framework presented in Chapter 4, will better equip practitioners for the comprehensive incorporation of the seven SCL tenets within the design process for SCDGBL experiences. Further, it ensures that the experience has fully considered the key principles of DGBL and

therefore increases the likelihood of producing a well-designed game as a vehicle for the desired learning outcomes.

The design of SCDGBL experiences should consider the role of the teacher during the learning experience. This is important for the integration of the SCL tenet *Teacher and Learner Interdependence*. If a teacher isn't involved in the game, then effectively the game is taking the place of the teacher, meaning there is no building of the relationship between the teacher and the student within the learning experience, because the student's engagement with the game occupies that space. For this reason, it is strongly recommended that the teacher have an active role within an SCDGBL experience, which allows them to engage interactively on a similar level to that of the students. This offers the opportunity for the teacher to not just supervise but play alongside and guide the students through the game as required without breaking immersion or removing control from the student.

When designing a game for an SCDGBL experience, all aspects of a game's design must be taken into account. Many students are familiar with professionally designed games of high quality, which they will encounter during leisure time. Such games are able to employ a combination of engaging gameplay and aesthetic principles which students become accustomed to and expect from the medium of games. While there are a variety of aesthetic styles and creative decisions taken in the breadth of games available, it is imperative that educational game designers strive to produce a similar quality of design and integrated aesthetic to that of commercial titles if such games are to be taken seriously. In addition, care must be taken to consider how these design choices suit the target audience for the intended SCDGBL experience. Failure to deliver experiences with a coherent and appropriate aesthetic may result in students not engaging with the games to a high degree through feeling that they are too childish, not serious or otherwise an inferior product to those commercial games with which they are accustomed. The adaptation of commercial games forms a powerful tool in the creation of SCDGBL experiences, as demonstrated within the LogicGate System, however such adaptation requires that a title offer a high degree of customisability to enable its conversion to a SCDGBL experience. Furthermore, the process of this adaptation requires the designer to understand the mechanics of that game, and to ensure that changes made in its adaptation adhere to the mechanical and aesthetic principles upon which the original game is based while also considering key SCDGBL elements including the desired learning outcomes and the integration of the seven tenets where not already facilitated. For this reason, it is recommended that an appropriate game design framework be used to aid this conversion process to address these implications.

To summarise the key points for designers:

- Designers should utilise open and highly customisable game platforms to integrate game mechanics and learning outcomes at the design stage, critical to the implementation of SCL tenets for a SCDGBL experience.
- Designers wishing to create SCDGBL experiences through designing new games or adapting existing ones should utilise a game design framework with an appropriate focus on the SCL tenets, such as the SCE framework presented in 4.4. This should be done in collaboration with teaching practitioners whose learning objectives are being integrated into the game.
- Designing the game for flexible adaptation by the teaching practitioner will enable ongoing usage of the game despite curriculum changes or varying cohort learning needs.
- Designers should consider assigning an active role to the teacher within the learning experience that does not remove control or break immersion for the student. This avoids the SCDGBL experience being a replacement for the teacher and further aids comprehensive delivery of SCL tenets.

To summarise the key points for teaching practitioners:

- SCDGBL learning experiences can offer greater opportunity in terms of social engagement, immediacy of feedback and that these effects can carry over into increased student engagement with the learning task and increased motivation. This has been demonstrated through robust and rigorous research.
- Teaching practitioners should seek SCDGBL offerings that hold flexibility to adapt them and tailor the experience as best suits their cohort of learners, based on appropriate evaluation to determine the adaptations required to offer the best experience for learners.
- Teaching practitioners wishing to be involved in the design of a game that delivers a SCDGBL experience should ensure a game design framework with an appropriate focus on the SCL tenets is used by the designer, and that they collaborate with the designer on the integration of learning and assessment objectives within the game's mechanics at an early stage.
- Teaching practitioners wishing to offer SCDGBL experiences to their learners should be willing to take an active role within the game to build relationships with their learners and guide them through the game as needed, without breaking immersion or removing student autonomy.

These implications and recommendations provide key direction in the creation and wider deployment of games for SCDGBL experiences based on the findings from the deployment and evaluation of the LogicGate System. However, there are opportunities for further research work which arise directly from the research undertaken within this project. These more direct research and evaluation activities will now be explored.

7.5 Future work in research

While this work presents strong results indicating a successful delivery of research aims and objectives and delivering a number of contributions to the research field, there are drawbacks and limitations which must be recognised as they offer potential areas for further research and improvement. Limitations specific to Experiments 1 and 2 are acknowledged and discussed within sections 5.5.2 and 6.6.2. This section will focus on the discussion of broader research limitations drawn from across the work that prompt further research, and any unaddressed challenges from the literature review performed in Chapter 2. Individual limitations associated with meeting the overarching research objectives of this work (**RO1-RO5** as discussed in 7.3) and future work arising from them will now be discussed.

1. **Limitation:** The integrative nature of the LogicGate System, which aims to incorporate all tenets of SCL, renders it challenging to evaluate the relative contributions of individual SCL tenets to the overall SCDGBL experience within the studies carried out.
1. **Future work:** Further adaptations to the LogicGate System may enable the removal of interlinked groups of tenets e.g. social aspects, deep/active learning, while maintaining the game environment and content delivery. This would enable the evaluation of an experience delivering different combinations of the SCL tenets, hence allowing for more granular evaluation of the benefits offered by a SCDGBL experience.
2. **Limitation:** As each study was performed on a one-off basis, there was no facility for follow-up of students to assess retention of knowledge gained from the SCDGBL experience, or level of interaction with the experience as a revision tool.
2. **Future work:** Subsequent evaluation studies could include repeat knowledge testing after an interval to assess effective retention, combined with usage data to determine whether students have interacted with the game since their original SCDGBL experience. Further changes to the artefact could improve its perceived utility as a revision tool, for example allowing solo or group revision through access to further custom areas.
3. **Limitation:** Due to the nature of the deployment within the researcher's institution, there is a need for wider feedback from practitioners on experiences of independently deploying the LogicGate System without direct supervision from the researcher.

3. **Future work:** Wider deployment in a number of classrooms without direct involvement of the researcher would enable the collection of feedback from practitioners about their experience of being involved and allow the evaluation of their perceptions of the artefact's usability and acceptability. Further, this would allow the adaptations practitioners make to accommodate their own classroom settings to be determined, demonstrating teachers can reflect upon and adjust the LogicGate System to suit individual learner requirements and particular learning outcomes.
4. **Limitation:** The LogicGate System represents a single expression of the SCE framework designed to deliver a specific set of learning outcomes, in this case the understanding of Boolean logic delivered through a collaborative, puzzle-based game.
4. **Future work:** Further applications designed using the SCE framework should be trialled within a number of subject and topic areas to further assess generalisability of the framework to a wider selection of intended learning outcomes.
5. **Limitation:** The deployment of the LogicGate System was constrained to one University, Brunel University London, and subsequently one student pool, which may limit generalisability to other educational institutions and student groups.
5. **Future work:** In order to determine the potential of the LogicGate System for delivering the same learning outcomes under differing circumstances and with other groups of learners, there is a need to explore wider deployment outside of one university. In addition to exploring wider generalisability, this deployment would allow investigation into the way in which the LogicGate System can be adapted and tailored to accommodate varying needs between educational institutions.
6. **Limitation:** Within the experimental design, the researcher fulfilled the roles of both designer and teacher when using the SCE framework to develop a game that created an SCDGBL experience. Due to this, it is not known how the framework performs when used by teachers or designers alone or as part of a coproduction process.
6. **Future work:** The SCE framework should be utilised by a variety of teachers and game designers, working individually and in cooperation. Wider utilisation of the SCE framework in a variety of settings and situations would allow for the evaluation of the utility of the framework where the roles are separate. This constitutes an important direction for future evaluation and refinement of the SCE framework
7. **Limitation:** The literature review presented within Chapter 2 called for greater use of emerging technologies, however the LogicGate System is currently limited to a conventional PC platform, without the utilisation of virtual reality or similar emerging technologies within the area of games design. This integration therefore remains unaddressed.

7. **Future work:** The SCE framework is platform agnostic, therefore there is capacity to accommodate the integration of emerging technologies within the design process. Future proof of concept design work could demonstrate the potential to design a SCDGBL experience to deliver learning outcomes using an emerging platform such as augmented or virtual reality.

7.6 Summary

This work has investigated the delivery of Student Centred Learning through the medium of digital video games. Based on a systematic literature survey identifying opportunities and needs within the domain of SCDGBL, a framework was developed for the design of educational games that implements all 7 tenets of SCL to create an SCDGBL experience. This framework was implemented to design a collaborative game which was deployed across two iterations with Brunel university students. Findings from these deployments demonstrate that SCDGBL experiences created by deploying such games can offer advantages over traditional student centred teaching techniques, while effectively delivering learning intentions. In particular the social experience was improved, allowing students to work together on tasks and engage in peer learning while maintaining students' ability to work autonomously and learn through their own actions. A well-designed SCDGBL experience allows students to engage in active learning and provides support to do so, while involving the teacher and granting them the ability to engage in and adapt the experience. This work represents a step towards clearer and more effective usage of SCDGBL in a classroom context and has the potential to create more engaging and effective learning experiences.

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Appendices

Appendix 1A. Ethics Approval letter – April 2018

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

w

ww.brunel.ac.uk 4 May 2018

LETTER OF APPROVAL (CONDITIONAL)

Applicant: Mr Thomas Coleman

Project Title: Student Centred Multiplayer Game Based Learning

Reference: 10335-MHR-Apr/2018- 12577-1

Dear Mr Thomas Coleman

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.
- Start date has passed. No research data collected prior to the final ethical approval should be included in your research.
- The Digital Game Questionnaire is not really a questionnaire but a list of statements - please agree with your supervisor how this will be used, any amendment to the type of questions will need to be agreed with the ethics
- committee prior to sending out. Please ensure all participants are over the age of 18
- Please could you amend your Participant Information sheet in the 'What if something goes wrong' section and also the end of the sheet to show the name of Prof Hua Zhao the Chair of the College Ethics Committee and take out Prof Tracy
- Hall.

Please ensure that all data is anonymized and held securely on an encrypted Brunel University computer. Do not hold data on any unsecure laptops etc.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor
  (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair
- of the relevant Research Ethics Committee.
  Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any
- conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study

You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences
Research Ethics Committee Brunel University London

Appendix 1B. Ethics Approval Letter – October 2018

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

8 October 2018

LETTER OF APPROVAL

Applicant: Mr Thomas Coleman
Project Title: Student Centred Multiplayer Game Based Learning

Reference: 10335-A-Oct/2018- 14301-1

Dear Mr Thomas Coleman

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair
- of the relevant Research Ethics Committee.
  Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any
- conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.

You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences
Research Ethics Committee Brunel University London

College of Engineering, Design and Physical Sciences

Department of Computer Science

CONSENT FORM

'Student Centred Multiplayer Game-Based Learning'

The participant should complete the whole of this sheet		
	Please tick the appropriate box	
	YES	NO
Have you read the Research Participant Information Sheet?		
Have you had an opportunity to ask questions and discuss this study?		
Have you received satisfactory answers to all your questions?		
Who have you spoken to?		
Do you understand that you will not be referred to by name in any report concerning the study?		
Do you understand that you are free to withdraw from the study:		
• at any time?		
• without having to give a reason for withdrawing?		
I agree to my focus group participation being recorded.		
I agree to the use of non-attributable direct quotes when the study is written up or published.		
Do you agree to take part in this study?		
Signature of Research Participant:		
Date:		
Name in capitals:		

Researcher name:	Signature:
Supervisor name:	Signature:

College of Engineering, Design and Physical Sciences
Department of Computer Science

PARTICIPANT INFORMATION SHEET

Study title: Student Centred Multiplayer Game Based Learning

Thomas Coleman, postgraduate student in the School of Computing, would like to invite you to take part in a research project. Before you decide you need to understand why the research is being done and what it will involve for you. Please take the time to read the following information carefully and ask questions about anything you do not understand. Talk to others about the study if you wish.

What is the purpose of the study?
The project aims to discover the effects of the integration of student centred learning elements, particularly group-work elements, into computer game design as a vehicle for education.

Why have I been invited to participate?
You have been chosen because you are a student taking the foundation course at Brunel University.

We aim to recruit 50 people as part of this study.

Do I have to take part?
No, there is no obligation on yourself to take part in this study. Participation is optional and there are no negative consequences if you decide not to take part.

What will happen to me if I take part?
You will be asked to sign a consent form, after which you will be taking part in your usual laboratory sessions within the module. During this process some anonymous data will be collected on your game-play. This will be followed by a questionnaire and the opportunity to participate in a feedback focus group.

What do I have to do?
You will be asked to show up to the lab at the appropriate time and take part in this session. Playing the educational game and practising logic skills. Following this you will be asked to fill in a questionnaire on the game experience. Should you wish to help further you will be given the opportunity to take part in a focus group to give further feedback on the game design.

What are the possible disadvantages and risks of taking part?
There are no disadvantages or risks associated with taking part - your legal rights and education will not be affected in any way by participating in this study. Your final marks for all modules will not be adversely affected by taking part in this study.

What if something goes wrong?
Any complaint or concern about any aspect of the way you have been dealt with during the course of the study will be addressed; please contact Dr Arthur Money, Director of Studies, on 01895 266758 or arthur.money@brunel.ac.uk in the first instance. You may also contact Prof Hua Zhao the Chair of the College Ethics Committee, on 01895 267512 or hua.zhao@brunel.ac.uk.

Will my taking part in this study be kept confidential?

Your questionnaire responses and any data collected will be anonymised before any publication. Your name will not be published however other students taking part in the research within same laboratory as you may be aware of your participation.

What will happen to the results of the research study?
The results of the study may be published in scientific journals and/or presented at conferences. However, this data will be fully anonymised and you will not be identified by name, or information you've provided in quotes, in any report/publication. We do not plan to publicly release any datasets or transcripts for this study, but if we do, all pseudonymised information contained within will be converted to be fully anonymous prior to release.

If you wish, you can obtain a copy of the published results by contacting us at the address below.

Who is organising and funding the research?
Funding for this research is provided by the Engineering and Physical Sciences Research Council.
The research is designed and lead by Thomas Coleman, PhD. student at Brunel University.

What are the indemnity arrangements?
The University has in force the relevant insurance policies for research involving human subjects, which apply to this study.

Who has reviewed the study?
This study has been reviewed by the College Research Ethics Committee.

Brunel University is committed to compliance with the Universities UK Research Integrity Concordat. You are entitled to expect the highest level of integrity from our researchers during the course of their research.

Contact for further information and complaints
For general information please direct all questions to:
Thomas Coleman
Thomasedward.coleman@brunel.ac.uk

Dr Arthur G. Money
arthur.money@brunel.ac.uk

For complaints and questions about the conduct of the Research
Prof Hua Zhao the Chair of the College Ethics Committee Hua.zhao@brunel.ac.uk

Appendix 3 – Post-experience test combining the Course Experience Survey and eGameFlow Survey

LogicGate System Survey

This questionnaire will ask a number of questions about the Logic section of the module and lab you have just experienced. All answers will be anonymised before being published or released and will not be shared with any identifying details. For each question you will be asked to enter either a rating from Strongly Disagree (1) to Strongly agree (5) or given the opportunity to enter your own response.
The questionnaire should take approximately 10 minutes to complete.
* Required

Demographic Data

This section asks a few questions about you. This data will not be shared outside the research team but allows us to identify and compare between this and future weeks.

1. What is your name? *

2. How old are you (in years)? *

3. What is your Brunel Username (used only to track what group you were in) *

4. Which Minecraft Account did you use? *

5. What Gender do you identify as? *

Mark only one oval.

- ◯ Female
- ◯ Male
- ◯ Other
- ◯ Prefer not to say

6. Please enter your ethnicity

_____

7. How often do you play video games? *

Mark only one oval.

	1	2	3	4	5	
Never	◯	◯	◯	◯	◯	Frequently (e.g. several sessions a week))

8. I have played Minecraft before *

Check all that apply.

- ☐ Yes, on PC or Mac
- ☐ Yes, on a console or mobile device
- ☐ No

Engagement

Thinking in particular about the session you just experienced, how much do you agree with the following statements?

9. Students are not asked to make connections between the course material and their own lives.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

10. This course requires a student to use higher order thinking (e.g., analysis, synthesis, application).

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

11. The instructor joins regularly in one or more small groups when the class is engaged in discussions.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

12. The instructor makes connections between course material and students' lives and experiences.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

13. Students do not receive a lot of feedback about their work in this course.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

14. Students are asked regularly to participate in small-group discussions.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

15. Topics covered in the course typically have classroom activities connected to them.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

16. The course material does not relate to students' experiences in everyday life.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

17. Students are encouraged and supported in improving their skills.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

18. Students are asked to work together on projects.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

19. The course emphasizes application of concepts and ideas.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

20. There is a lot of small group discussion in this class.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

21. Most classroom activities do not require students to interact with each other.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

22. The instructor(s) helps students understand how their prior experiences are related to concepts in the course.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

23. The instructor(s) helps students develop ways to solve problems related to the content.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

24. The instructor plans small group discussions with a specific goal in mind.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

25. A student does not have to engage with others to do well in this course.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

26. Collaborating with class peers, in and/or out of class, is part of this course.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

27. The instructor helps students become better writers.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

28. During small group discussions, students talk more than the instructor.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

29. The instructor works with small groups of students to build new understandings.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

Game Related Questions

This section relates to the LogicGate game system, if you did not take part in that please skip this section.
Thinking about the game, you just played, how much do you agree with the following statements?

30. I took part in using the Minecraft-based LogicGate system in this session. *

Mark only one oval.

- ◯ Yes
- ◯ No

31. The game provides content that stimulates my attention.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

32. I do not get distracted when I play the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

33. Generally speaking, I can concentrate on the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

34. I understand the goals of this game from the start.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

35. The overall game goals are clear to me.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

36. I understand the overall progress of the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

37. I know what will happen next in the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

38. I receive feedback on my progress in the game

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

39. I receive immediate feedback on my actions.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

40. I receive information on my game performance immediately.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

41. I am always aware of the score of the game

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

42. The level of difficulty in this game is suitable for me.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

43. My skills gradually improve through the course of the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

44. I am motivated by the improvement of my skills.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

45. The game provides new challenges at an appropriate pace.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

46. The game provides different levels of challenges tailored to different players.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

47. I feel a sense of control over my movements while playing the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

48. I feel a sense of control over my interactions with the game itself.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

49. I feel that I can use strategies freely.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

50. I forget about time passing while playing the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

51. I become unaware of my surrounding while playing the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

52. I can become deeply involved in the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

53. I feel emotionally involved in the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

54. The game supports social interaction between players.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

55. The game supports communities within the game.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

56. The connection with other players helps me improve my game playing skills.

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

57. The game increases my knowledge

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

58. I catch the basic ideas of the knowledge taught

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

59. I try to apply the knowledge in the game

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

60. The game motivates the player to integrate the knowledge taught

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

61. I want to know more about the knowledge taught

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

62. Do you have any other comments on the game experience?

Final Section

Thank you for your help, just a couple of questions about whether you'd like to take part in further studies on this project.

63. I would be happy to be contacted for future studies on this project, which may include compensated studies.

Mark only one oval.

- ◯ Yes
- ◯ No

64. What is the best email address to contact you on? (You can opt out at any time)

Appendix 4 – Focus group topic guide

Approximate running time of for 50 minutes. Begin session with an introduction thanking participants and coving the rough topics at the start and refresh again on the use of data.

Sample prompts are provided to help elucidate answers.

Icebreaker: Previous experience with games and any experience with games for learning

- Getting into the game and the onboarding experience
    - Prompt: How did you find getting started in the game?
    - Prompt: Did you know what to expect going into the game, and did the game fit those expectations?
- Becoming accustomed to the controls, tasks and in-game instructions
    - Prompt: How easy was it to get around in the game?
- The play experience:
- Challenges faced by different players
    - Prompt: How did you deal with the challenges you faced?
- Communication with other players in the group
    - Prompt: How was the communication within your team facilitated by the game?
- High and low points during the experience
    - Prompt: What were the worst points about the game, things that need to be improved?
- How did you feel about the group-based nature of the challenges?
- How did you feel about the feedback you received when you took an action or changed something?
- What improvements do you think could be made to your play experience?
- How does the game fit as a teaching tool?
    - Thoughts on learning through gaming?
    - Would you consider using it in future to revise with?
    - How would you feel about this as feature of future courses?

Wrap up and any last items of feedback.

Appendix 5 – Post-experience survey combining Knowledge Test, Course Experience Survey and eGameFlow Survey

LogicGate System Survey

This questionnaire will ask a number of questions about the Logic section of the module and lab you have just experienced. All answers will be anonymised before being published or released and will not be shared with any identifying details. For each question you will be asked to enter either a rating from Strongly Disagree (1) to Strongly agree (5) or given the opportunity to enter your own response.
The questionnaire should take approximately 10 minutes to complete.
* Required

Demographic Data

This section asks a few questions about you. This data will not be shared outside the research team but allows us to identify and compare between this and future weeks.

1. What is your name? *

2. How old are you (in years)? *

3. What is your Brunel Username (used only to track what group you were in) *

4. Which Minecraft Account did you use? *

5. What Gender do you identify as? *

Mark only one oval.

- ◯ Female
- ◯ Male
- ◯ Other
- ◯ Prefer not to say

6. Please enter your ethnicity

_____

7. How often do you play video games? *

Mark only one oval.

	1	2	3	4	5	
Never	◯	◯	◯	◯	◯	Frequently (e.g. several sessions a week))

8. I have played Minecraft before *

Check all that apply.

- ☐ Yes, on PC or Mac
- ☐ Yes, on a console or mobile device
- ☐ No

Check Your Understanding

A few questions to help check how well you understand logic.

9. Which of the following describes an OR Gate?

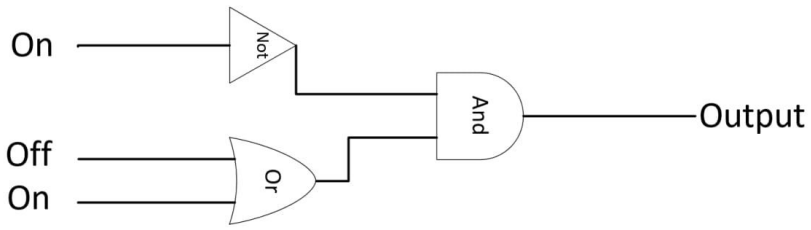
Mark only one oval.

- A gate that turns on when all inputs are active.
- A gate that turns on when no inputs are active.
- A gate that turns on when any inputs are active.
- A gate that only has one input.

10. Which gate can be described as an 'Inverter'?

Mark only one oval.

- OR Gate
- NOT Gate
- AND Gate
- XOR Gate



11. What is the output above

Mark only one oval.

- Off
- It will change over time
- On
- Neither

12. When is an XOR gate turned off?

Check all that apply.

- [ ] When either input is active
- [ ] When both inputs are active
- [ ] When neither input is active
- [ ] When only the first input is active

13. Which of the following describes an AND gate?

Mark only one oval.

- ◯ A gate that turns on if any inputs are active.
- ◯ A gate that turns on when no inputs are active.
- ◯ A gate that turns on every 2 seconds.
- ◯ A gate that turns on if all inputs are active.

Engagement

Thinking in particular about the session you just experienced, how much do you agree with the following statements?

14. Students are not asked to make connections between the course material and their own lives. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

15. This course requires a student to use higher order thinking (e.g., analysis, synthesis, application). *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

16. The instructor joins regularly in one or more small groups when the class is engaged in discussions. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

17. The instructor makes connections between course material and students' lives and experiences. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

18. Students do not receive a lot of feedback about their work in this course. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

19. Students are asked regularly to participate in small-group discussions. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

20. Topics covered in the course typically have classroom activities connected to them. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

21. The course material does not relate to students' experiences in everyday life. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

22. Students are encouraged and supported in improving their skills. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

23. Students are asked to work together on projects. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

24. The course emphasizes application of concepts and ideas. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

25. There is a lot of small group discussion in this class. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

26. Most classroom activities do not require students to interact with each other. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

27. The instructor(s) helps students understand how their prior experiences are related to concepts in the course. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

28. The instructor(s) helps students develop ways to solve problems related to the content. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

29. The instructor plans small group discussions with a specific goal in mind. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

30. A student does not have to engage with others to do well in this course. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

31. Collaborating with class peers, in and/or out of class, is part of this course. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

32. The instructor helps students become better writers. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

33. During small group discussions, students talk more than the instructor. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

34. The instructor works with small groups of students to build new understandings. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

Game Related Questions

This section relates to the LogicGate game system, if you did not take part in that please skip this section.
Thinking about the game, you just played, how much do you agree with the following statements?

35. I took part in using the Minecraft-based LogicGate system in this session. *

Mark only one oval.

- Yes
- No

36. The game provides content that stimulates my attention. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

37. I do not get distracted when I play the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

38. Generally speaking, I can concentrate on the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

39. I understand the goals of this game from the start. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

40. The overall game goals are clear to me. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

41. I understand the overall progress of the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

42. I know what will happen next in the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

43. I receive feedback on my progress in the game *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

44. I receive immediate feedback on my actions. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

45. I receive information on my game performance immediately. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

46. I am always aware of the score of the game *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

47. The level of difficulty in this game is suitable for me. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

48. My skills gradually improve through the course of the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

49. I am motivated by the improvement of my skills. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

50. The game provides new challenges at an appropriate pace. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

51. The game provides different levels of challenges tailored to different players. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

52. I feel a sense of control over my movements while playing the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

53. I feel a sense of control over my interactions with the game itself. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

54. I feel that I can use strategies freely. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

55. I forget about time passing while playing the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

56. I become unaware of my surrounding while playing the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

57. I can become deeply involved in the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

58. I feel emotionally involved in the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

59. The game supports social interaction between players. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

60. The game supports communities within the game. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

61. The connection with other players helps me improve my game playing skills. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

62. The game increases my knowledge *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

63. I catch the basic ideas of the knowledge taught *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

64. I try to apply the knowledge in the game *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

65. The game motivates the player to integrate the knowledge taught *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

66. I want to know more about the knowledge taught *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

67. Do you have any other comments on the game experience?

Final Section

Thank you for your help, just a couple of questions about whether you'd like to take part in further studies on this project.

68. In what form would you like to receive your gift voucher? *

Mark only one oval.

- ◯ Amazon
- ◯ Google Play
- ◯ iTunes
- ◯ Other: _____

69. I would be happy to be contacted for future studies on this project, which may include compensated studies. *

Mark only one oval.

- ◯ Yes
- ◯ No

70. What is the best email address to contact you on? (You can opt out at any time) *

_____