SIMULATING CHARACTERS FOR OBSERVATION: BRIDGING THEORY AND PRACTICE

A thesis submitted to the University of Manchester
for the degree of Doctor of Philosophy
in the Faculty of Engineering and Physical Sciences

2012

By
Adrian Albin-Clark
School of Computer Science

Contents

List of Tables

List of Figures

Abstract

Observations of young children are conducted in an educational setting by practitioners to plan and assess activities based on the individual development and needs of the child. Challenges include: recording, how to be an observer rather than a participant, and connecting developmental theory to observable behaviour.

Several projects have simulated children in their learning environments, aimed mainly at pre-service teachers, but these have neither been for young children where the activity is play-based nor where the adult is supportive of the child's interests. Some simulations have used 3D graphics to represent a child via a role-playing adult but there have been few attempts to use autonomous characters.

A novel real-time interactive 3D graphical simulation—Observation—was developed, providing a physical sandbox for users to: add autonomous characters (representing children), add objects, and customise the play-based environment. The definitions of the characters were informed by the findings from early childhood research. The simulation was evaluated using two complementary serious game frameworks and its utility was evaluated by professionals within the field of early childhood education comprising university students and educators, and local education authority advisors. An explorative, mixed methods approach was taken, triangulating across: a pilot study and a main study; different research instruments (simulation activity plus questionnaire, focus groups, interviews); and a range of participants.

The simulation has utility because: it is an interesting way to explore the behaviours of young children, the theoretical understanding behind children's play can be deepened, and observational skills can be developed. The simulation has wide appeal because the perceived utility of the simulation is not influenced by: professional experience, number of real-life observations of young children, or time spent playing video games. Age is considered to be the most important omission from the abstract character in the simulation.

Declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright

Acknowledgements

Firstly, I would like to express my gratitude towards my supervisor Toby Howard for his encouragement, support, and advice.

I would like to thank Babs Anderson, an early childhood education specialist, for acting as a peer debriefer.

I am deeply grateful to all the individuals who agreed to be research participants, especially those who kindly gave up additional time to be part of a focus group or to be interviewed.

I would like to thank the School of Computer Science for supporting me with a scholarship.

Finally, I would like to thank my wife Joanne, and our three children, William, Joseph, and Eleanor, for sharing my exploration of simulated worlds, but mostly for sharing my exploration of the real world.

Chapter 1

Introduction

1.1 Background to the study

The inspiration for this work came from a number of places, and these are now described.

An initial investigation by this author explored the automatic generation of plausible humans for 3D virtual environments [ACH09]. In this work, the focus was upon uniqueness of physical appearance, particularly of the head area, looking at techniques such as genetic algorithms to create populations of individuals. Visualising these three-dimensional characters using computer graphics, for long periods of time, resulted in a feeling of wanting to breathe life into them, to focus more on the behaviour of the characters rather than the appearance.

At this time, a personal contact who was working as an educational advisor for a local authority, was conducting many observations of young children in educational settings, in order to support practitioners in raising the levels of well-being (a term used in a particular observational system) in the children. Reflecting upon this observational process led this author to speculate that there must be certain things an observer looks for when conducting observations and also to speculate that there must be things observed in one child that are also observed in other children.

There was also a growing interest in the use of virtual worlds by academia from many spheres, with one particular anthropologist [Boe08] spending more than two years conducting fieldwork in the alternate universe of Second Life [Lin10], observing its residents in the same way that anthropologists traditionally learn about cultures and social groups in the so-called real-world.

This author had also, as a tutor, been recently investigating the use of 3D virtual worlds for educational purposes in an undergraduate computer science course as part of a tutorial session.

Merging these threads together led to an interesting question: Would it be possible to simulate young children in their educational environment, using 3D graphics, for the purposes of simulated observation by learners?

But is there a need for such a simulation? Observations are routinely conducted by practitioners to plan and assess activities based on the individual development and needs of the child. Theories may be used when analysing the activity of young children to help the observer predict how the children might behave, and to make sense of what they have observed. However, there are challenges when performing observations of humans in general, which are also applicable to young children, and include: the extent to which the observer takes part in the study, the extent to which the observation is structured, and whether the observation is conducted in an overt or covert way. Particularly with young children, one of the biggest challenges is trying to observe without taking part in the activity of the children. Other challenges are concerned with the practicalities of recording the observation.

But who would use such a simulation? As part of their studies, students on early childhood education programmes learn about the work of child development theorists, learn how to observe children, and gain practice conducting observations of young children during their placements. This group of learners appears to be a sensible choice as potential users of such a simulation.

Do any simulations like this exist already? There have been several projects looking at simulating children in educational environments, mainly aimed at pre-service teachers, but these simulations often have the user role-play a controlling adult. A typical environment for young children is play-based and more supportive of the child's interests. There have been a few cases where 3D graphics were used in the simulations and some attempts to use automated 3D characters to represent the children.

So, a gap in the research has been identified, namely that *there have not been any real-time simulations using 3D computer graphics of young children in play-based educational environments where the behaviour of the children is modelled using research-inspired developmental theory.*

The aim of this research and also its scope will now be stated.

1.2 Aim and scope

The aim of this research is to answer the following question:

What is the perceived utility of a real-time 3D graphical simulation of children's play behaviour for early childhood education professionals?

The scope of this research will now be made clear.

This is research rooted in computer science, exploring technology within an educational context, it is not research rooted in learner education, using technology as a means to an end. In education research, a new technological tool might be implemented in a classroom and a researcher may then see how student academic achievement is affected. However, this would involve using one or more experimental groups and a control group. Section 3.4.1 discusses the difficulties of using an experimental approach in educational contexts in general, and specifically in this work. Therefore, *this research is not about academic performance as a result of an intervention.*

Since this research is not experimental, investigating the result of an intervention, it would be difficult to compare task performance using the simulation with task performance using an alternate method. Therefore, *this research is not about comparative task performance.*

The pilot study provided some useful feedback on an early version of Observation from the potential users. However, the interest was more on feedback from a conceptual point of view, rather than trying to establish the simulation's ease of use, learnability, efficiency or elegance, through an iterative development cycle involving the users. It is possible that there would be comments from the users covering one or more of these aspects, but users would not be asked explicitly about any of them. Therefore, *this research is not about the usability of a developed simulation.*

Dalgarno and Lee [DL10] propose that the development of 3D games, simulations and virtual worlds for educational purposes should be dependent upon further investigation into the precise relationships between the characteristics of 3D Virtual Learning Environments (VLEs) and their potential learning benefits. However, *this research is not about investigating which aspects of a 3D experience may be beneficial for learners.*

The intention is to incorporate 3D interactive graphics in the development of a novel simulation. The 3D graphics may well be used in imaginative ways but they will essentially be based on tried-and-tested techniques. Therefore, *this* *research is not about developing new techniques in computer graphics.*

By involving educators and students as participants, either of which may be experienced practitioners in early childhood education, the intention is to discern professional perceptions of a simulation's utility. Therefore, *this research is about the perceived utility of a developed simulation.*

1.3 Research contribution

The work contained within this thesis makes the following research contributions:

Comparison of several implementations in a novel way Simulations of children in their learning environments from the literature have not been analysed before to indicate the mechanism for simulating the child.

Identification of a novel problem The challenges of observing young children for a practitioner include recording, how to be an observer rather than a participant, and connecting developmental theory to observable behaviour. These challenges present themselves as an interesting problem.

Combination of several existing ideas to reveal something new and useful By combining the following ideas: simulated observations, learning about developmental theories, child-initiated play, 3D graphical simulation, and emergent gameplay, something interesting has been created.

Demonstration of a concept By creating the simulation and evaluating it using domain specialists, it has been shown that the concept of simulating observations of young children in their play-based learning environment is feasible and that it has utility.

Design and implementation of a novel system No previous simulation existed of young children in their play-based learning environment. A novel design was implemented mainly using novel program code, but also making use of existing code libraries, to create Observation, a novel simulation (Figure 1.1).

Implementation of theoretical principles Child development from three areas (social play stage, blockplay stage, and egocentrism) is represented in the characters within Observation. The child development is taken from theorists in the field of early childhood and interpreted into play behaviours for the characters. These developmental theories have been made concrete, in an attempt to show how they might look in practice.

Re-contextualisation of an existing technique Virtual environments using 3D graphics have been used for many application areas but not for visualising young children within their play-based learning environments. This technique is therefore used in a new context, and it has been shown to be effective.

Application of serious games evaluation frameworks Two complementary frameworks have been used to evaluate the simulation, which because of its novelty, means that these frameworks are being applied to this simulation for the first time.

Figure 1.1: Observation, the novel simulation developed.

1.4 Thesis overview

This Chapter has introduced this research, drawing together the various influences to explain the motivation behind it. The aim and scope of the research has been elucidated. Chapter 2 gives the background to this research, describing how practitioners work with young children in educational environments, and how observation is important to their work. A range of simulations of children in their learning environments are looked at and a technological overview of simulations and games. Chapter 3 describes the methods used in this research, including the sampling and recruitment of participants within the field of early childhood education, and the data collection processes associated with using the simulation. Chapter 4 looks at how autonomous, observable characters within a 3D graphics environment were implemented in the simulation Observation. The findings for this research, during which participants used and provided feedback on the simulation, are split across two chapters, Chapter 5, the pilot study, and Chapter 6, the main study. Chapter 7 evaluates this research in several ways, by using two evaluation frameworks for serious games, by considering how the simulation compares to video, by considering the findings in relation to the findings of others in the field, by considering the findings in relation to the research questions in this work, and by reviewing some elements of the research design. Chapter 8 provides the conclusion for this thesis.

Chapter 2

Background

This chapter provides the context for this research. Various aspects of simulations are examined including the relationship to games, how examples might be classified, the extent to which the user experience is scripted, the use of 3D graphics, and the benefits to the user of using 3D graphical simulations for learning. A number of simulations attempt to represent children in their learning environments and these are explored, classifying them according to how the child is represented. The field of early childhood education is introduced, presenting the defining characteristics of how young children learn, with practitioners providing support for that learning. After considering the observation of human behaviour in general, the reasons for observing young children in learning environments by practitioners are given, and some of the challenges when conducting those observations are highlighted.

2.1 Simulations

2.1.1 Simulations, games, contest

The terms simulation and game are sometimes used interchangeably without it being clear what is the intended meaning. This confusion is exacerbated by the element of competition, which many see as the defining characteristic of a game, but this is not necessarily the case. Greenblat and Duke [GD75] devised a (technology-free) taxonomy of gaming and simulation activities, based upon simulations, games and contests, and is presented here in full.

Simulation (Non-contest, Non-game) A simulation is anything that simulates or models reality. Representative examples of simulations ranging from the very abstract to the concrete include: mathematical formulae; models of physical, military, industrial, economic, and social systems; role playing; film making; literature; painting; and sculpture [GD75].

Contest (Non-Simulation, Non-Game) This is all about competition and falls into these categories: man against man, e.g. competition between businesses; man against himself, e.g. a person trying to overcome an addiction; man against nature, e.g. a person climbing Everest; and man against animal, e.g. a tiger hunt [GD75].

Games (Non-Contest, Non-simulation) A game is an activity in which people agree to abide by a set of conditions (not always rules) to reach a desired state or end, and those conditions may involve using inefficient methods. For example, in golf, it would be more efficient to place the ball directly into the hole, but players agree to hit it with a metal stick which has a flattened end [GD75].

Contest Game (Non-Simulation) A game in which the conditions one abides by are designed to create competition and winning, e.g. sports, gambling, mathematical games, and word games [GD75].

Non-Contest Simulation Games These games simulate reality but are not contests. For example, Ring Around the Rosies is based upon deaths from the Black Plague [GD75].

Non-Game Simulation Contest These activities are contests and simulations but not games. For example, an industrial engineer might simulate a contest between two methods for warehousing a product, to determine which method is the most efficient [GD75].

Simulation Game Contest Most of the experiences called Educational Simulations and Simulation Games belong here. They are contests because they concerned with the allocation of scarce resources, e.g. money, influence, time, space. As simulations they model reality and as games, participants abide by a set of conditions using inefficient means [GD75].

2.1.2 Computer simulations

Prensky acknowledges that simulation is a rather broad term, but defines all simulations (many of which are computation-based) as tools that give an ersatz (as opposed to real) experience, which amounts to 'interactive pretending'. At the heart of a simulation is a model, which is what is deemed important by the simulation's creators, including the relationships between the simulation's elements. Simulations accept user input and give feedback according to the model [Pre04].

Two complementary taxonomic approaches for classifying simulations are provided by Prensky [Pre04], and summarised here.

Purpose: prediction, teaching, entertainment

One way to classify simulations is by their purpose, which can be to predict, to teach, and to entertain. In the field of economics, a predictive simulation might use an economic model for forecasting, a learning simulation might be used by students to practice budgeting, and an entertainment simulation like Roller Coaster Tycoon (cited in [Pre04]), built by a games company, might be used for making economic decisions in a fun way [Pre04].

What: things, systems, people

Another way to classify simulations is by what they simulate, which is typically things, systems, and people.

Things tend to be machines and equipment with repeatable and predictable data. As long as the data stays within certain known parameters, predictions will be accurate for engineering simulations, such as those used in building design. Virtual things such as flight simulators allow people to learn how they work without actually being in an aircraft, and simulations without the danger, such as for bomb disposal, are also a possibility. Simulating things for entertainment, may incorporate the manipulation of objects using real-world physics in fun ways, such as in GMod [Fac11], or the things might be vehicles in a racing game [Pre04].

Unlike things, systems are more open, or less-defined, with a larger number of interactions. As the complexity increases, such as with the weather, the predictability becomes more difficult. Sometimes the complexity of a system may be represented mathematically or by using automata with individually simple rules. Systems for entertainment need to be engaging, for repeated playing, but not necessarily accurate, such as SimCity (cited in [Pre04]) or battlefield simulations. Systems for learning need to strike a balance between realism and entertainment [Pre04].

People are difficult to simulate because of their complexity. Predictions of an individual's behaviour with any accuracy is a challenge for a simulation model, though probabilities might be estimated from a set of alternatives. In learning simulations, providing educated guesses about behaviour, and different alternatives for exploration, is usually good enough. Entertainment simulations have characters whose behaviour is realistic enough to be entertaining, with sporting games concentrating upon realistic movement, rather than psychological realism [Pre04].

2.1.3 Scripting and emergence in computer games

There are two approaches to game development lying at either ends of a continuum, scripting, and emergence, which are provided by Sweetster [SW05], and summarised here.

At the scripting end of the continuum, every aspect (sequenced narrative, challenges, interactions, feedback, placement of characters and objects) of the game must be hand-crafted and tested, making scalability and extensibility difficult, but the main benefit is that the developers have total creative control. However, there is no room for uncertainty or unexpected events, and the players are locked into playing the game in a predefined (linear) way, with no possibility to express their creativity [SW05].

At the emergence end of the continuum, are emergent game worlds that contain general rules for how the environment, objects and agents will interact; behaviours and events emerge from the interactions of the general rules. Developers may not be totally sure how such a sandbox type environment will behave when it is used. Emergent games give the player freedom to experiment, more control, and less prescriptive paths set by the developers. The gameplay is about exploring the possibilities, and repeated playing gives the player a different experience [SW05].

The characteristic difference between the two approaches is that emergence is about what the player wants to do, whereas scripting is about what the developer wants the player to do [SW05].

2.1.4 3D graphics

Three-dimensional (3D) graphics have become a common element of most modern computer games, including massively multiplayer online games such as World of Warcraft [Bli04]. They are also fundamental to immersive virtual worlds such as Second Life. A 3D virtual environment provides the ability to explore, construct and manipulate virtual objects, structures and metaphorical representation of ideas [DL10].

2.1.5 Serious games

When educational aspects are introduced into simulations, they may be called serious games. Rather confusingly, there are many other examples of terms used to describe serious games, including: educational games, simulation, alternative purpose games, digital game-based learning, games for good, and synthetic learning environments. Although there appears to be no agreement on definition, there is a consensus that serious games have a learning objective (explicit or not), provide engaging interactive media, have some game element, and may or may not provide fun [UW10].

2.1.6 Learning affordances of 3D virtual environments

Internationally, educational institutions are recognising the potential use of 3D virtual environments (simulations, games, virtual worlds) for teaching and learning. The learning affordances (actions made possible) of a 3D virtual environment facilitate learning tasks that: lead to enhanced spatial knowledge of a domain; would otherwise be impractical or impossible; lead to intrinsic motivation and engagement; contextualise learning, enabling knowledge transfer and skills to real situations; and tasks that enable richer collaborative learning than with 2D alternatives [DL10].

2.2 Simulations of children learning

It is challenging to organise the simulations of children in their learning environments from the literature into meaningful categories. Only occasionally does the research specify the age range represented by the children in the simulations. The authors (Table 2.1), which are international, may allude to the age range by simply using an educational label for the provision, such as 'Primary', but the age range for that provision may be determined by a number of factors: the country, the geographical region within a country, the current statutory requirements, and whether non-statutory education is included. Some authors additionally specify ages for the children represented in the simulation. Some simulations claim to span the complete range of statutory education, and some also include non-statutory education. Some authors only provide an approximated age based upon the visual appearance of the child. One author uses the term 'early childhood' which, although generally accepted as the age range from birth to eight, in this case is not qualified by any particular age range. One author gives no information at all about the age range of the children represented.

Since it is not possible to discretely categorise the simulations by internationally common age ranges to give something neat like a statutory/non-statutory (compulsory/optional) education split, the simulations are categorised according to how the children are represented within the simulation. The definitions of the terms used in the categories are: *Child* (simulated child); *Student* (education student); *Static* (cannot change in any way); *Media* (storage system - paper, film/sound module, computer disk); and *Software* (computer program). So, the category 'Student as child' means that an education student simulates a child.

All the simulations described in the rest of this section are summarised in Table 2.1.

2.2.1 Media as static child

Early work by Durrett and Richards [DR76] demonstrated that the use of sound/-colour film modules, combined with questions posed from a computer terminal, increased the observational abilities of early childhood education students. The purpose of the study was to compare two ways of learning how to observe: using a computer-based simulation; and observing real children in a nursery school. Participants were students on an introductory course in child development and were randomly assigned to either an experimental group or a control group. Participants in the experimental group were taught to observe behaviour using a combination of sound/colour film modules and open-ended questions presented by a computer terminal which gave immediate feedback and assistance. Participants in the control group observed children in the nursery school. The observable material covered the following areas of child development: physical, motor, language, cognitive, emotional, and social.

From the title of the article, it can be seen that this was a *computer-based* simulation rather than a *computer* simulation. It would appear that the simulation aspect here was the use of recordings of real children, with the computer providing recording-based questions and answers. The article does not report any detail about how the open-ended questions were answered, other than, 'The computer assisted the student if he failed to observe accurately.'

The findings were that all students improved their ability to observe (based on their descriptions of behaviour) from pre-test to post-test, and the experimental group improved more than the control group. Each of these tests required the students to describe a child's behaviour in a seven-minute tape. Over two weeks, between the tests, both groups attended five lectures, and observed using the respective methods for two-and-a-half hours per week.

The authors acknowledge that the experimental group may have become adept at watching certain types of behaviour but what is not clear is how much similarity there was between the behaviours observed by each of the groups during the experimental period and the post-test films that they watched. For instance, the experimental group may have seen very similar behaviours in both the training films and the post-test film, whereas the control group may have observed very different types of behaviour in the nursery compared to the behaviours observed in the post-test film. It is not clear whether students in the control group were given any support from any educators during their time observing in the nursery.

Falender et al. [FJMM79] describe an administrative paper-based role-playing simulation, based on the UCLA Day Care Simulation Model, where participants adopt roles within the early childhood decision-making process, using in-box materials. The simulation is aimed at child care practitioners, and early childhood students and educators. The roles include: parent, community representative, executive board member, and other individuals in day care programs. Taking on a new role in the simulation allows staff to explore issues from a variety of perspectives. The 'in-box' approach uses documents relevant to day care administrators, including: letters, memos, and policy statements. In-box materials represent problems originating from: parents, children, staff, funding agencies, and governmental regulatory agencies. Examples of in-box items might focus on:

health, where a teacher is concerned about a child's eating problems; and curriculum, where a letter from a parent requests that their child does not play with other children. To develop the simulation, participants together: establish the goals of the simulation, decide on the issues to be explored, and decide whether the simulation should be about a particular setting, or whether a model setting is used. After developing the in-box materials, which are later trialled and reviewed during rehearsals, the simulation is run.

Through role-play, this multi-user simulation enables participants to focus on the issues surrounding child development, by discussing and solving them. The simulation appears to be static in nature in that actions around an in-box item do not impact upon any other in-box item in the simulation. The dynamics comes from the interactivity between the participants.

There were no findings as such but an evaluation of the process showed that several refinements to the running of the simulation were possible.

Foley and McAllister [FM05] describe a web-based blended learning simulation for pre-service teachers. Students develop a teacher identity completing assignments which involve planning for teaching at a simulated school, and reflecting upon their experience. An example of an elementary assignment includes developing a budget and a design for the classroom. Classes of simulated students are generated from a database of 800 static profiles, which include 'race, language, culture, interests, learning styles, family backgrounds, academics, and others.' Findings were that students felt more like a teacher by using the simulation, to visualise a real classroom and to appreciate the scope of a teacher's work. Some classes were too challenging for the students because of the amount of diversity in the students, which included creating cooperative groups. Students felt a sense of community, working with other teachers.

Lee and Choi [LC08] designed a web-based system for prospective early childhood teachers to expand their views of teaching, particularly classroom management, focussed more on exploring educationally appropriate strategies, rather than discipline. Students complete problem solving for a child's case in five stages: listen to an audio case description and complete a pre-essay, identifying initial solutions to any problems; listen to audio of other peoples' perspectives (teachers, administrators, parents); create a solution; revisit the solution using provided literature; and listen to audio of both the result and to multiple stakeholders' reactions to it, followed by a post-essay of their reflections. Findings demonstrated that students did show an awareness of the need for multiple perspectives, that they did explore diverse ways of problem solving, and that they could articulate a justification for their positions.

2.2.2 Student as child

Cheong [Che10] explored the use of role-play in Second Life where pre-service teachers delivered didactic sessions to their university peers, with avatars for both teacher and students (who could be located anywhere) situated in simulated 3D classrooms containing tables and chairs. Students were expected to use certain skills, such as reinforcement, in their session. Slide presentations, instant messaging, text chat, and voice chat were used for communication. Before practising their teaching, students learned how to use the software and observed some model teaching by their instructor. Afterwards, students took part in various reflection activities, some of which included watching captured machinima (real-time animated film using 3D graphics technology of computer games). The author concludes that pre-service teachers can practice teaching skills without a negative impact on (real) students and that repeated teaching practice is easier than in real life.

Gregory et al. [GDC$^+$11] used Second Life to simulate classroom management for pre-service teachers. They expanded the facilities on their existing private island. A focus group was held with 8 experienced teachers to identify common types of students in a classroom. The authors reduced the list and categorised them as ‘good’ or ‘naughty’. 40 primary school student avatars and 8 teacher avatars were created. The student avatars were small, looked young and wore school uniform. In groups of 6 to 8, student-teachers role-played a student (both as good and naughty), and a teacher, who would have to control the class during a short teaching episode. Machinima was recorded for assessment and reflection. Findings were that students felt the simulation was interesting, entertaining, and novel. They found playing the role of teacher was more important to them than being a student. There were some delayed display issues of avatars and surroundings as well as some chat communication problems. Students suggested the need for activity guidelines, such as not walking on desks. When role-playing the teacher, students found typing to communicate too slow. The authors plan to develop bots to take the part of the problematic children in the next phase of the research.

2.2.3 Software as child

Virtual School [Ree11] offers an authentic (content written by school leaders) scenario-based computer simulation for emerging leaders within (primary, secondary and special) schools and aims to introduce leadership issues within a simulated school environment. It periodically depicts cartoon-like identifiable children in the isometric corridor, where the contentment of the child can be discovered by hovering the mouse over the character's avatar. Children are represented as static 2D images and disappear from the corridor when classes begin. Classrooms show a static scene of children (around tables, at computers) and a teacher. The same classroom image is repeated in other classes; only the teacher's name changes. The image may change if the class is considered to be transformed in some way. Static information presented as a CV (e.g. years experience) and dynamic information (e.g. health) about the staff is available. The simulation is not real-time; it can be paused, rewound to the previous event, and fast-forwarded to (by choosing) the next event. The effects of the users' actions include changing attainment levels of the children and the morale of teachers. The findings from user evaluations were that users were not engaged due to the lack of variety, lack of ability to fail, and lack of reward. The feedback provided within the simulation was confusing, including numbers and descriptions of unconnected events, and unclear associations between action and consequence. Lack of integration into the teaching resulted in the simulation being considered unnecessary. There was little common ground in gameplay, due to randomisation of the simulation. In-game characters provided only introductory support. The look and feel of the simulation (cartoon-like) was an issue for the commissioners (a large UK training organisation) and users, which both exist in a risk-averse world under extreme scrutiny. The simulation has since been modified by: replacing scenarios with more discrete events, using photographs of real schools to be less cartoon-like, further integration into teaching, and being used in groups to encourage reflection.

Ferry et al. [FKC+04] present a largely text-based web application for preservice lower primary school teachers, to develop their decision-making, using scenarios. Users role-play the teaching of literacy to three children (aged 5 to 6 years), for which there is a profile, including a 2D, cartoon-like, head-and-shoulders image. Decisions include lesson organisation, classroom management, and responding to individual students. Reflective notes can be recorded throughout the simulation. The progress of the children, based on a regional model of pedagogy, is monitored during the simulation. Time is compressed into slices, based on days of the week. Users make predictions about the performance of the students and compare this to a prediction generated from a panel of experts. The findings were that students felt safe exploring the consequences of their decisions, without affecting real children. Students made connections between the simulation, their school-based experiences, and the theory of their pre-service education.

Fischler [Fis06] describes a web-based blended learning simulation for pre-service teachers. Instructors add predefined classes of simulated students or create their own. Classes occur in a school, for which other staff (e.g. nurse, parents) are generated. A student role-plays a teacher at a school and must complete timed assignments set by instructors. The assignments include ‘situations’, such as taking attendance, and ‘activities’, which are branching narratives (created by instructors) with photographs of children and question and answer sessions. Instructors role-play (covertly) simulated characters, such as a parent and communicate electronically with students. Simulated characters make remarks and hold opinions about other characters. The findings were that it was time-consuming for the instructors to create the branching content. Also, when the simulation was not integrated into classes, in-class discussions were not as successful.

Girod and Girod [GG06] developed a text-based web-based simulation, Cook School District, for pre-service teachers at university to explore the connections between their actions as teachers and the learning and engagement of simulated students. Profiles of the 200 simulated students are all based on a real person described by one of the authors who knew them as their teacher. Teachers make certain instructional choices and an algorithm uses a mathematical formula to generate reasonable outcomes based upon the student profiles. To encourage reflection the simulation can capture reflective teacher notes at any time, as well as the answers to context-sensitive questions. The authors found significant differences in the pre- and post-test scores of perceived skillfulness, for most participants.

The proprietary simSchool [Cur10] is a web-based application for pre-service teachers which simulates interactions between a teacher and simulated students. The teacher makes academic or behavioural assertions and observations, or poses questions. When setting up a simulation, students and tasks can be randomised or if they are manually created, students or tasks can be defined along identical dimensions. Student personalities are based on several models of personality, behaviour, and learning. For each student, the system represents language proficiency, academic capability, emotional states, and physical traits. simSchool can generate many different student profiles from the emotional variables openness, conscientiousness, extroversion, agreeableness, neuroticism, together with visual, auditory, and kinaesthetic capacities. The intelligence and emotional models are valid for five-year-olds and over, although the 2D cartoon-like graphics depict adolescents. Students sit at desks in a classroom, facing forward, in several states ranging from bored to engaged. The simulation experience is designed to be open-ended, dynamic, with no pre-determined paths, and no scenarios. Graphs allow the teacher to track the student's performance over a time period, and find out if it was as expected, better, or worse than expected.

The following findings are from a reflective report provided by an unnamed professor [sim08] on the simSchool blog. Students that invest time (over 10 hours), over several sessions, have more success. Students felt that: the comments took too long to select, because in that time the simulated student change their behaviour; and the comments were unrealistic, and wanted to be able to type in their own. Some students wanted to add more background information to the simulated students, and some wanted to create 'problem' students from their own experience. Students felt that the instructional activities were too limited because cooperative learning and creative approaches could not be used. Students only created small groups of simulated students.

Skrødal [Skr10] produced a simulation called Virtual Classroom Simulation (VCS) for pre-service teachers. The software simulates typical interactions and behaviours found in a real classroom. The students' variables (attributes) include mood, distractibility, self-efficacy, knowledge and meta-cognition. These variables can change depending upon teacher actions such as asking a distracted student to pay attention, asking a difficult question, and whether or not feedback is given. Changes in students are teacher-centered, dependent upon the 'what', 'how', and 'when' of teacher interaction. The simulation runs in real-time for added realism, which puts pressure on the teacher. Visual indicators such as facial expressions (indicating six underlying moods ranging from 'Happy' to 'Upset') on six student disembodied heads (all about fifteen years of age, with both sexes, and a range of ethnicity) are continuously updated. The static images of the heads were modified (to add hair) screenshots from 3D face modelling software, which uses a facial database. Every second, events are stored in a database, including student attributes. After a simulated session, interactive graphs, produced from the database, enable the teacher to explore how their teaching affected individual students during the course of the session. The findings show that students who are frequent games players are less likely to have a positive reaction to the simulation and the author postulates that this might be because there was less interactivity than found in games. Also, before using the simulation students had fixed ideas about certain aspects teaching and learning but afterwards showed a shift in focus.

2.2.4 Software or student as child

Mahon et al. [MBBK10] used Second Life to enhance the classroom management practice (maintaining discipline) of pre-service teachers. On a private island, a 3D campus was modelled, which included four classrooms with desks and seating. 30 middle school student avatars were created, for which individualised sociocultural profiles were assigned, including factors such as health and language background. Additionally, notes about behavioural and physical habits, and relationships with other avatars, helped to define the characters. The avatars were either controlled by real university students role-playing the middle school avatars (using the profile), or controlled by software ('bots') using finite state machines (Section 4.2.4). The bots' animations and text utterances were determined by their current state. State transitions were based on a timer or action/inaction by the person role-playing the teacher, as an avatar. Overall, the authors found that using Second Life for a simulation of classroom management had promise. However, they reported several performance issues running the simulation, considerable expense using the proprietary infrastructure, and long development times. Some students took the (disruptive) role-play too far and some moved the furniture in the classrooms. A big limitation is that, at any one time, only one person can ever role-play the teacher, even if all the students are controlled by bots. There are plans to make more use of bots, so students do not have to keep role-playing the same scenario again and again.

2.2.5 Summary of simulations

All the simulations of educational environments previously described are summarised in Table 2.1. In the 'Simulated environment' column, the original terms from the authors have been used as well as any specific ages supplied. Where it was not stated what sort of educational environment is represented in the simulation, the term 'Unspecified' is used. The column 'Simulation theme(s)' sums up what appears to be the essential characteristics of the simulation. The entries are grouped according to how the child is represented within the simulation, and then listed chronologically as they appear in the literature.

When totalled, the simulations are distributed as follows: planning activities (5), classroom management (5), problem solving using multiple perspectives (2), didactic teaching (1), questioning (1), management decisions (1), admin (1), and observation (1). With the exception of a few simulations ([DR76, FJMM79, LC08]), these simulations are about the performance of the adult, focussing upon adult-led activities and control, including those simulations that describe their simulation as being able to represent very young children. It is interesting that these three simulations, that are different from the rest, all use a static approach to represent children, although the time period in which two of these publications were written must certainly have influenced this. One of these simulations (though computer-based rather than a computer simulation) is the only one, out of all the simulations, which is about observing (visually) the child.

2.3 Defining early childhood

2.3.1 Terminology

Early childhood can mean several things. It can be described from three different but related perspectives: chronological age, developmental stage, or traditional school grade level [Gul04]. However, these three areas are all considered to be within the ages of birth to eight years old.

Unfortunately, in terms of ages, in the field of comparative early childhood education, similar words have different meanings in different countries, and different terms can sometimes have the same meaning. The term 'early years' is difficult to define. Alternatives to this such as 'pre-school education', 'preparatory education', 'pre-elementary education' or 'early childhood education' are also difficult

Reference	Simulated environment	Simulated child	Simulation theme(s)
[DR76]	Nursery, 3–4 yrs	Media	Observation
[FJMM79]	Day care	Media	Problem solving using multiple perspectives
[FM05]	Elementary, high schools	Media	Planning activities
[LC08]	Early childhood	Media	Problem solving using multiple perspectives
[Che10]	Unspecified, references other research in schools	Student	Didactic teaching
[GDC+11]	Primary school	Student	Classroom management
[Bri02]	Primary, secondary, special schools	Software	Management decisions
[FKC+04]	Kindergarten, lower primary, 5–6 yrs	Software	Planning activities, classroom management
[Fis06]	Kindergarten through 12th grade	Software	Planning activities, classroom management, admin
[GG06]	P–12	Software	Planning activities
[Cur10]	Unspecified, 5 yrs through adulthood, visually fifth grade through high school	Software	Planning activities, classroom management
[Skr10]	Unspecified, visually 15 yrs	Software	Questioning
[MBBK10]	Middle school	Software, student	Classroom management

Table 2.1: Simulations of children in their learning environments.

to define. The use of 'pre' in the terms conveys an impression that this age phase is viewed as a preparation for the compulsory system, and is considered inaccurate by many who work with young children in an educational capacity. The statutory age of admission to compulsory schooling (statutory education) varies around the world, ranging from 4 years to 7 years, though it is more commonly 6 years, and 5 years in England [BP02]. In England at least, 'early years' is the generally accepted term for the non-statutory educational provision for a child before they start school. The non-statutory here means that it is optional.

To summarise then, 'early childhood' is birth to eight years old, and 'early years' is (within England) birth to five years old.

Early childhood education refers to the education of children (birth to eight years old) by people outside the family or in settings outside the home. Early years education is similarly defined for its age range.

For those children that do receive non-statutory education, there are statutory requirements to which providers of the education must adhere. In England, the current legal requirements for learning and development for children from birth to five are set out in the *Statutory Framework for the Early Years Foundation Stage* [Dep08b]. The framework covers six areas: Personal, Social and Emotional Development; Communication, Language and Literacy; Problem Solving, Reasoning and Numeracy; Knowledge and Understanding of the World; Physical Development; and Creative Development. The framework states [Dep08b, p. 11] that, 'All the areas must be delivered through planned, purposeful play, with a balance of adult-led and child-initiated activities.'

Here, adult-led activities means that the adult decides what the child does, and child-initiated activities means that the child decides what activities to do [MAM02].

2.3.2 Play

There is much debate [Ale09] not about when children should 'start school' but when they should move from play-based learning to a domain-based curriculum (domains are areas of knowledge).

Free play is described by Play England [SGG07, p. xi] as:

> ... children choosing what they want to do, how they want to do it and when to stop and try something else. Free play has no external

> goals set by adults and has no adult imposed curriculum. Although adults usually provide the space and resources for free play and might be involved, the child takes the lead and the adults respond to cues from the child.

The phrase 'learning through play' is a non-negotiable principle of how early years practitioners work with young children and support their learning, development and understanding. This approach is strongly evidenced in research and protects children from inappropriate and premature over-formalisation [Dub12].

In play, children make sense of the knowledge and skills they have and apply it to their own interests, driven by their own motivations; this is often described as 'self-initiated activities'. In play, children: assimilate learning into their everyday experience, take risks, make mistakes, experiment, and explore. Play makes sense of the curriculum for the child [Dub12].

It is not possible to plan children's play (if it's self-motivated) but it is possible to plan for it, which includes: finding out how children are using resources; ensuring that there are opportunities for children to self-initiate activities and all areas of provision are always available; enhancing areas of provision and resources, which will raise the level and quality of play and encourage exploration; providing adult-directed activity to teach children new skills and knowledge which they can use and explore in their own play [Dub12].

Practitioners should use their judgement, based upon their knowledge of the child, to decide if they should observe and let the child's play develop, or intervene in some way, such as: making a suggestion, asking a question, or demonstrating a skill [Dub12].

2.3.3 Characteristics of the early years specialist

Some of the core characteristics needed to be an early years specialist are: spontaneity and flexibility, skills of reflection and analysis, an ability to take the lead, an ability to be playful and make learning fun, and an in-depth understanding of child development and effective learning [Edg04].

Working with young children is unpredictable. Young children are making sense of their world and do not always see things that adults do. They interact with experiences, materials and people in unexpected ways. If an adult is only comfortable when there is control and predictability, they will find working in the early years challenging. In fact, the controlling approach, encouraging dependence on others, is seen as inappropriate. The specialist needs to abandon plans that do not work, follow the child's lead, responding to spontaneous events or interests [Edg04].

Early years teaching is not just about what has to be done. It is also about thinking about its complexity. Teachers need to ask 'why' questions, gather evidence, draw tentative conclusions, and plan for development. Specialists are required to talk to others about their practice providing strong justifications based on analysis and reflection [Edg04].

Teachers are required to lead their teams and take responsibility for them, directing less experienced members of staff where necessary. As leaders they should be able to explain the links between theory and practice [Edg04].

There is an expectation for early years specialists to offer children access to the curriculum through play and through motivating first-hand experiences. This requires setting up high-quality play contexts and planning for exciting and relevant experiences inside and outside. To support children's learning through play, specialists need to be child-like and get involved as an equal participant, resisting the urge to direct the play [Edg04].

Through training, reading and observation, an early years specialist gains an in-depth knowledge of child development and effective learning. Non-specialists focus on curriculum content and learning objectives with little regard for the learner, unable to see which content is developmentally appropriate or how to introduce the content in engaging ways [Edg04].

2.4 Observation of human behaviour

The observational method of research for humans involves the watching, recording, and analysis of observed behaviour, the data from which can be used for drawing conclusions. There are five main types: participant observation, non-participant observation, structured observation, unstructured observation and naturalistic observation [Kee09].

In participant observation, the researcher takes an active part in the study. The advantages are: this gives an 'insiders view'; the behaviours are less prone to misinterpretation because the researcher was a participant; and for outsiders, they can become an accepted part of the environment. The disadvantage is that there may be a lack of objectivity by the observer [Kee09].

In non-participant observation, the researcher does not take an active part in the study. The advantage is that the observer effect is avoided. The observer effect is when the participant's behaviour changes as a result of the observer's presence. The disadvantage is that the observer is detached from the situation, so there is more reliance on their perceptive abilities, which may be inaccurate [Kee09].

In structured observation, the researcher uses a controlled environment. The advantages are: control of extraneous variables (environmental variability, participant variability, observer/observation variability); reliability of results can be confirmed by repeating the study; and a safe environment can be used to study controversial concepts. The disadvantages are: the controls may have an effect upon behaviour, lack of ecological validity (reflecting real-life), observer effect, and observer bias (influenced by prior knowledge/experience) [Kee09].

In unstructured observation, the researcher informally observes behaviour in a natural environment. The advantages are that it gives a broad overview of a situation, and is useful when the study has no particular focus. The disadvantage is that it is useful only as a first step [Kee09].

In naturalistic observation, the researcher observes behaviours within a natural environment. The advantages are: specific participants can be observed, ecologically valid recordings of natural behaviour, and spontaneous behaviour is more likely. The disadvantages are ethical issues when wishing to publish results of findings if consent has not been obtained [Kee09].

These five types of observation can be overt or covert. In overt observation, the participants are made aware that their behaviour is being observed, and recording devices such as video cameras are clearly visible. In covert observation, the participants are unaware that their behaviour is being observed, and recording devices such as video cameras are hidden from view [Kee09].

2.5 Observations in early years provision

2.5.1 Purpose

Observations of young children are used to plan and assess activities based on their individual development and needs. Skillful use of these observations enable practitioners to ensure that provision in early childhood environments optimises children's learning.

Examples of observational schemes are: *Practice Guidance for the Early Years Foundation Stage* [Dep08a] (in the United Kingdom), which covers the six areas of learning and development (Section 2.3.1); and *A Process-Oriented Child Monitoring System for Young Children* [LVKD02]. Both approaches present a schedule of observable behaviour. The former places the emphasis upon a stage-related development continuum, whereas the latter identifies stage-independent core behaviour.

There are several ways to measure quality in care and education. One approach is to look at the 'Treatment' such as infrastructure, equipment, activities, teaching methods, and teacher's actions. Another approach is to look at 'Outcomes', by considering the objectives and results. Sandwiched in the middle of these two approaches is 'Process' which looks at the experience of the individual [LVKD02]. The Early Years Foundation Stage, with its play-based curriculum certainly considers this as important, though the emphasis is more on 'Treatment' and 'Outcomes'. The process-oriented child monitoring system known as Experiential Education (EXE) is wholly about 'Process' and looks at the degree of 'emotional well-being' and 'involvement' in an individual. Well-being is associated with basic needs such as: physical needs, tenderness, safety, social recognition, competence, meaning in life, and moral value. Involvement is linked to development and requires the adult to provide a challenging environment for intrinsically motivated activity. The quality of an educational setting is assessed by observing the well-being and involvement of individuals within it.

2.5.2 Theory and practice

When conducting observations, theories can help the observer to predict how children might behave. Theories help the observer to structure what they observe and to make sense of it. However, rather than narrow down thinking about childhood play, theories can be used to open up thinking and challenge observer's assumptions, which will help to develop the observer's understanding. When analysing play, the observer can link what they have found with that of theorists. The observations may or may not fit with theories, but the process helps the observer to think deeply about play, and continue to find out more about it [Bru01].

2.5.3 Types

There are three main types of observation used by early years practitioners: informal noticing, participant jottings, and focussed observation [Edg04].

Informal noticing (or having eyes and ears everywhere) is what is done all the time and may be about a wonderful construction, the fight over a toy, or phoning for pizzas (which might result in the practitioner supplying menus, order pads and so on, to support the play) [Edg04].

Participant jottings are quick jottings when the adult is working directly with the children within adult-led experiences or when the adult joins in with child-initiated play [Edg04].

Focussed observation involves standing back from what is happening, and writing down as objectively as possible what takes place. The focus is a single child and the observation is most effective and illuminating when the play is child-initiated. Small teams of practitioners may observe a child separately, coming together later to discuss their findings and consider next steps [Edg04].

2.5.4 Challenges

An observer should ideally aim to be an onlooker, not directly involved in the learning episode. However, children often expect adults present to be a resource to which they can turn. This makes simultaneous supervising/helping and observing difficult; children's needs may not be met, plus there may be health and safety risks. The presence of an observer writing notes, shooting a video, or taking a photograph, can also affect the way children play and behave. To minimise the impact of the observer, a distance should be kept away from the children's activity [BM06].

Video recording has its own challenges. Fixed cameras are limited to activity demonstrated within an area and may require editing during periods of inactivity. In addition, an edited recording is no longer a true representation of events. Hand-held cameras provide more flexibility but are more intrusive. If the observer is filming, they may miss something interesting; it is also quite difficult to walk and film at the same time [BM06].

2.6 Summary

The nature of simulations has been discussed, and how they may incorporate elements of game, contest, and emergence. 3D graphics are a common element in modern computer games and provide learning affordances in 3D virtual environments.

Various simulations developed in the literature for the learning environments of children, as used by education students, have been reviewed. The simulations have been classified according to how the child is represented, which has revealed the degree to which the authors have attempted to automate the behaviours of the children. An attempt has been made to identify the main themes of the simulations (Table 2.1), recognising that some simulations have several themes.

The nature of education in the early years has been shown to be based on a statutory, play-based curriculum. Within this context, early years specialists support the learning of children by working in very flexible ways, including planning for child-initiated play, where controlling the child is not the priority. Early years practitioners observe young children, to plan and assess activities, using developmental theories and curriculum guidance to make sense of the play. Observing is challenging, particularly because the practitioner must usually balance observing with participating, and also attempt to record the observation. The challenges of observing young children are very much related to the challenges of using observation as a general research method for human behaviour.

Chapter 3

Research design

This chapter provides an account of the methods used in this research. After reviewing the context described in Chapter 2, the research questions are identified. The reasons for using a peer debriefer are given. The use of experimental studies within educational environments is considered, and a comparison with another observation-based study using simulation software is made, before describing the approach taken in this work. Using humans as research participants introduces various ethical issues and the procedures followed are set forth. The sampling approach taken for participants is justified. The research is broken down into a pilot study and a main study, for which the recruitment approaches are given and participant conversion rates are reported. Descriptions of the research instruments used and their characteristic benefits are provided. An overview of the data analysis approaches, combining quantitative and qualitative aspects is presented. The process of content analysis is described, including how it was applied in this work. The importance of the project web site is made clear.

3.1 Review of context

In Chapter 2 the findings in the literature, in which simulations of children's learning environments were used by education students, were reported. These findings collectively demonstrated that the students were able to: improve observation skills, explore the consequences of decision-making in a safe environment without affecting real children, feel more like a teacher, visualise a real classroom, appreciate diversity, relate theory to practice, and be entertained. It was also established that most of these simulations, even those that claim to represent young children, have themes of planning and control, whereas, in practice, for very young children, a more supportive approach is used to facilitate learning through play, informed by observations of the child. An analysis showed that there are various levels of automation used to represent the children in the simulations, with only a few simulations using 'bots', and only a few simulations using a 3D graphical environment. Some of the terminology relating to simulation and gaming technologies was examined. The challenges of observation, in general, and by practitioners working with young children, were described.

Putting all this together, an area of investigation has been identified with the following ingredients: young children, child-initiated play, developmental theories, 3D graphics, simulation, emergent gameplay, education students, and observation.

Would it be possible to combine research data gathered from real observations of early childhood development, and any associated theories, and represent simulated children for the purposes of simulated observations?

A similar approach has been taken by astronomers [HCB+02], to bridge the gap between observers and theorists working on star clusters, where the approach involved 'observing simulations'. They collected the results from their star cluster simulations, generated simulated observations, and offered these up to observers for analysis.

The research questions will now be stated.

3.2 Research questions

These questions are aimed at early childhood education professionals.

Central question What is the perceived utility of a real-time 3D graphical simulation of children's play behaviour?

Sub-questions

- Is the simulation an interesting way to explore the behaviours of young children?
- Can the understanding of the theory behind children's play be deepened?

- Can observational skills be developed?
- Does professional experience influence the perceived utility of the simulation?
- Does the number of real-life observations conducted of young children influence the perceived utility of the simulation?
- Does playing video games influence the perceived utility of the simulation?
- What level of abstraction is appropriate for the representation of young children in a play environment?

3.3 Peer debriefing

This author's academic and professional experience includes computer science and the education of adults, which has no doubt shaped the work in this thesis. However, although the work is rooted in computer science, the theoretical knowledge domain which provides the contextual focus, early childhood education, had not been formally experienced by this author, although being a parent of three children would have certainly provided some level of informal experience. Inevitably, there would be new domain knowledge to acquire and synthesise. It was therefore desirable, for validity, to make use of a professional with expertise in the field of early childhood education. This professional would largely act as a debriefer [Spi03], contributing philosophical and theoretical perspectives to the study, and providing a sanity check to confirm that any ideas are sound.

A lecturer in Early Childhood Studies within the Faculty of Education at Liverpool Hope University agreed to act as a debriefer during this research project.

Five meetings were held with the debriefer. Four of the five meetings were held in the academic year 2009–2010, one of which included the supervisor of this work, and one meeting was held in the academic year 2010–2011. The meetings began at the inception of the study, when a simple version of a simulation had been built, including a 3D graphical environment with animated characters, and this author was ready to discuss ways forward, such as the possible representation of character behaviours. Further meetings reviewed the development of the simulation and other discussion included: getting ready for a pilot study, sources for recruiting participants, and outlets for publications.

Email correspondence was used, particularly throughout the academic year 2011–2012, when trying to recruit participants at the debriefer's university, and also during content analysis. For the latter, the debriefer's experience in qualitative research methods was valuable when they agreed to check the coding process, and ascertain whether the categorisation of data reflected the participant's perspective (Section 6.2.4).

3.4 Methodology

Quantitative research generates statistics from large-scale surveys, using methods such as questionnaires or structured interviews. This type of research reaches many people but the contact is much quicker than qualitative research. Qualitative research explores attitudes, behaviour and experiences and attempts to get an in-depth opinion from participants using methods such as interviews or focus groups. Fewer people take part, but the contact tends to last longer [Daw09]. Phenomenology, whereby the researcher attempts to explain and explore the way people view the world in the light of their own experience, underpins much of qualitative research [Dav07].

The term quantitative research conceals the fact that there are two methodologically related but different approaches within it: experimental research and survey research [Dav07]. Section 3.4.1 discusses the issues of using an experimental approach. The approach chosen, which combines a quantitative survey approach and qualitative methods, is then presented in Section 3.4.2.

3.4.1 Issues with experimental research

In experimental research the researcher manipulates a variable (the independent variable) and changes that variable to determine the effects on one or more outcome variables (dependent variables). For example, a new technological tool (the independent variable) might be implemented in a classroom and a researcher may then see how student academic achievement (the dependent variable) is affected. To make experimental research designs meaningful, the major threats to internal validity must be understood [Ran08]. However, a technological intervention was not introduced into an educational environment to see whether academic achievement is effected. This would have required integrating the intervention into specific academic programmes, and attempting to measure the difference in outcome using one or more experimental groups and a control group which had not been exposed to the intervention. The ownership of the research would have made this approach very difficult anyway because the intervention was not a national, regional, institutional, or faculty initiative by early childhood education professionals.

Research designs built around random selection permit justifiable inference from the sample to the population, at quantified levels of precision, and guards against bias [Sta00]. However, even if some sort of experiment had been devised, whether or not the outcome was academic achievement, there are several issues with conducting randomised experiments in educational research projects which Falaye [Fal09] proposes, and is adapted here.

There should be fairness in the assignment of individuals to any of the study groups. This can be achieved by determining eligibility to participate in an experiment before randomisation, so eligible individuals would not be disadvantaged relative to others [Fal09].

During experiments the control group does not undergo new interventions. To make sure that those in the control group are not disadvantaged, or denied the benefits of those in the treatment group, participants must be given equal opportunity to be assigned to the treatment group [Fal09].

Unlike fields such as medicine, isolating the effects of an intervention in education from all the other influences is a difficult task [Fal09].

Individuals assigned to groups at the start of the experiment may change in some way during the experiment and contaminate the results [Fal09].

In an educational setting, random assignment is difficult because students are already grouped into classes. It is more practical then to use intact classes as treatment groups, rather than individuals from those classes. This is known as quasi-experimental research and the degree of confidence in making inferences of causality is lower than true experimental design [Fal09].

There is a nice example of a quasi-experimental design which investigates the changes in students' conceptions about moon phases based upon observations [TB10]. Data was collected from three groups of participants: observations using a computer simulation only, observations using a computer simulation and from nature, and observations from nature alone. The findings report that the people who used a computer simulation to learn about moon phases understood the concepts just as well, and in some cases better, than those who learned by collecting data from viewing the moon. Due to its apparent similarity with this work, the moon phases research is worthy of a compare and contrast exercise.

Comparing this research to the moon phases research gives:

- Computer technology is being used for the simulation.
- A simulation running on the computer technology contains things from the natural world.
- Observations using the simulation address impracticalities of observations in nature.
- Participants are students in the domain of early childhood education.
- Participants are expected to gain knowledge when using the simulation.

Contrasting this research with the moon phases research gives the analysis in Table 3.1.

It can be seen that there are, in fact, considerable differences between this work and that of the moon phases research. Of particular interest is that the authors in the moon phases research have more control over data gathering from participants, since the research is integrated with the teaching of the students. Even if the moon phases research had been published earlier, it is unlikely that it could have been used as a research design template.

There are some parallels here between the moon phase research and Skrdal's research [Skr10]. For the latter, the software had already been partly developed during an undergraduate project. The research was conducted at the university of the author, receiving firm support from the School of Education, with the simulation software being incorporated as an integral part of a compulsory course called Student-Teacher Interaction in the Classroom 1.

3.4.2 Approach taken

The issues of an experimental approach have been considered in Section 3.4.1 and specifically a randomised experimental approach. However, these are not really appropriate for this study as a more exploratory approach is being taken.

In order to match methodology to this research topic, consideration needed to be given to quantitative or qualitative research. By considering the types of words that underpin the research questions, it can be established whether there is

Item	Moon phases research	This research
Simulation software	Proprietary	None exists
Domain-knowledge content in simulation software	Part of a rich knowledge base	None exists
Basis for domain-knowledge content	National standards for children's learning	Researcher-led, supported by domain-knowledge specialists
Nature of domain-knowledge content	Scientific facts	Behavioural models interpreted by researcher
Domain-knowledge content observable in nature	Mostly—depends on geography and weather	Sometimes—depends on infrastructure of setting, plus interests and personalities of observees
Intended outcomes of exposure to domain-knowledge	Pass on facts to others	Understand and support development of others
Ownership of research in knowledge domain	Yes	No
Research integrated with teaching	Yes	No

Table 3.1: Contrasting the moon phases research with this research.

a leaning towards quantitative or qualitative research [Daw09]. Table 3.2 shows the types of words that suggest quantitative or qualitative research and whether those words are relevant for this research. It can be seen that there is not one clear research approach (quantitative or qualitative) that emerges, which suggests either changing the research questions, or making use of a mixed-methodology approach. The latter is now discussed.

Research type	Underpinning research words	Relevance of words
Quantitative	How many	Yes
	Test	No
	Verify	No
	How often	Yes
	How satisfied	Yes
Qualitative	Discover	Yes
	Motivation	Yes
	Experiences	Yes
	Thoughts	Yes
	Problems	Yes
	Behaviour	Yes

Table 3.2: Matching research methodology to this research topic based upon the underpinning words of research questions.

Methodological triangulation combines the use of quantitative research and qualitative research to counteract the weaknesses of each approach [Daw09] and to provide a more complete set of findings than could be arrived at through the administration of just one approach. Furthermore, triangulation determines how far the different approaches arrive at convergent findings, in order to establish their validity, provided that the data from both approaches is not flawed [Bryndb]. However, Bryman [Brynda] acknowledges the criticisms of seeking to enhance the credibility of the research in this way, which are summarised here. First, it is difficult to establish that evidence from one type of research can legitimately provide support for the other since quantitative and qualitative research are derived from contrasting epistemological and ontological positions (Positivism vs. Interpretivism and Objectivism vs. Constructionism). Second, is the problem of dealing with a disparity between the two sets of evidence. It is possible that an assumption may be made that one is more likely to be valid than the other and to use that as the yardstick of validity. Third, triangulation uses an approach based on realism which is inconsistent with a constructionist position adopted by many qualitative researchers which denies the possibility of absolutely valid knowledge. Fourth, it may be assumed that a multi-strategy approach is better than a mono-strategy approach but in practice the research design may not allow one strategy to add anything substantial to what is already known using the other strategy. Fifth, although some researchers may be experienced in both approaches, others may have strengths in only one particular approach.

Whilst recognising the philosophical limitations of triangulation, a mixed methodology (quantitative and qualitative) approach was chosen together with triangulation to establish convergent validity. Quantitative data was collected using questionnaires, and qualitative data was collected using focus groups, interviews, and questionnaires (Table 3.5).

3.5 Ethical approval

This research project makes use of human participants and it is important to conduct the research in line with ethical standards, treating both the participants and the information they provide with honesty and respect. Typical considerations include: how participants are recruited; obtaining informed consent from the participants; minimising the disruption to a participant's life; keeping data provided by the participants secure, anonymous and confidential; making the research overt, so that participants know who the researcher is and what they are doing, possible benefits to be gained by taking part, and what will happen to the results; and identifying any potential risks to the participants [Daw09].

After first being subjected to an internal ethical validation process within the School of Computer Science, this research project was later ethically reviewed and approved (ref 11272) by the University of Manchester Senate Committee on the Ethics of Research on Human Beings.

A description of how confidentiality was maintained can be found in Section A.5.

3.6 Pilot study and main study

A pilot study was conducted before a main study to test the feasibility of the mixed methodology research design. More specifically, consideration was to be given to: the response to the simulation, the use of a supporting website, the design of the activity, the design and administration of questionnaires, and the conduct of focus groups. The pilot study was reported through three peer-reviewed publications [ACHA11b, ACHA11a, ACHA12].

3.7 Sampling

The sampling approach taken was the nonprobabilistic method of purposive sampling in which one or more specific predefined groups are sought. An example of this is when a market researcher is on the street with a clipboard looking to interview Caucasian females between the ages of thirty and forty. Purposive sampling is useful for situations where a targeted sample needs to be reached and where sampling for proportionality is not the main concern. The specific type of purposive sampling used was heterogeneity sampling, because all opinions or views were required, and those views did not need to be represented proportionately. Such an approach is used in brainstorming and nominal group processes to get a broad spectrum of ideas, from a broad and diverse range of participants [Tro06].

It should be noted that participants were self-selecting volunteers and thus likely to be the most motivated, which introduces a self-selection bias.

Research participants were males and females, between the ages of eighteen and sixty-five, and undertaking continuing professional development or on an accredited course with an aspect of early childhood education as part of their studies. The study was open to both students and educators involved with early childhood education courses. By becoming a participant, educators were considered to be undertaking continuing professional development, and were therefore eligible to take part.

Since the sampling approach was nonprobabilistic, it is not possible to generalise statistically beyond the sample, although it is possible to generalise theoretically.

3.8 Recruitment

During the period of this research, The University of Manchester did not offer any academic programmes based upon early childhood education, so research participants in this field were recruited from outside the university.

3.8.1 Pilot study recruitment

During the pilot study, a personal contact at Liverpool Hope University (Section 3.3) facilitated access to early childhood education lecturing staff for a focus group, and to early childhood education students for both evaluations and a focus group. An application to Liverpool Hope University Education Research Ethics Committee was accepted. There was no coercion of students at any point and the students were reassured that they would not be disadvantaged if they chose not to take part in the research.

The participants used in the pilot study were not going to be used in the main study.

3.8.2 Main study recruitment

A multi-pronged approach was taken to recruit participants for the main study: a personal contact introduced the research to several hundred students, followed by a VLE post; a national email call for participation to 59 institutions; personal contacts used formal sessions at their academic institutions; and personal contacts used professional networks.

In order to establish a contact list of named individuals associated with early childhood education academic programmes in the United Kingdom, the following approach was taken. Names were obtained from the following early childhood research organisations: European Early Childhood Education Research Association (EECERA) Special Interest Groups, European Early Childhood Education Research Journal (EECERJ) editorial board, International Journal of Early Years Education (IJEYE) editorial board, TACTYC Member profiles, and Contemporary Issues in Early Childhood (CIEC) journal editorial board. If no email address was provided, a search was performed on the website of the institution to which the individual was affiliated. A search was carried out at `http://ucas.com` and `http://postgrad.com` using the keyword 'early' to obtain a list of programmes containing 'early childhood' or 'early years' in the title. The lists returned were then used as a starting point to find named individuals on the institution's website. Academic programmes at universities and at university colleges were pursued but not programmes at colleges. It was often necessary to search institution websites for academics associated with early childhood education courses, hoping to find an email address listed for the academic. A few people's email addresses were no longer valid, so either the correct one was found, or alternative individuals were found as a replacement for the original person at that institution. Sometimes there would only be a general email address for admissions, in which case it was not used. With the contact list established, 59 emails were sent in December 2011 to named individuals at different Higher Education Institutions (HEIs) (Section A.1) in England, Scotland, Wales, and Northern Ireland, asking them to circulate the call for research participants to relevant individuals at their institution. The email call was sent again in January 2012. The actions contained within the responses to the call, reported by the individuals, are classified in Table 3.3.

Action type	Frequency
Forward to specific relevant people	1
Forward to unspecific relevant people	5
Forward to unnamed manager	2
Forward to named programme leader(s)	1
Forward to unspecified programme leader(s)	1
Forward to named person	1
Forward to specific research network	1
Introduce through specific curriculum area(s)	1
Put on intranet	1
Put on virtual learning environment	1

Table 3.3: Actions by 14 contacts in response to recruitment mailshot by email.

For the main study, a personal contact at Edge Hill University approached programme leaders in early childhood and asked them if it would be possible to run some simulation evaluation sessions with their students. Two programme leaders, one for a foundation degree, and one for an undergraduate degree, agreed to a session being run for each programme. One of the programme leaders said that they had already seen the call for participation which had been sent to the universities, which included Edge Hill, and was already interested. The personal contact did not have any academic relationship with any of the students. For the main study, a personal contact at Liverpool Hope University facilitated access to early childhood education students to complete some evaluations.

For the main study, a personal contact at Edge Hill University approached lecturers on early childhood education programmes who taught at the same institution, and also colleagues who worked elsewhere, such as local education authorities, to consider becoming a research participant.

3.9 Participant conversion

In total, 132 people signed up to be a participant, of which 24 people signed up for the pilot study (at Liverpool Hope University), and 108 people signed up for the main study, although not all of these participants provided research data.

With the exception of the educators in the pilot study, all participants were expected to complete an evaluation, which means the completion of a questionnaire, following on from the completion of a common activity using the simulation. Only a small number of participants additionally took part in focus groups or interviews. The triangulation matrix in Table 3.4 shows the number of participants from whom data was used, covering students and educators, from various institutions, using the different data collection methods.

	Evaluation	Focus group	Interview
Students	Edge (39) Hope (5) Hope *pilot* (9)	Edge* (4) Hope* *pilot* (6)	
Educators	Edge (3) Knowsley (2) Trafford (1)	Hope *pilot* (4)	Edge* (1) Knowsley*,† (1)

Table 3.4: Triangulation matrix showing data collection methods against participant type. Entries indicate the number of participants (in parentheses) from whom data was used at specific institutions. Edge = Edge Hill University. Hope = Liverpool Hope University. Knowsley = Knowsley Local Education Authority. Trafford = Trafford Local Education Authority. *pilot* = pilot study. * = completed evaluation. † = videoconference.

Since most of the participants were expected to complete an evaluation, the conversion rate from participants signing up, to participants providing evaluation data, for both the pilot study and the main study, is described in Section 5.2.2 and Section 6.1.3, respectively.

3.10 Research instruments

3.10.1 Simulation

A 3D graphical simulation environment was developed. The simulation provides an interactive sandbox for users to add characters (representing children), by defining them manually or having them randomly generated. The behaviours of the characters are informed by the findings from research in early childhood. The terrain of the environment can be customised and objects added and manipulated. The simulation gives the user the ability to explore the continuum between observer and participant. The implementation of the simulation is described in Chapter 4.

3.10.2 Evaluation

Participants complete a questionnaire, which follows on from the completion of a common activity, using the simulation. Since the activity and questionnaire are closely interconnected, they are collectively termed an ‘evaluation’.

In order to give participants a similar experience using the simulation an activity was devised for the pilot study and the main study. This would be useful in exposing the participants to the major features of the simulation and would ensure that they were at least able to give meaningful answers when asked about their experiences.

A questionnaire is a form of survey in which two possible types of question are posed, closed-ended and open-ended. A closed-ended question is used to generate statistics in quantitative research and poses a question where the respondent is given options to select, perhaps using some form of rating scale. An open-ended question offers a blank section for the respondent to write in a more detailed response, which makes the data analysis more complex as there are no standard answers [Daw09]. In the pilot study and main study questionnaires were used which had a combination of closed-ended questions and open-ended questions. It could be argued that, for the participants, certainly the students, and possibly the educators, completion of the questionnaire after the activity was not just a way to gather attitudes, but that it also fulfilled an important role as a self-directed debriefing exercise, to deconstruct the activity (using the simulation) and then connect it into their existing mental models [Nic12].

3.10.3 Focus groups

A focus group could also be considered a discussion group or a group interview. A number of people are asked to join a group to discuss an issue. They are popular in market research, political research, and educational research. A focus group is facilitated by a moderator who prompts with questions, probes for further detail, ensures the discussion does not digress, and endeavours to achieve participation from everyone without any one individual dominating the discussion [Daw09]. It could be argued that, for the students concerned at least, the focus groups were not just a way to gather attitudes, but that they also fulfilled an important role as a group debriefing session, to deconstruct the activity (using the simulation) and then connect it into their existing mental models [Nic12]. A focus group transcription sample can be found in Section A.3.

3.10.4 Interviews

A semi-structured interview is used when the interviewer has a framework of themes to explore but also wants the flexibility to find out other information during the course of the interview. This format lies somewhere between an unstructured interview, where there is no structure at all, and a structured interview, where only certain questions are asked [Daw09]. Interviews were used in the main study with educators to explore their attitudes both as someone who has used the simulation, and also as an educator of others who might potentially use the simulation. An interview transcription sample can be found in Section A.4.

3.11 Data analysis

The approaches taken for data analysis have been grouped into four categories (Table 3.5): quantitative analysis of quantitative data, quantitative analysis of qualitative data, qualitative analysis of qualitative data, and qualitative analysis of quantitative data [Ran08].

Statistical analysis SPSS Statistics [Ibm10] was used for analysing the data obtained from the questionnaires in the main study (Section 6).

Analysis type	Data type	Data source(s)	Analysis Method(s)
Quantitative	Quantitative	Questionnaire	Pearson's correlation coefficient Mann-Whitney U test Logistic regression Central tendency
Quantitative	Qualitative	Focus groups Interviews Questionnaire (free-response answers)	Content analysis
Qualitative	Qualitative	Focus groups Interviews Questionnaire (free-response answers)	Content analysis
Qualitative	Quantitative	Questionnaire	Graphs

Table 3.5: Data analysis approaches grouped into four categories.

Content analysis Analysing documents resembles the work of the historian but content analyses can be performed on anything that is written down or recorded such as film, TV programme or website [Dav07]. Using content analysis, a researcher systematically works through transcripts assigning codes, which may take the form of numbers or words, to specific characteristics within the text.

The large amounts of transcribed text from the focus groups and interviews, plus the data collected for the open-ended response items on the online questionnaire, in the main study (Section 6), were subjected to content analysis.

Constant comparison was used when coding the text. This means that every time a passage of text is coded, it is compared with all the passages that have already been coded that way. This ensures that the coding is being performed consistently and allows re-examination of passages that no longer fit so well, and which might be better coded in a different way.

TAMS Analyzer [Wei11] was used for the content analysis of the text. The purpose of the program is to identify themes in texts, assign codes to passages of text using TAMS (Text Analysis Markup System), and analyse the data using reporting features.

3.12 Project web site

A PHP/MySQL driven web site was developed for participation management and data collection, and was available here:
`http://www.cs.man.ac.uk/~aac/observation/`.

The home page provided: information about the project, including a brief video introduction from this author; information about the simulation; screenshots of the simulation; a brief promotional video of the simulation; dynamic statistics about downloads and involvement in participant studies; and a list of related publications by this author. There were links to check eligibility for participation, signing up, signing in, and resetting a password.

If potential participants were interested in becoming a participant they proceeded from the home page to the signup page. They were given brief information about what they were signing up for and a link to the participant information sheet approved by the University of Manchester Senate Committee on the Ethics of Research on Human Beings. Participants completed a web form, providing an email address and password. By doing this, they were giving informed consent to be a research participant. An automated email was sent to the potential participant immediately, containing an activation code, requesting them to reply to the email to activate their account. Once account activation was complete, access to the members area was made available by logging in.

The members area had: download links for Windows, Mac OS X, and Linux application bundles of the software (which include a printable user manual); software running instructions and troubleshooting information; a multilingual web version of the user manual; a series of brief video tutorials on the main features of the simulation; a link to the activity, available as a printable download or as a multilingual web version; a link to the online questionnaire for evaluating the simulation; and a form to post comments at any time.

It was thought that the use of videos would give a lot of flexibility for any participating organisations in the following ways: educators could show the videos at a point in a session (e.g. lecture) convenient for themselves, using their usual computer/projector setup; and students could view the videos independently in their own time. The videos were hosted on YouTube using the 'Unlisted' privacy option which means that anyone with the link could view it. The videos were not searchable or public in any way, and at the same time were not private, which requires viewers to hold YouTube accounts and to be added individually, up to a maximum of fifty users. Invitation to participate was therefore carefully controlled, only targeting groups that have aspects of early childhood education as part of their professional development or studies.

After completing the activity using the simulation, the online questionnaire was completed. The questionnaire validated all participant responses (except two open-ended answers) to prevent any non-sensical or missing data.

Weekly email reminders (between January and March 2012) were sent to those participants that had signed up but had not completed the evaluation.

3.13 Summary

This chapter described the approach taken in this research. There are challenges when conducting research using human participants in an educational context, and especially when than context is outside that of the researcher. The sampling approach taken was justified and the multi-pronged approach to participant recruitment for both the pilot and main study was given. The chosen survey-based mixed-methods approach to data collection was described, as well as the data analysis approaches used. The project website, which provided the infrastructure for the participants, including controlled access to the simulation, was described.

Chapter 4

Realisation of observable characters

This chapter looks at the development of the simulation Observation used in this research. Some of the tools available are considered and the approach taken for development is justified. The features of the simulation, and techniques used to create those features, are described in terms of three main areas: character representation, the environment, and the role of the adult.

4.1 Approach to development

It was not an easy task deciding how much emphasis should be placed upon original development and how much should be placed upon the use of toolkits for development. Prerequisites were that any toolkits used should be: free, cross-platform, open source (preferably), have permissive licensing agreements, and not require the latest computer hardware to run.

The nature of the simulation was going to be a 3D world with characters exhibiting behaviours, under some control by the user, so the place to look for suitable toolkits were those that at the very least incorporated 3D graphics, such as: Open Scene Graph [Ope09], MAVERIK [Adv02], and G3D [G3D09]. Graphics toolkits are given several names, such as 3D engine, graphics engine, rendering engine, or a combination of these terms. Graphics toolkits provide a higher level of abstraction than pure source code, hiding the details of graphics APIs such as OpenGL from the developer; some of them provide yet another level of abstraction by way of a scene graph approach.

Some toolkits support further functionality such as character animation, movement of entities, and physics, such as: Ogre [Ogr09]; Irrlicht [Irr09]; Crystal Space [Cry09], using a set of plugins called CEL; Panda3D [Car09]; and Delta3D [Del09]. Other toolkits focus upon the portrayal of human characters such as VHD++ [PPM+03], a real-time development framework for virtual character simulation applications. More sophisticated toolkits come with powerful editing tools such as Unity [Uni09], which supports scripting in JavaScript, C#, and a dialect of Python called Boo.

As the toolkits become more complex and combine different technologies to cater for various aspects of 3D games or simulations they tend to be known as game engines, with Panda 3D described as a game engine, Delta3D described as a gaming and simulation engine, and Unity described as a game development tool. A game engine is a framework composed of a collection of different tools, utilities, and interfaces that hide the low-level details of the tasks that make up a video game. Such tasks include: graphics, physics, input detection, audio playback and control, scripting, artificial intelligence (AI), networking, and core utilities [She06]. These features, or support for these features, will be present in a toolkit, to varying degrees, depending upon whether its main function is largely as a graphics-based 3D engine or as a more comprehensive game engine.

The features available with most of these toolkits has continued to grow since development started on this research project.

The advantages of using toolkits are: most (or all) of the coding is done for you (no need to re-invent the wheel), so you only have to be concentrate upon the content; performance management has been designed and tested thoroughly; and cross-platform code requires little or no work to port to another platform.

The disadvantages of using toolkits are: if you modify anything, or hook into any of the source code from your program, you need to become familiar with a new codebase; overwhelming application programming interface (API); if there is a bug, or performance issue, unless it's open source, you cannot fix it; they are not designed specifically for your requirements and may not do what you want; lack of support (documentation, community forums, tutorials, sample source code); and lack of control, since other programmers are responsible for development.

To maximise flexibility and control, the decision was made to implement the codebase from scratch using C++ and OpenGL, which involved developing a library for rendering, animation, and character AI, and being highly selective in the use of existing libraries, minimising dependencies on large, complex toolkits. A bottom-up approach was taken to development, implementing essential features only, attempting to create reusable library code wherever possible, inspired by the techniques used in game development. This author had no prior experience in graphics programming, so although costly in terms of time, it was felt that it would be beneficial in the long run to acquire fundamental skills in graphics programming at a low level, in order to understand how to integrate graphics with: character AI, physics, and user interaction including a graphical user interface. This author wanted to gain experience developing a cross-platform application, from the ground up, learning about and incorporating multiple techniques and technologies. The approach taken enabled complete control over how character AI was implemented and provided the opportunity to develop a straightforward way of programming basic animated characters in a 3D world.

Early experimental prototypes were written using C and OpenGL, making use of textual heads up displays (HUDs), and as more interaction was added, a simple graphical user interface (GUI) was developed (Figure 4.1) using GLUI [Rad07].

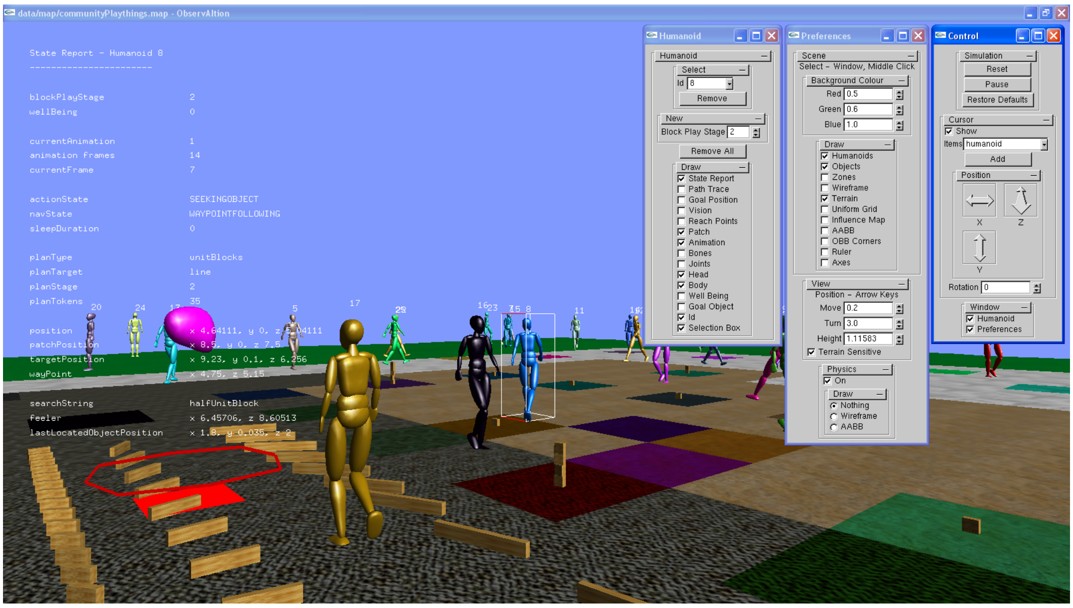


Figure 4.1: Early version of Observation showing a Heads Up Display (HUD) and initial Graphical User Interface (GUI).

As the codebase grew, C code was replaced by C++ classes (with the exception of a few routines), making use of the Standard Template Library (STL), largely for dynamic data structures, and a more sophisticated graphical user interface was developed as part of a Qt [Nok10] application, using the open source version of the Qt cross-platform application and user interface framework. External dependencies are limited to portions of the Bullet physics library [Cou10], although it is possible to compile and/or run the simulation without physics; and GLM [Rob00], for manipulating meshes in the Wavefront OBJ [Fil09] format.

The simulation has been compiled for Windows, Mac OS X, and Linux.

4.2 Creating believable characters

Of the three perspectives of early childhood introduced in Section 2.3.1 (chronological age, developmental stage, and traditional school grade level), developmental aspects have been chosen as a basis to define the characters in the simulation, as these have the interesting property of being open to interpretation with respect to age.

4.2.1 Selective aspects of child development

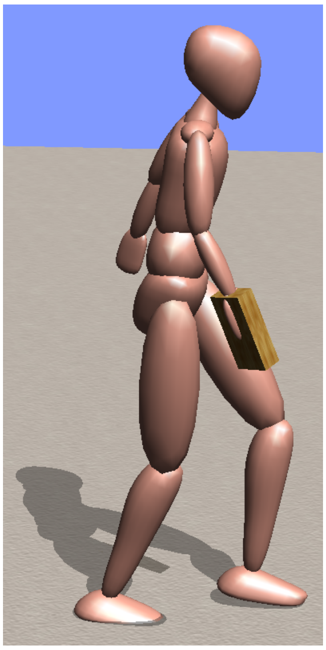
Three representative aspects of a young child's observable behaviour have been incorporated into the simulation and they are all based upon research in child development. This is, of course, a gross abstraction [Pre02] of a child, but it does permit the exploration of a given 'possibility space' [Wri04]. The three aspects are blockplay, social play, and egocentrism, which are now discussed.

Blockplay Blocks are usually made from hardwood and can be arranged together in geometric patterns. A unit block from Community Playthings [Com10] has the following dimensions: width 140mm, height 70mm, and depth 35mm. Half, double and quadruple unit blocks are half, twice and four times the width of a unit block. Blocks are important as they are unstructured toys which require children to use their imagination. Blocks allow children to explore many aspects of learning including: science, mathematics, physical development, social studies, social-emotional, art, and language [Hir84]. Blockplay can be thought of as a symbol system and powerful nonverbal language [GF92]. Early childhood research has shown that children pass through common stages in blockplay, with older children doing this at a faster rate [WK00]. The stages, which are also depicted in Table 4.1 from sketches and photographs gathered during blockplay research [Hir84, GF92, WK00], are:

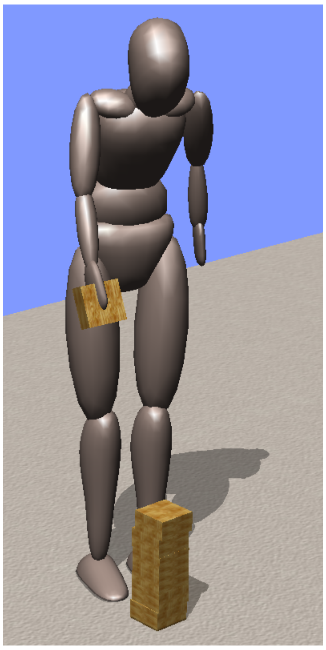
- Carrying - carry blocks, explore with senses, hit blocks together or against other objects - no building takes place
- Stacking - stack the blocks either vertically (towers) or horizontally (rows)
- Bridging - bridge the space between two upright blocks with a third block
- Enclosures - purposefully place blocks to enclose a space
- Patterns and symmetry - build structure with balance, symmetry, and decorative elements
- Early representational - incorporate building techniques from earlier stages, begin naming structure during or after construction
- Later representational - announce name of structure before building begins, build familiar settings, use structure and related accessories for dramatic play.

Social play The inclusion of a character's social play representation was informed by a focus group with educators during the pilot study, where it was suggested that the characters might collaborate on blockplay constructions (Section 5.1.2). Several social play stages have been identified, which shows the extent to which children play with other children [Par32]. The stages are:

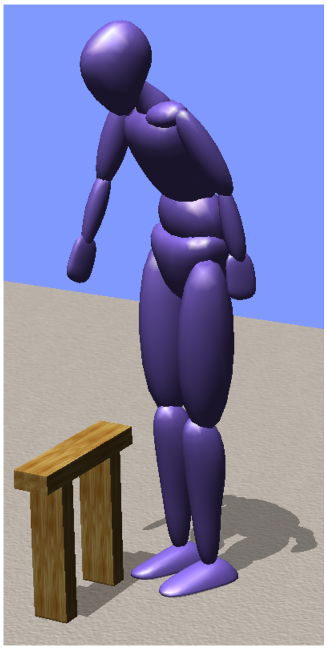
- Unoccupied - watches anything, plays with body, stands still
- Onlooker - watches others
- Solitary - plays alone
- Parallel - plays beside but not with others
- Associative - plays with others, sharing resources
- Cooperative - plays with others, sharing resources, common goal.



Carrying

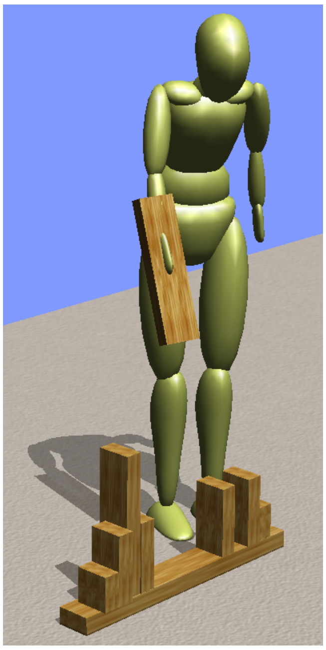


Stacking

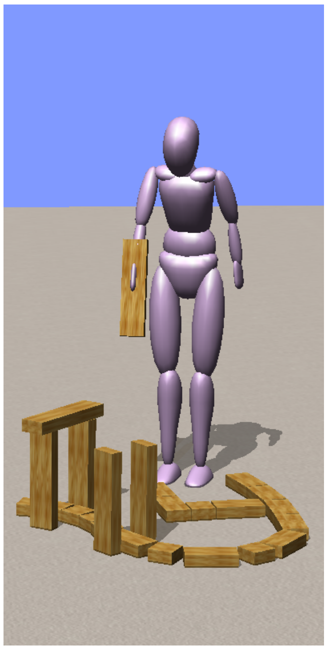


Bridging

Enclosures



Patterns & symmetry



Later representational

Table 4.1: Stages of blockplay, showing examples of constructions.

Egocentrism The inclusion of egocentrism was informed by a focus group with educators during the pilot study, where it was pointed out that the characters do not take the blocks of others (Section 5.1.2) and that it is quite common for children to take objects from other children. This is not selfishness but cognitive egocentrism, one of Piaget's ideas with respect to child development. An egocentric child cannot see the world through the eyes of others [KM11], so taking an object from others is not wrong to them, since they merely view the object as their own (Figure 4.2).

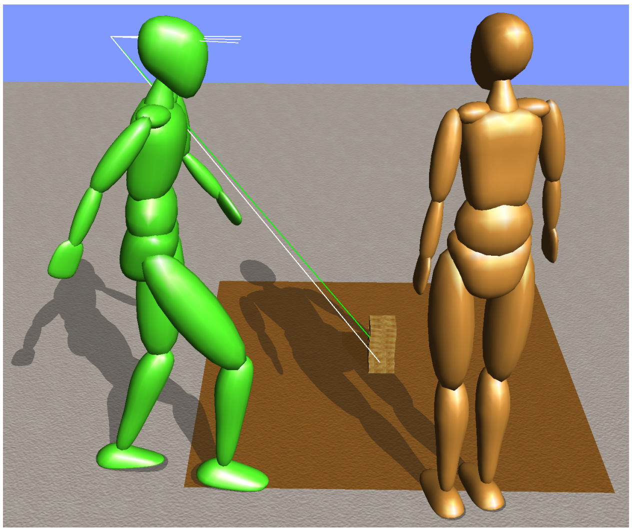


Figure 4.2: Egocentrism in action. The character on the left has located an object of the type they need for their construction and has planned to obtain it by removing it from the construction belonging to the character on the right.

4.2.2 Defining the development of characters

There are many possible combinations of the three options: blockplay stage, social play stage and egocentrism. However, some combinations would not be sensible, such as socially being an Onlooker whilst at the same time being at the Stacking stage of blockplay. Therefore, Observation forbids incompatible selections (Figure 4.3). If a character is defined manually, the social play stage is selected first. Next, any blockplay stages are made available for selection, together with egocentrism. When random mode is in effect, the same constraints are used to generate random combinations of the three characteristics.

The following is a summary of the type of characters that can be added, classified by their social play stage:

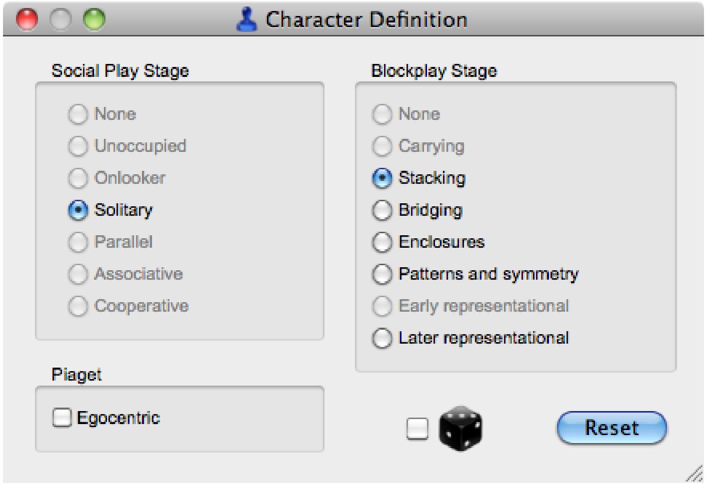


Figure 4.3: Character definition dialog box with random character definition turned off.

None No social play behaviour. Blockplay is Carrying only. Can be egocentric (take blocks from others).

Unoccupied Remains on their patch. Behaviour switches between watching any blockplay builders and moving their body about. No blockplay.

Onlooker Remains on their patch. Will relocate their patch to be close to other blockplay builders if necessary. No blockplay.

Solitary Will relocate their patch away from others if necessary, at any time. Blockplay is any stage after Carrying. Can be egocentric (take blocks from others).

Parallel Forms or joins a small group. Will relocate their patch to be close to other parallel blockplay builders if necessary. Blockplay is any stage after Carrying.

Associative Forms or joins a small group. Will relocate their patch to be close to other associative blockplay builders if necessary. Blockplay is Representational only. Sharing of inventories within the group. Works independently within a group, on their own construction. Comments on common activity.

Cooperative Forms or joins a small group. Will relocate their patch to be close to other cooperative blockplay builders if necessary. Blockplay is Representational only. Sharing of inventories within the group. Works with the group on the same construction (Figure 4.10). Leader can refuse entry to the group.

4.2.3 Abstracting the appearance

In many video games, player-characters can be customised [Ele10], to establish an identity, sometimes to match the appearance of the player [CDS07]. There may be options for the modification of: gender, facial features, hair, body size and proportions, clothing, and ethnicity. A few non-player-characters (NPCs) may be main characters in the narrative and are represented in high detail, with supporting characters (e.g. enemies of some kind) being clones of several archetypes [Ele10, Val09, Inf09]. What level of visual fidelity (realism) should be used for the characters representing the children? Should they look like children? Should they be unique?

Abstract characters are used in Steiner Waldorf kindergarten, where featureless/expressionless dolls provide the opportunity for the young child to place their own individual interpretation onto a universal figure [Nic07]. A similar approach is being used by Observation, enabling the character to be viewed as an active embodiment of behaviour and well-being [MP62], a physical manifestation of engagement in play, rather than representing distracting features of the character. The concept of amplification through simplification is used, in a similar way that cartoons strip down an image to its essential meaning, to focus the attention on an idea [McC94].

By not representing gender, facial features, hair, body size and proportions, clothing, and ethnicity, stereotyping [Isb06] because of appearance is totally eliminated and there is no place for cultural or gender bias in observations. The abstraction of physical appearance therefore removes any cultural labelling, but it also simplifies implementation, since generating variety in a meaningful way amongst individuals is not an easy task [ACH09]. For example, what does a typical four-year-old girl look like? Of course this cannot be answered, unless through the medium of stereotypes.

Software such as Endorphin [Nat12], an animation tool for creating virtual stuntmen in movies and games, which uses the Euphoria engine made by the same company, displays the humanoid figures with separate articulated geometric shapes, and generic three-dimensional facial features. Teaching examples of hierarchical modelling in computer graphics for humanoid figures or robots often use rigid body parts such as cylinders for limbs and body segments, with a sphere for the head [Ang09]. The game Minecraft [Moj11] uses cuboid shapes for the body segments of the player-characters and the non-player characters, in keeping with all other geometry which is composed of cuboids, with texture packs used for decoration of the geometry. What all this software has in common is that the outward appearance of the characters is not particularly important; it is the *behaviour* that has the focus.

In Observation, separate meshes represent the body parts, including a featureless head. The body parts were taken from a Blender biped rig [Ces08], and were adapted using Blender [Ble08]. The meshes are loaded in using the GLM library [Rob00].

Children do have different body proportions to an adult, and varying body proportions at different ages, so should this be represented at all? The approach taken to this was to globally scale the (adult) skeleton (Section 4.2.4) so that the height matches the average for a child of a given age, for relative height compared to an observer (Section 4.4.1), but the proportions were not aligned with a typical child of that age. The age chosen was that of a typical three to four-year-old, which is approximately one metre. Consequently, all characters in the simulation have identical height, with identical body proportions. This was done so that the overall look and feel of the character would be more like an artist's articulated wooden mannequin used for posing, which has a generic human form, but otherwise featureless.

For even more levels of abstract representation, there are options for displaying characters which include one or more of the following: bones (Figure 4.14), joints (Figure 4.14), and rigid body parts.

When there are many characters in a scene, what can be used for identification? In video games, player-characters and even non-player characters may be assigned names, but identifiers are usually culturally-bound, and very often gender-specific. A more abstract representation is used, giving random colours (a combination of Red, Green and Blue components) to every individual, along with a numerical label (Figure 4.4). If the colour of one character is close to another character, this could be interpreted as similarity in some unspecified dimension.

4.2.4 Autonomous behaviour

The real-time characters in Observation behave autonomously in that they react to changes in the environment and make decisions by themselves based on acquired information or internal stimuli [TM02].

Finite state machines (FSMs) are popular in video game AI programming

Figure 4.4: Abstract appearance using colour and number for identification.

for creating and controlling behaviours defined as a sequence of actions. An FSM has a number of states which are scripted with heuristic-based rules, and transitions between the states. At any time, there is one active state which performs its action, while other states are inert. The FSM continues to execute its state until a transition occurs. When the number of states grows, a Hierarchical Finite State Machine (HFSM) provides a more structured way to manage the complexity [AN07].

The implementation makes use of an HFSM, split into two main areas: Action and Navigation (Figure 4.5). Action is concerned with what the characters actually do and Navigation is concerned with how the characters get around the world.

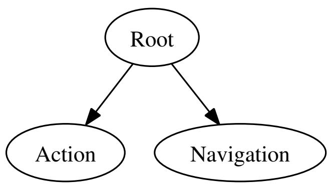


Figure 4.5: Hierarchical Finite State Machine (HFSM).

The Action branch of the FSM (Figure 4.6) controls the activity of the character. If they will be undertaking blockplay, they will make constructions either individually or as part of a cooperative group. If their blockplay stage is Carrying they will not build, just carry a block about. If they are merely a spectator they will be on the lookout for characters doing something active and they may also switch between moving their body about if they are a certain type of spectator (Unoccupied).

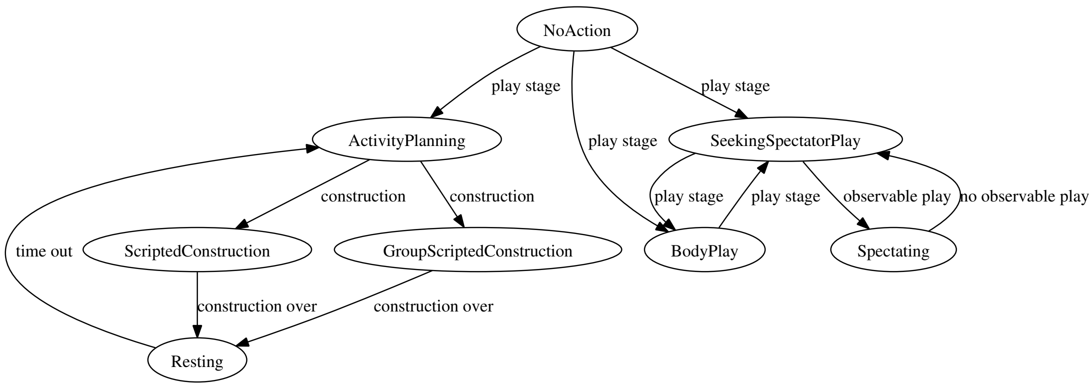


Figure 4.6: Finite State Machine (FSM) for Action.

If a character has been assigned a blockplay stage, they randomly select from construction plans on file, representative of their stage. These are called Scripted Construction Plans as the position and orientation of the elements in the construction have been specified in advance. If a user creates a Scripted Construction Plan by building the construction themselves, the placement sequence of blocks is calculated by Observation based upon the location of the objects' centres, as the construction is saved to file, to ensure that blocks that rest upon other blocks are placed after the ones upon which they rest.

A finite state machine controls the character's behaviour during scripted construction (Figure 4.7). Just before placing down an item into a construction, a character will check whether their construction has been disturbed. This may have been caused by an egocentric character removing one or more items, or perhaps by the adult dropping an object onto it, or an adult removing one or more items from the construction. A Construction is made up of a number of Construction Items. Each Construction Item has its intended position within the Construction, which is obtained from the Scripted Construction Plan. Each Construction Item in the Construction is checked to see if its current position has moved beyond a certain threshold. If there is a mismatch between the intended Construction and the actual Construction, the character will cease work on that Construction and start another one. Although not explicitly shown on the FSMs, the character quits the ScriptedConstruction state and enters the ActivityPlanning (Figure 4.6) state. Characters can only build as long as there are blocks available to them in the scene; they cannot 'spawn' objects. The unusual block-play stage of Carrying is included here as indefinite Transporting in the FSM. A character that carries does not actually build, so in the simulation, once the character has an item, it is carried indefinitely, without putting it down.

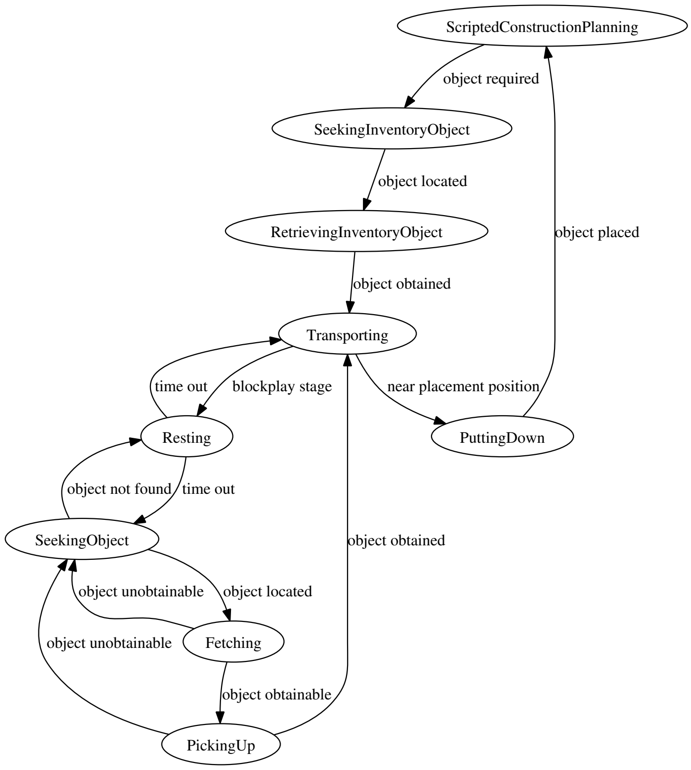


Figure 4.7: Finite State Machine (FSM) for Scripted Construction.

The inclusion of a character inventory was informed by a focus group with educators during the pilot study, where it was pointed out that the characters do not maintain a collection of blocks (Section 5.1.2). Each character has their own inventory to hold a database of currently owned objects, similar to a player-character inventory system in a video game. If displayed (above the head, Figure 4.8), it shows the quantity of each type of object. The major benefit is that virtual physical objects occupy no world space at all when they are in inventories, which allows the patch to be used just for displaying constructions. A character checks the inventory first when they are seeking a block (Figure 4.9), because they may not need to travel to obtain it. To keep the terrain free from clutter, characters periodically claim objects within their patch and place them in their inventory, removing them from view. Inventories are shared by group members for Associative and Cooperative blockplay builders.

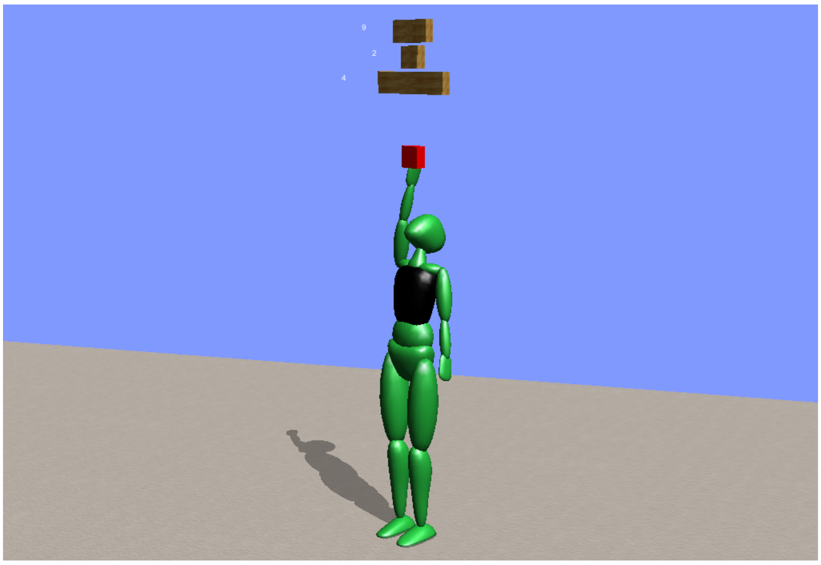


Figure 4.8: Inventory system. The character reaches up for a half unit block because there is one in the inventory.

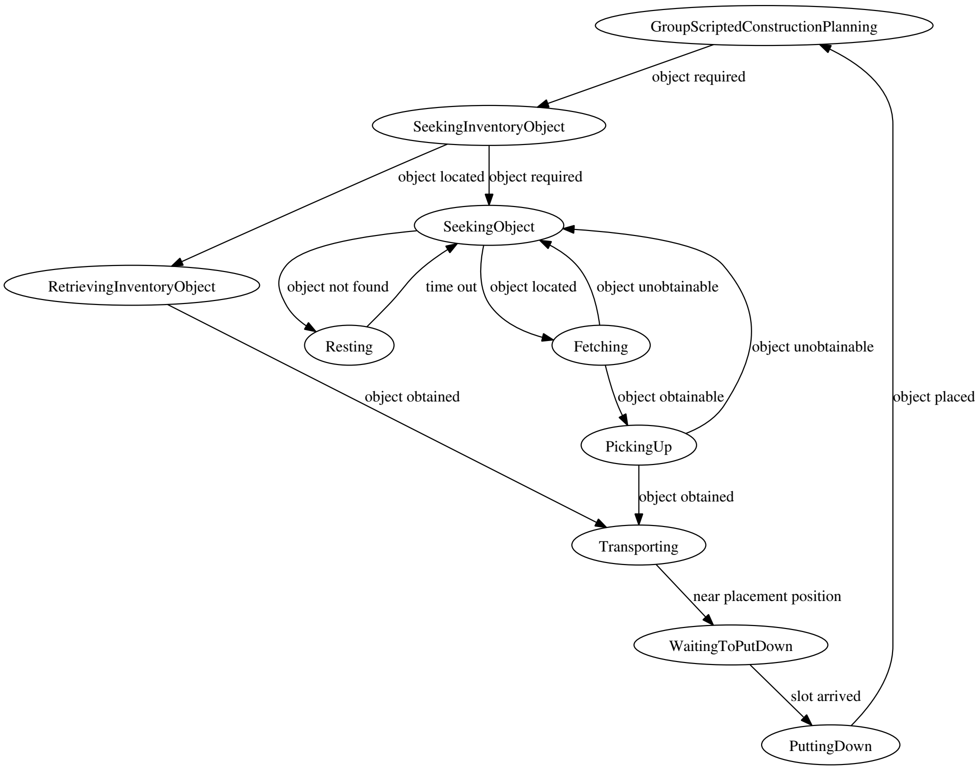


Figure 4.9: Finite State Machine (FSM) for Group Scripted Construction.

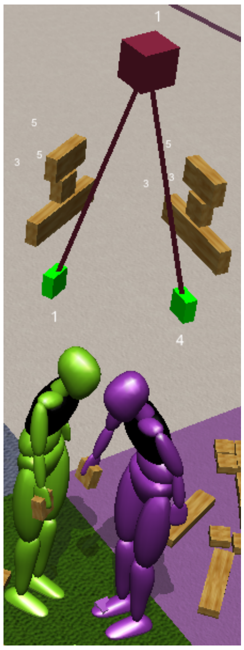


Figure 4.10: Two cooperative characters working together in a group on the same blockplay construction, and sharing their inventories.

Similar to individual blockplay construction, a random construction is selected for cooperative blockplay, although in this case the construction is restricted to those that are Later Representational, and it is the leader of the cooperative group who makes the selection. The building work takes place on the leader's patch. Group members are allocated an item (e.g. a type of block) in the construction in a particular sequence. They need to locate that item from their own inventory, from the inventory of other group members, or by looking around in the world. If they manage to get the necessary item, they position themselves at the construction ready to place it down, but they may have to wait, so that the order of placing the items down is preserved (Figure 4.9, Figure 4.10).

The relationships between the characters within the social play stages (Section 4.2.1) can be visualised (Figure 4.11). A spectating character (Unoccupied, Onlooker) is connected to an active character (Solitary, Parallel, Associative, Cooperative) with a colour-coded line, attached mid-torso, to match that of the active character. Group members (Parallel, Associative, Cooperative) are connected to a group node above their heads, which has a coordinate based upon the average of the group member's coordinates. Each group has a random colour assigned, which is applied to the group node and connecting lines, and also a numerical identifier.

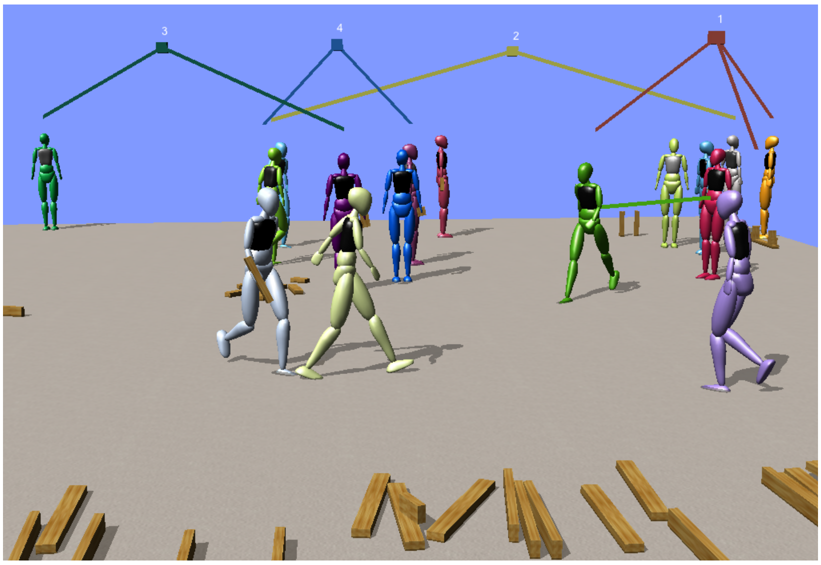


Figure 4.11: Groups indicated by the connections between the members via a central node.

Giving characters perception attempts to reduce the global knowledge of the environment to a more individual experience. The characters do not have global knowledge of the objects within the environment. Instead they have a simple visual perception system. A uniform grid is used for spatial indexing and objects with their centre in a grid cell are registered with that cell. A ray cast from the character simulates vision for objects in the environment; each frame, the length and angle is adjusted, scanning grid cells which intersect the ray. This field of view is used when looking for objects in the environment. Characters will therefore only see things within this field of view, which means they are unaware of what is behind them, unless they turn and face that direction. There is no structured memory as such but characters do remember where they last found an object.

Characters pathfind to obtain the shortest route through the world and around obstacles using the A* search algorithm. Pathfinding is fundamental to game AI. Poor pathfinding, where a game character cannot navigate around obstacles, can make the character seem brainless, and this ruins the immersive effect for the player [BS04]. A* is a popular pathfinding algorithm because it is guaranteed to find the least cost path between two points, assuming that a path exists, and it is also efficient. A* finds a least cost path in a graph from a starting node to a goal node. The cost is calculated as the cost from the starting node to the current node plus an heuristic estimate of the distance to the goal node. A* follows a path of lowest known cost, keeping a sorted priority queue of possible path segments, abandoning high cost segments for lower cost segments, until the goal is reached, or it fails to find a path. Once a path is found, characters then undertake pathfollowing, which involves following waypoints generated by the pathfinding (Figure 4.13).

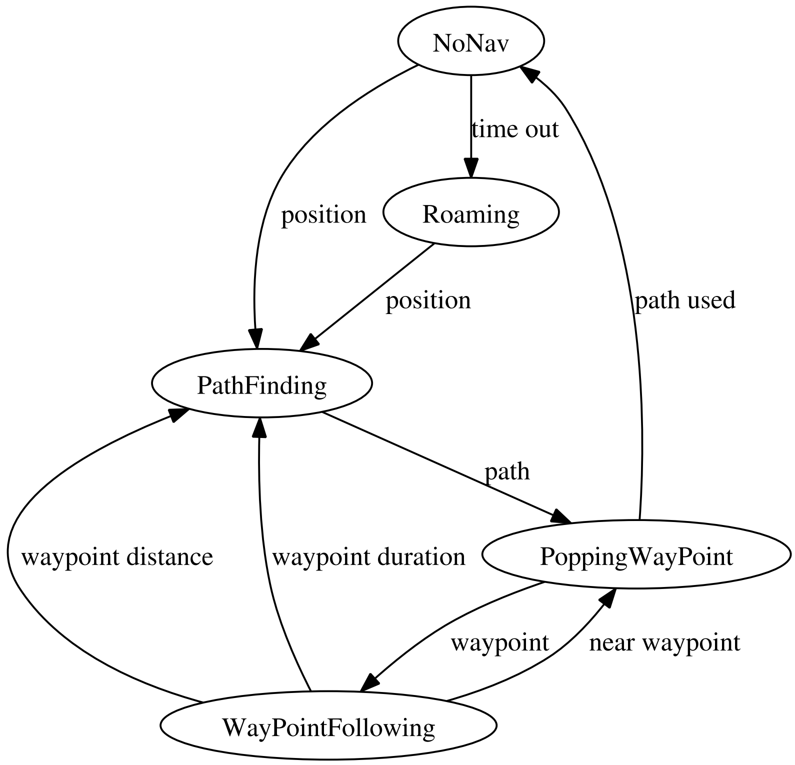


Figure 4.12: Finite State Machine (FSM) for Navigation.

An occupancy grid is used for path planning. There are many objects of various dimensions, at different orientations, and some blocks are long and thin, so it is difficult to quantise each object to a discrete cell. Bresenham's line algorithm is used to calculate lines between the edge vertices of bounding boxes and the squares that form the Bresenham line are used to record an occupied piece of the world. This allows A* search using the occupancy grid. As characters do a lot of picking up and putting down of objects, points are calculated within a character's reach around an object's position, using points of the compass, where the terrain is obstacle-free, and an attempt is made to find a path to the nearest reach point.

The location of an object and planning a path to get it is illustrated in Figure 4.13. The goal object is above the character (in red, as it has not been obtained yet). The white ray indicates the uniform grid cell last queried. The green ray indicates the goal object which has been found in the scene. The blue ray indicates the goal position, a calculated reach point. The red squares on the terrain are the occupancy grid. The small coloured cubes around the compass points of the goal object are the reach points. The A* path goes around the obstacles to the reach point. Sometimes a character is searching the environment for an item, so they temporarily enter a Roaming state whilst attempting to find a clear random position in the world, after which they attempt to find a path to that location.

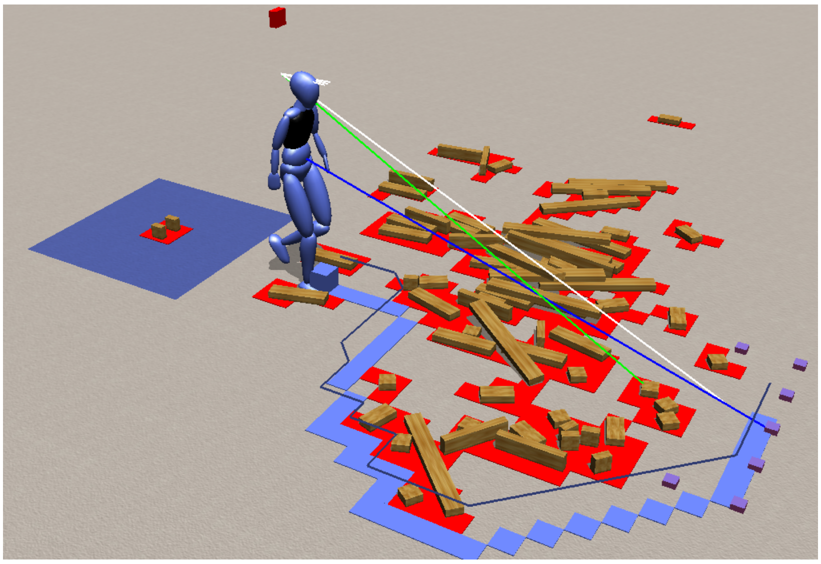


Figure 4.13: Locating an object within visual range and using A* pathfinding to a suitable reach point.

Local steering using three feelers (on the head in Figure 4.13) is accomplished by testing for intersections with other characters, who are effectively represented as a sphere. Steering forces for each feeler are calculated separately based upon penetration of the sphere, and the separate forces are then combined. A movement priority system is also used when several characters are in close proximity to each other, to help them avoid one other. The movement priority system is based upon the numerical id of the characters. Each character maintains a list of characters that are effectively colliding with them. All characters currently colliding stop moving temporarily. Characters with the lowest character id are given priority and resume movement, updating their list of colliding characters.

Since a game development toolkit was not going to be used, a decision needed to be made early on; what would be the development pipeline for getting animated characters into a real-time OpenGL program? It was desirable to create character animations but the characters did not need to be particularly sophisticated visually. In fact, a more abstract appearance was desirable. The ability to make simple animations by posing a sample figure within an application and having the ability to save the data for those movements would be useful. The suggestion of a body could be added later and made to move with the skeletal movements. It was felt that separate skeletal animations would potentially give more flexibility than hard-coded animated meshes as in the MD2 file format, since meshes (one or many) could be bound to skeletal data at a later date, in various ways. Also, separate animations can be independently applied to specific parts of the body to create interesting effects.

To keep things (reasonably) straightforward, and keep skeletal animations separate from any geometry, QAvimator [QAv10] was used (to pose a mannequin figure) for the creation and editing of the skeletal and animation data which conforms to the Biovision Hierarchy (BVH) motion capture standard. QAvimator was developed for the users of Second Life and supports one unisex skeleton. Code was written to parse the BVH animation text file (produced by QAvimator) into the simulation. A BVH file has two parts, skeleton data describing the hierarchy of joints and initial pose of the skeleton, and a data section in which frame data describes how the joint rotations change over time. The initial pose for the skeleton is used for binding to meshes as a neutral starting position, which in this case is the classic T-pose. A BVH animation file includes no information about geometry at all. The joints from a BVH animation are visualised in Figure 4.14.

Ideally, a skinned mesh would have given a more continuous look and feel to the characters. This would have required the vertices of a single mesh to be associated (and weighted) with one or more skeletal joints so that the mesh deforms sensibly when animated. However, since novel software was being developed, this was not considered a priority, and rigid body parts (Section 4.2.3) which move according to skeletal joint rotations would be used instead. A minimal set of animations have been used in the simulation. Firstly, there only needs to be enough animations to characterise the behaviours depicted. Secondly, opportunities for animation reuse were identified in the operationalisation of behaviours which are depicted in the Finite State Machines. The animations and how they are mapped to the character states are shown in Table 4.2.

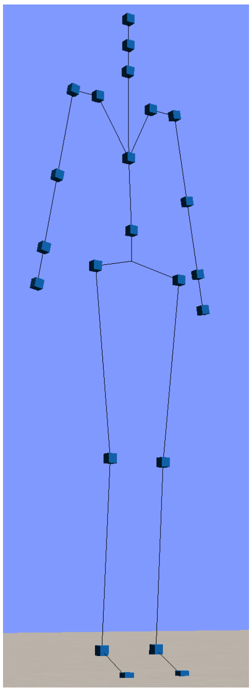


Figure 4.14: Visualisation of a character's BVH skeleton. Lines are drawn between the joints (drawn as cubes) to represent bones, which can be derived from the position of the joints.

Characters have a representation of well-being, inspired by the well-being of the process-oriented child monitoring system (Section 2.5.1). The chest area can be used to show the character's well-being (Figure 4.15). The colour fades from black to white as the level of dissatisfaction increases, triggered by events such as not being able to find certain objects with which to build. This visualisation of well-being is a continuous representation of the discrete Leuven well-being scale [LVKD02], which uses a five-point scale: Extremely High, High, Moderate, Low, and Extremely Low. As the well-being changes, the Red, Green and Blue components of the chest geometry's colour are adjusted in equal quantities to give the many shades of grey between black and white. Internally, well-being is represented as a value between 0 and 1. At intervals of .2, it is mapped to the Leuven discrete stages and reported as text through the event log and character information pane. The inclusion of a discrete representation was informed by a focus group with educators during the pilot study, where it was suggested that the character's well-being might be aligned with an existing observation schedule

Animation(s)	State(s)
Stand	Resting, Spectating, WaitingToPutDown
Walk	SeekingObject, Fetching, Transporting
PickUp	PickingUp, PuttingDown
LookUp	SeekingInventoryObject
PickUpAbove	RetreivingInventoryObject
BendSideways TurnHeadRight TurnHeadLeft	BodyPlay

Table 4.2: Animations mapped to states in the simulation.

(Section 5.1.2).

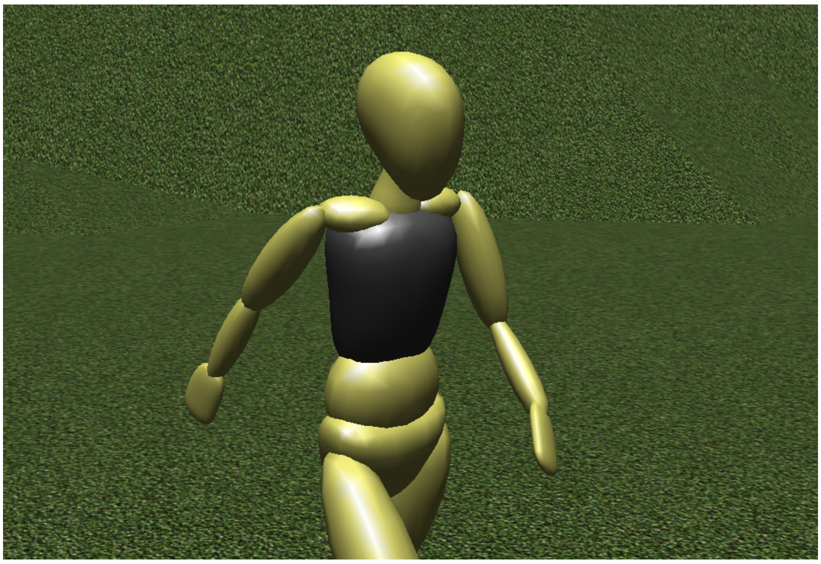


Figure 4.15: Well-being vest showing a continuous representation of the discrete, five-point Leuven well-being scale.

There are various factors that determine the well-being of a character, depending upon the definition of the character.

Well-being is *lowered* when:

- no active blockplay builders to watch
- character currently being watched is out of range
- unable to find a sought-after object
- unable to pick up a sought-after object that was due to be picked up

- construction has been disturbed
- play patch location is not optimal
- hungry from moving about.

Well-being is *raised* when:

- character currently being watched is within range
- finding a sought-after object
- picking up a sought-after object
- successful patch relocation
- hunger is satisfied by coming into range of food
- empathy is received over a period of time.

4.3 Environment

4.3.1 Unconstraining the play space

There is no one right way to arrange early years settings. For instance, Reggio Emilia schools in Italy have central piazzas, which are used as a social space and built into the fabric of the building, something not usually seen in the UK. So, rather than having one fixed layout, the ability to configure different layouts is therefore provided.

Usually, there are zones of activity within a region in an early years setting, where certain resources are based. These regions typically have flooring appropriate to those activities and tend to come under two main types: dry and messy. Community Playthings have examples of how to arrange the space [Com06], and the blockplay area is situated within the active zone of the dry region. They divide the internal areas into two regions, dry and messy, which have different floor coverings. Each of these is further divided into zones like so: Dry region - active zone, quiet zone; Wet region - messy zone, entry zone. Some exploratory programming was performed to define zones and confine blockplay activity within a zone marked as Active. However, this raised several issues. For instance, in the Community Playthings floor layout example, a very small corner of the Active area for blockplay is allocated. If these dimensions are replicated, hardly any characters could be added to the scene if they were constrained to play in that area. There is also the need to define zones manually and associate activities such as blockplay with those zones. The sandbox nature of Observation enables the user to create their own scenes very quickly, so the decision was made to not use constraining zones, allowing characters to engage in blockplay anywhere. There is still the option to use textures for representing zones within the space, at least visually, such as a region with carpet, and a region with wood flooring.

On the surface, having walls seems sensible, since they constrain movement, delimit areas, and help to define inside and outside, concepts which are relevant in play, as some activities only occur in some areas. For instance, children do not usually run indoors. Some exploratory programming was performed with a main building, but even having just walls with no roof seemed too restrictive. After all, the whole point is to be able to observe, not have your view obscured by a wall! So there are no walls, and no doors. This raises an interesting problem though because it is difficult to represent a doorway, to be used as a point of entry and exit, without a wall. To facilitate observation it was decided that there would be no building, no dividing walls and no representations of doorways. Fortunately, this is in line with the practice of free movement between areas in early years settings.

4.3.2 Territory

When a new character is added to the world, an activity patch (1 square metre) is allocated at that location, provided that the patch is: flat, which means that all four terrain vertices have exactly the same height value (to prevent constructions collapsing under the control of the physics simulation); and not occupied by any geometry. If the patch location is less than optimal for the social play stage of the character, a relocation algorithm attempts to find an alternative location, while satisfying the other criteria. The number of characters in the world at any time is therefore determined by the number of available patches. Every patch is colour-coded to match the character (Figure 1.1), and its display can be toggled on/off. Unless a character happens to be egocentric, they do not touch the patch contents of other characters.

4.3.3 Terrain

Although unit blocks in this simulation are typically used indoors, where the floor tends to be flat, hollow blockplay, which uses larger wooden blocks than unit blocks, usually occurs outside, so the ability to represent terrain would be useful, if hollow blockplay were to be added, or any other sort of outside play.

Rendered geometry which is not physical (Section 4.3.5) is offset from the terrain using bilinear interpolation of the four underlying terrain vertices that also form a cell of the uniform grid.

Whilst it is desirable for characters to walk up and down variable height terrain, this should not happen when the terrain appears too steep to do so. To accomplish this, whenever terrain is created or interactively edited, a set of vertices is overlaid onto the surface of the terrain, at the same resolution as the occupancy grid used for A* pathfinding. An algorithm samples heights across the terrain, checking for differences between neighbouring vertices and if the difference is beyond a certain threshold, the pair is flagged as steep. The higher vertex in a steep pair is then recorded in the occupancy grid as blocked. When characters plan a route through the scene, they will disregard any areas that are considered too steep, as illustrated in Figure 4.16 by the red areas.

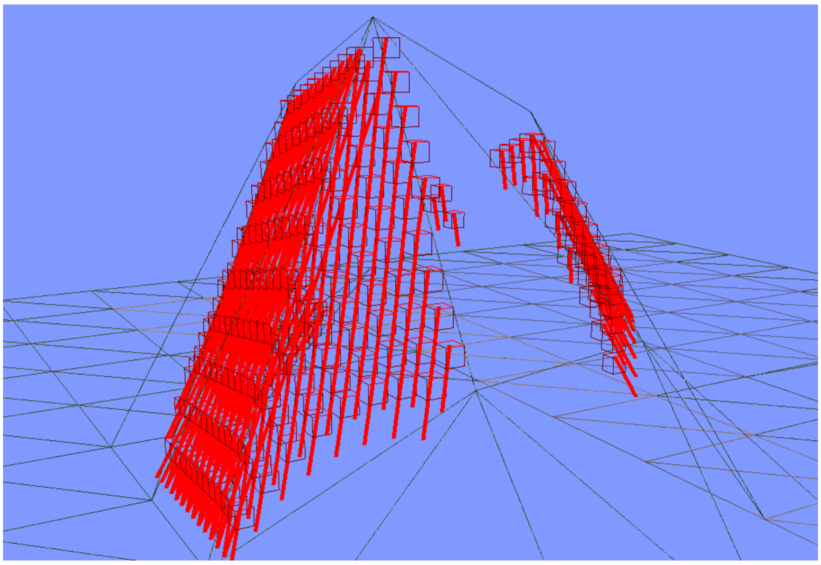


Figure 4.16: Geometry calculated as steep.

To ground characters and objects onto the terrain, shadows are created using OpenGL stencilling with the accepted limitation that this particular method is for planar use only. For characters, there is also the option to display a Blob Shadow, an early video game technique, where some coloured and/or textured geometry (in this case a triangulated circle), is displayed constantly beneath the character's feet.

New scenes can be constructed quickly by adjusting two sliders, which modify the ground plane along two dimensions, giving a blank slate for the user. Exploratory terrain generation code was written to produce random height variations in the scene for outdoor areas. However, this was later superseded by interactive terrain editing. Terrain vertices can be manipulated (displaced) directly to modify the height of the terrain, even when the world is populated with characters and physical objects. Characters will follow the terrain, even while the terrain is being edited (Figure 4.17). Observation locks the corners of a character's patch, so these cannot be moved. If a character relocates patch, those corners will be unlocked automatically. If physical objects are on the terrain area which is being modified, they will move with the terrain. Interactively editing the terrain causes a number of events to occur: the terrain surface normals and vertex normals are recalculated, the terrain physics rigid body is destroyed and recreated from the modified triangular mesh of the terrain, the uniform grid is updated, the occupancy grid is updated, and the terrain steepness (Section 4.3.3) is re-calculated. Textures can be applied to individual squares of the terrain or the terrain can be filled with the same texture. A variety of textures reflect the typical surfaces found in early years settings: carpets, wooden flooring, tiles, and grass.

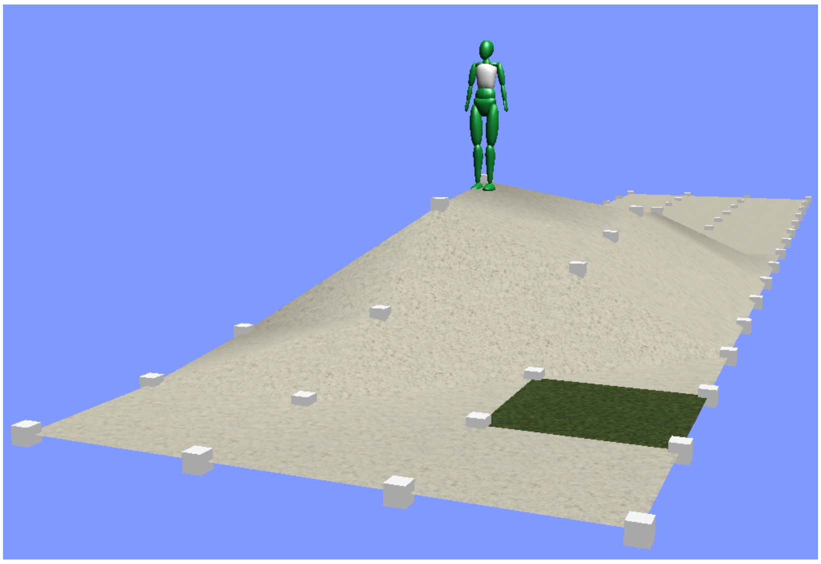


Figure 4.17: Character following the contours of the terrain as the terrain vertex heights and textures are being edited.

4.3.4 Objects

Using the mouse, objects in the scene can be selected, picked up, placed down, and deleted by the observer at any time. Selected objects can be moved up and down, rotated, and also flipped in 90 degree increments about each axis. Selected objects appear as being within the grasp of the observer, represented by the closed hand cursor icon, until the object is released into the scene.

Custom shapes are defined (in a file) in terms of other primitives, inspired by example Virtual Reality Markup Language (VRML) worlds [ANM96]. For example, a unit block, as described in Section 4.2.1, is represented as *cube unitBlock 140 70 35*, where *cube* has been defined within Observation. This allows further custom shapes such as blocks of any dimensions to be defined, and referred to by name when creating map files.

3D models such as furniture can also be defined, provided that they are already triangulated and in the OBJ file format. If texture coordinates are not specified, they will have any specified texture mapped linearly to the geometry. A cuboid collision shape (and subsequent rigid body) will be generated for the mesh in the physics simulation, based upon its bounding box, as it is added to the scene.

Objects that have been defined, are used to populate a dialog box accessible from the toolbar, if they are flagged as being a menu item.

4.3.5 Physics

The open source physics library Bullet has been integrated (using glue code) into Observation, to give added realism to objects in motion and at rest, as illustrated in Figure 4.18 on the shelves and terrain.

Bullet has three types of rigid bodies: static, dynamic, and kinematic. Static bodies do not move. These can be used for non-moving furniture in a learning space and also the floor and walls. However, the majority of objects in a setting for young children are meant to be picked up and would not be static. Dynamic bodies are subject to physics; they collide with other objects in a natural looking way. Kinematic bodies are controlled by the programmer but the bodies' interaction is one way only, so they can knock into dynamic objects and cause them to move, but the reverse is not true. A character moving an object around needs control of it but when it is no longer in their hands it needs to be subject to the laws of physics. A grasping hand using forces like a robot is not required, so a simpler approach was taken; once an object is picked up, its dynamic rigid body is deleted from Bullet. When the object is placed back down again, a new dynamic rigid body is created to take the place of the original, supplied with an updated transform for the target position and orientation. The limitation of this approach is that it relies upon the target space being unoccupied.

Bullet provides the facility to define an infinite ground plane. This is used to define (in addition to a ground plane) four additional vertical planes or walls, by supplying the appropriate surface normal for each plane, to contain the physics objects within the scene. The triangles that constitute the terrain are passed to Bullet to form a static triangular collision shape and rigid body.

When objects are added to the scene, a collision shape is created in Bullet based on the object's local coordinate system bounding box, and used for all objects of that type. Shelf objects have a static collision shape defined and can have other objects rest on them. All other objects are defined as dynamic, subject to physics, colliding with other objects in a natural way. All physical geometry has a rigid body based upon the collision shape, shown in wireframe view as green in Figure 4.18. The object's transform (position and orientation) is then used by Bullet to situate the object within the physics environment. If objects move, their transform is obtained from a Bullet motion state and used by Observation firstly to update a uniform grid, which is used for spatial indexing of world objects, and secondly for rendering. With the world being constantly updated, characters are able to see the objects in the new locations, fetch them, and continue about their activity.

4.4 Role of the adult

4.4.1 Viewing

Where should an observer be situated? Should they be embodied, fully immersed in the scene, rather like a video game, colliding with scenery, characters and objects? If embodied, should they be constrained to walking about the environment at a sensible speed, with a viewpoint determined by the direction of the head? Alternatively, should an observer be a disembodied entity, one that can go anywhere, freely passing through everything? The decision was made not to represent them as a 3D character, nor to give them any sort of volume. Viewing in the

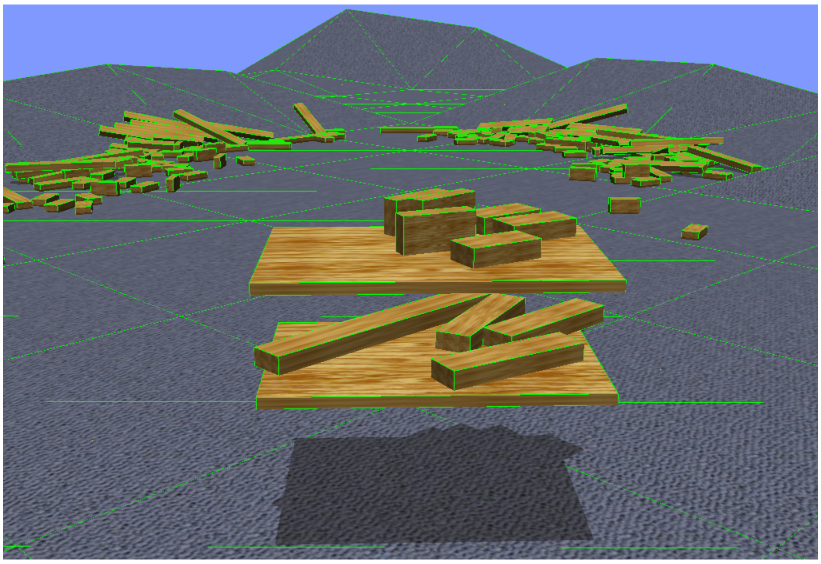


Figure 4.18: Physical objects and terrain.

graphics pane is supposed to be through the eyes of a disembodied observer.

Viewing options include: walking, flying, and following a character. For walking and flying, rotation is constrained to pitch and yaw. When walking, since females constitute the majority of early childhood education professionals, the observer is based on the terrain with an eyepoint set at 1.6 metres initially (Figure 4.19), which is approximately the average height for an adult female in the United Kingdom [JD09]. The height can be modified to match that of the standing observer by dragging a slider. In fact, the height can be set to any value all the way down to just above the terrain level.

The observer can optionally have their viewpoint rise and fall relative to the contours of the terrain. Flying takes advantage of using a computer simulation to do things that would not be possible in real life, by enabling the observer to have a top-down view of the world (Figure 4.20).

Multiple viewports have not been used as these were considered too similar to Closed Circuit Television (CCTV) surveillance. There is, however, the option to follow a selected character, where the observer's viewpoint is calculated automatically, and focussed upon the position of the centred character.

Full-screen graphics can be toggled on or off. This gives the observer the option of only using visual cues within the scene, or having additional textual information provided in the event log and character pane.

It is possible to play with the concept of a real-time simulation by pausing,

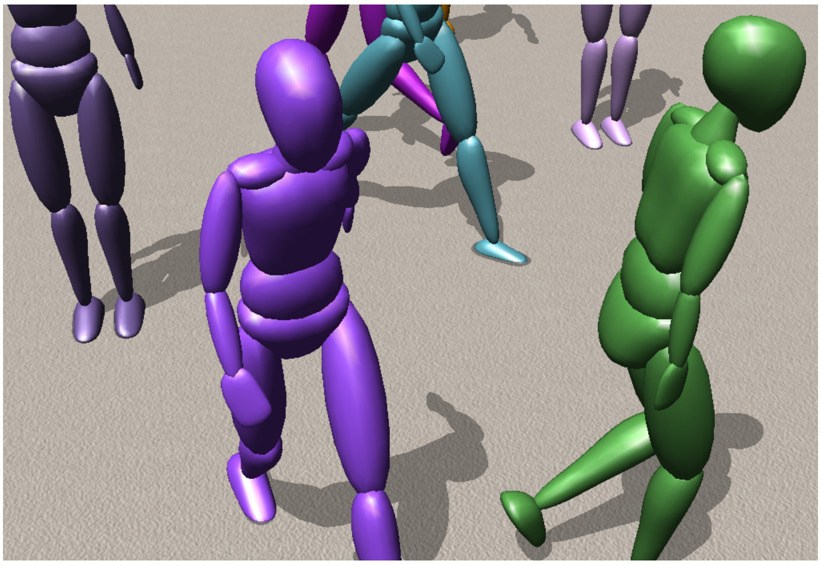


Figure 4.19: View when walking with eyepoint at 1.6 metres.

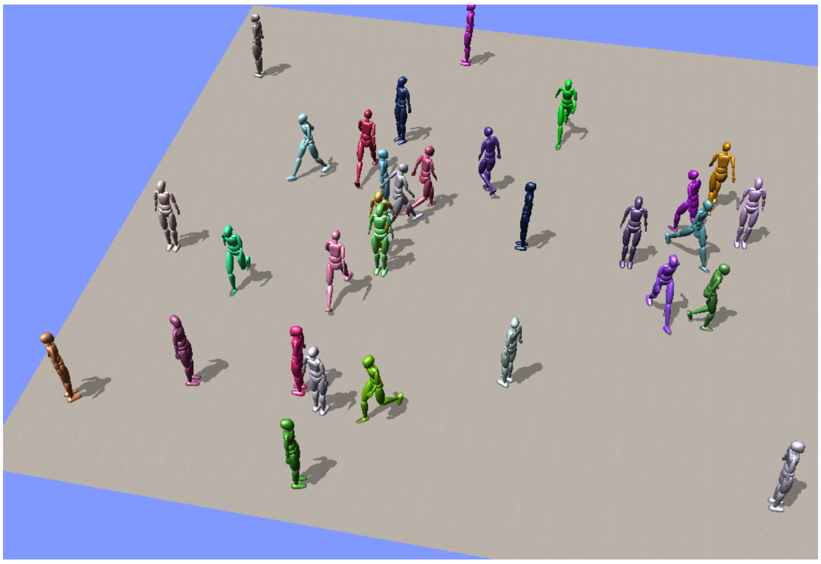


Figure 4.20: View when flying.

running at half speed, or running at double speed.

4.4.2 Inspection

Characters can be selected within the scene. Picking has been implemented by grabbing the mouse coordinates from Qt [Nok10], using OpenGL's gluUnProject to obtain a world coordinate, then testing to see if this point is inside an approximated bounding box of any character.

If full screen graphics are not in use, the character pane and event log provide data about activity in the world (Figure 4.21). The character pane displays data about a selected character. Dynamic data includes: well-being, action, and the physical object of interest. Static data includes: play stage, blockplay stage, and whether they are egocentric.

The status bar gives summary data (size, and average well-being) about the entire population (Figure 4.21).

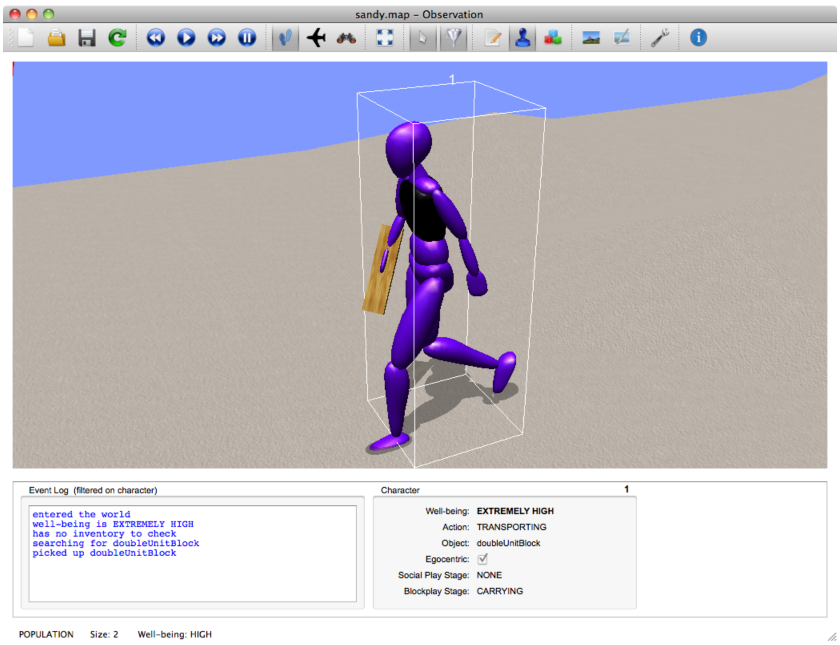


Figure 4.21: Character selection, showing a filtered event log and the character information pane.

A timestamped event log (Figure 4.21) shows archived and real-time events, for all characters, or filtered on the selected character. The events are expressed using factual language, rather than an interpretation, which mirrors the preferred way of recording observational findings by practitioners [BM06]. The simulation can be paused to make monitoring the data easier. A very brief snippet of some events that occurred over a matter of a few seconds is shown in Table 4.3. Five characters were added, with the random character generator option selected. The scene already had quite a few blocks strewn on the floor and no further blocks were added. After these events, Observation was paused, and a snapshot of the characters was taken (Figure 4.22).

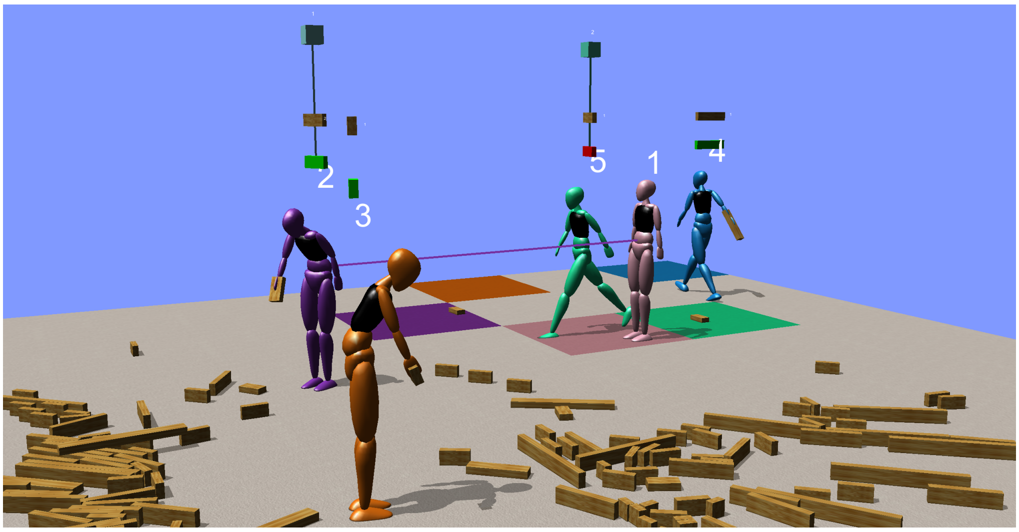


Figure 4.22: Snapshot of the characters after the events in Table 4.3.

4.4.3 Intervention

There are three direct ways in which interventions can be made: adding resources required by the characters to the scene such as wooden blocks, adding food to the scene, and empathising with a character. This gives opportunities for the adult to explore where on the continuum their participation lies between that of complete participant and that of complete observer [Smi97], a dichotomy faced by those attempting simultaneous supervising/helping and observing.

An indirect way of making an intervention is to modify the terrain. This can have knock-on effects such as characters not being able to relocate their patch.

Objects can be dropped into the scene and interactively manipulated. An experimental credit system allows the adult to choose whether they should be charged for objects. When the credit system is activated: the price of objects added to the scene will be deducted from the user's credit balance, credits are not recouped when objects are deleted, and maintaining an extremely high well-being

Character	Event
1	`entered the world`
1	`well-being is EXTREMELY HIGH`
1	`looked for others to watch`
2	`formed a new group`
2	`entered the world`
2	`well-being is EXTREMELY HIGH`
3	`entered the world`
3	`well-being is EXTREMELY HIGH`
2	`started a new construction`
2	`announced what they are going to build`
4	`entered the world`
4	`well-being is EXTREMELY HIGH`
2	`has no inventory to check`
2	`searching for unitBlock`
4	`moved away from others`
4	`started a new construction`
4	`announced what they are going to build`
4	`has no inventory to check`
4	`searching for doubleUnitBlock`
5	`entered the world`
5	`formed a new group`
5	`well-being is EXTREMELY HIGH`
3	`started a new construction`
5	`started a new construction`
5	`announced what they are going to build`
3	`has no inventory to check`
3	`searching for halfUnitBlock`
5	`has no inventory to check`
5	`searching for unitBlock`
2	`picked up unitBlock`
5	`picked up unitBlock`
2	`put down unitBlock`
2	`checked inventory for unitBlock`
4	`picked up doubleUnitBlock`
2	`searching for unitBlock`
5	`put down unitBlock`
5	`checked inventory for unitBlock`
5	`searching for unitBlock`
3	`picked up halfUnitBlock`
2	`picked up unitBlock`

Table 4.3: A snippet of events from the event log for five random characters.

for the population (for populations over size 5) for a period of time gains some credits. The credit system can be turned off at any time, but the credit balance will be remembered from the last time credits were active.

Young children often have snacks in an educational setting. Unless they are very young, they can help themselves to food such as a slice of apple and a drink of water. Although it would be possible to select a character and directly ‘feed’ them, such as with a character in the style of a virtual pet, a different approach has been adopted whereby it is the responsibility of the adult to ensure that the environment is stocked with food. When a character has been moving about for a while, they will become hungry (for a single food item), and an apple will appear above their head. The well-being of the character will continue to decrease while it remains hungry. If there is food (an apple) already in the scene it could be moved close to a character, or the character can be allowed to stumble across it. If there is no food in the scene, it can be added. Food is added/deleted/selected/manipulated like any other object.

The Adult Engagement Scale [Ber96] defines three categories of teacher behaviour, and sets out a schedule for observation and recording to allow a profile to be built up of an educator’s style of intervention in the learning process, in order to increase the effectiveness of interaction. In the Sensitivity category, there is an intervention ‘empathises with child’s needs and concerns’. An abstraction of empathetic game play [BF10] has been implemented by enabling the adult to literally walk in the shoes of the character, where the world is viewed as though through the eyes of that character. The well-being of the selected character increases, while empathy is taking place, up to a maximum level.

4.5 Data-driven scripting

Customisation is possible, by taking advantage of data held in external text files. Maps (scenes) can be saved containing the terrain and its textures, and objects. Scripted construction plans can be created by building the construction within the world, then saving it to a plan file. Maps and plan files both reference custom shapes and models, defined in other files.

4.6 Summary

This chapter described how a minimal set of toolkits were used in combination with bespoke programming code to develop a novel real-time 3D interactive graphics simulation of young children in a learning environment. The theoretical background behind the selective aspects of child development implemented in the characters was provided, some of which was informed by educators during a pilot study focus group. An abstract approach to the appearance of characters was justified. The implementation of the autonomous behaviour of characters was described, representing child-initiated play, in which characters use resources in a dynamic environment which incorporates a physics simulation. The tools available for the adult observer to create, monitor, and influence the activity of the characters, were described.

Chapter 5

Findings from pilot study

An early version of the simulation was presented to some educators and students, both in the field of early childhood education, at the same university. The educators took part in a focus group with this author. The students used the simulation, completed an activity and a two-part questionnaire. Some of those students also took part in a focus group with this author. Collectively, this work was considered as a pilot study to inform the work of a larger, main study which would follow later. The findings from the data collected during the pilot study are now presented.

5.1 Focus group with educators

5.1.1 Data collection

A focus group meeting was held early in the first semester of the academic year 2010–2011. The venue was a small learning pod at Liverpool Hope University. In attendance were four early childhood education lecturers from the university, together with this author. A semi-structured walkthrough of an early prototype of the simulation software Observation, was provided for the lecturers, focussing upon its key features. Open discussion took place during the walkthrough. Each participant was given a pen and paper, and everybody jotted down thoughts and suggestions during the meeting, to form a record of events. The findings from the focus group with educators can be found in Section 5.1.2.

5.1.2 Findings

The format was considered to be quite intriguing, unlike anything encountered before in this field. To facilitate analysis and discussion, case studies traditionally include any or all of the following: text, images, and video. Comparatively, the approach taken in this work was perceived as offering more dimensions, as well as being more appealing to this generation of learners.

Due to its exploratory nature, the simulation could be used for problem solving within teams. Areas of investigation might include: negotiation, cooperation, social interactions, and movement. In addition, it was suggested that children themselves might benefit from a tool to design their own models before building them, although this is really beyond the scope of the target audience.

Adaptation, such as making a smaller enclosure, is a facet of play, when resources are constrained. It was observed that characters attempt to complete a predefined construction, by locating the appropriate blocks, but cannot change their plans mid-construction if they do not have the blocks. In such cases, it was suggested that some form of negotiation take place between characters, in order to obtain blocks from each other. It was thought that this would be easier to model if characters maintained a collection of blocks. Collaboration might also be employed to enable a construction to be finished by another character or perhaps several characters.

Characters did not take the blocks of others. It was noted that it is quite common for children to do this.

The representation of well-being was well received. It was suggested that the scale could be aligned with an existing observation schedule, such as the five-point Leuven scale. In addition, it was postulated that it would be interesting if frustration could be factored into the well-being score.

It was generally felt that the abstract nature of the characters should be preserved, rather than try to replicate real life, on the grounds that such abstraction would encourage more creative analysis of behaviour for students, if there are fewer visual cues such as: no facial expressions; no gender; and no cultural references. People preferred the characters with a body, rather than just seeing the underlying skeleton with or without joints. There was also a comment that the abstract characters were not particularly endearing and that perhaps alternative representations could be made available. It was also noted that the body has adult proportions, despite the youthful gait. It was explained that this is because QAvimator produces animations based upon the adult, unisex Second Life skeleton, and that the skeletal data was being used unmodified. It was suggested that movements were kept simple but that perhaps a kneeling animation could be incorporated.

An adult in an educational environment may feel obliged to intervene based on an observation that they have made. However, the freeing up of this responsibility means that observers do not have to intervene, something almost impossible to do in a real situation. It was also thought that multiple observers would have a shared experience by being able to view the simulated world from the same viewpoint and with identical information. The ability to follow a character was considered a useful option as it made it considerably easier to make sense of what was going on when a scene becomes busy with many characters and many objects.

5.2 Questionnaire with students

5.2.1 Data collection

In the middle of the second semester of the academic year 2010–2011, a group of twenty volunteers attended a session at Liverpool Hope University in which an introductory presentation to the research was given by this author. All of the students were female undergraduates at the university and undertaking a programme with an early childhood education theme. The students had been released from tutorial sessions to attend this session, which was outside of their usual programme timetable. Once students had agreed to be participants by giving informed consent, they completed a pre-simulation usage paper-based questionnaire that asked questions about their early childhood background, including observational experience, and questions about their knowledge of the theoretical material represented within the software. They downloaded Observation (and user manual) within the session for a brief orientation and were asked to complete an activity (Section C.1) and web-based (PHP/MySQL) questionnaire in their own time. The activity was designed to cover the main features of the simulation software and to give them exposure to the full range of character behaviours. The activity asked participants to define characters with certain characteristics, add the characters to the world and monitor their well-being. It was the underpinning theory behind the behavioural modelling of the characters that was being addressed here.

This two-part questionnaire was considered a pilot for a questionnaire in the main study [Dav07]. To avoid repetition, a detailed description of the questionnaire development is included with the main study (Section 6.1).

5.2.2 Participant conversion rate

11 people out of the 20 students who signed up to be a participant in the pilot study did not complete the evaluation. None of the 11 non-evaluators in the pilot study appear as participants anywhere in Table 3.4.

Of the 11 non-evaluators in the pilot study, 11 were students who attended a classroom session at Liverpool Hope University at which they were invited to become participants. All of these 11 students downloaded the simulation, and were asked to complete the evaluation.

Of the 11 non-evaluators in the pilot study, nobody replied to an email reminder to complete the evaluation.

Thus, there were 9 evaluations in the pilot study (9 students) that could be used for analysis.

5.2.3 Findings

The pre-simulation usage questionnaire revealed that some students had several years experience working within their field of study. Most were familiar with at least some of the theoretical content within the simulation, collectively showing prior knowledge of 37% of the seven blockplay stages. Everyone had conducted some observations of young children, either as a learner, or as a learner and as an early childhood education professional, collectively showing prior observational experience of 29% of the seven blockplay stages. Table 5.1 shows to what extent the theoretical content within the simulation was already known and how much of it had been observed in real-life.

In the post-simulation usage questionnaire, some statements, using a five-point Likert-scale, were given to the students, to establish the usefulness of the simulation; Table 5.2 presents this data combining the Agree and Strongly Agree

Area	% Prior knowledge	% Prior observations
Social play stages	61	41
Blockplay stages	37	29
Egocentrism	33	0

Table 5.1: Summary of students' prior knowledge of social play stages, blockplay stages, and egocentrism, and respective prior observations.

responses. In the comments section, one student said, 'I believe that the simulation is an excellent way of possibly seeking links between the needs of individuals in the real world.' Another said, 'The outcome of the observation can be exaggerated.'

Agreed	Statement
8/9	It was useful to influence the well-being of the characters
7/9	It was useful to move among the characters
6/9	It was useful to change my viewing position
5/9	It was useful to define the behaviour of the characters
3/9	This simulation has increased my understanding of social play stages
5/9	This simulation has increased my understanding of blockplay stages
5/9	This simulation has increased my understanding of egocentrism
5/9	This simulation has increased my understanding of the connections between social play, blockplay, and egocentrism

Table 5.2: Summary of the simulation's usefulness as perceived by the students.

5.3 Focus group with students

5.3.1 Data collection

A focus group meeting was held in middle of the second semester of the academic year 2010-2011, one week after the formal session. The venue was a teaching room at Liverpool Hope University. In attendance were six early childhood education students from the university, together with this author. The session was semi-structured and explored participants' attitudes towards the simulation. Notes were taken during the discussion. The findings from the focus group with students can be found in Section 5.3.2.

5.3.2 Findings

The comments have been organised according to the themes that emerged.

It was stated that an observer would not automatically witness all possible behaviours in a setting, so being able to choose what is seen is an advantage. One student said, 'Observation would be perfect for developing observational skills in childcare courses, for those lacking in confidence to go into settings and just do it.'

There was a comment that lots of thought and effort had been put into the theoretical aspects of the simulation to maintain the interest of the observer. Some students had not conducted many observations and felt that such a simulation could provide a great deal of information, and enable the fine-tuning of observational skills. Some felt that the user needs some understanding of the underlying theory before using the simulation. For instance, blockplay stages had not featured on many of the students' programmes. Some students were not sure why some characters appeared to be just waiting, as they had not familiarised themselves with the behaviour descriptions in the user manual.

The students were impressed with the amount of information that was available for the characters and also that it is possible to filter this specifically for one character. They also appreciated being able to follow a character when the scene became quite busy. The comment was also made that reading the events on the event log was quite difficult when there were a lot of characters in the scene. It was claimed that an observer may have more information available because a child will be known to them; for instance, something may have happened to them the night before. Somebody pointed out that the ability to pause time is a luxury that is not afforded in real-life observations.

Some students had watched a video as part of an assessment, which they said was quite difficult as they had no say in who would be in the video. It was felt that being able to choose the type of children that would appear in an observation gives more control over the observational episode.

There was a consensus of opinion that being able to intervene in a simulation was a good thing. However, the comment was made that it isn't always possible to improve the situation, unlike in Observation, where one of the main vehicles for increasing well-being is the provision of resources.

Some had tried adding random characters and felt that this was more like real-life, where you cannot define people. The process of adding characters within Observation reminded one student of the simulation game RollerCoaster Tycoon. Comments were made that it was very effective when the characters were actively building with blocks. One student felt that the representation of the characters within the environment was a bit clinical.

Some students were quite experimental and enjoyed changing the terrain and applying textures, such as flooring. They found setting the scene to be very useful because this is something that must be done in real life; 'A practitioner provides things,' said one student. In contrast, another student was surprised to find that scenes are defined by the user; they thought it would be more like loading in a scene already populated with objects and people that you would watch, rather like a video.

5.4 Brief review of pilot study

There was an encouraging response to the simulation in the pilot study from both educators and students. Comments by educators on the representation of the character behaviours would inform further development of the simulation. The website worked well during the pilot study and would continue to be used to support the participants (Section 3.12). The website would also be used to attract further targeted participants in the main study. In addition, plans were made for the website to have video tutorials of the simulation, together with a user guide and activity, both of which would be web-based and multi-lingual. The activity would be extended for the main study (Section 3.10.2). The questionnaires would be modified and extended for the main study (Section 3.10.2). The focus group would use a protocol and be recorded using a digital voice recorder in the main study. Some individual interviews would also be conducted in the main study.

5.5 Summary

This chapter has reported the findings from a pilot study with educators and students in early childhood education studies at one university, investigating the potential of a novel 3D interactive simulation developed by this author. The feedback from the participants was both informative and encouraging, suggesting that a larger-scale, main study would be entirely appropriate, and would incorporate both refinements and extensions to the pilot study (Section 5.4).

Chapter 6

Findings from main study

In Chapter 5 the encouraging findings from a pilot study were presented, which led this author to progress to a larger, main study, the subject of this chapter. The findings for the main study are split into two main areas: statistical findings from the questionnaire, and findings from a content analysis study spanning multiple sources. The questions within the questionnaire (completed by all participants, students and educators) are described, and justifications given for their inclusion. The formation of the Simulation Utility Scale and the Understanding Scale is described, and an account is given for their reliability and validity. For the content analysis study, the development of the coding frame used to analyse textual content is detailed, together with an account of the coding frame's reliability and validity.

6.1 Questionnaire with students and educators

6.1.1 Asking the right questions

In the main study, a revised questionnaire was devised (Section A.2). The two separate questionnaires used in the pilot study, one paper-based, one web-based, were conflated into one online questionnaire (using PHP/MySQL). Some questions were rephrased based on feedback from participants in the pilot study. Some additional questions were also added to the new questionnaire. The questionnaire was designed to be completed by participants only after completing the activity.

Although participants had effectively already given informed consent when signing up as a participant, a preliminary questionnaire item was used to remind participants about informed consent, before they began responding to the questionnaire, and to record this, by getting the participant to actively check a box on the web form.

The questionnaire in the main study was divided into five sections: early childhood experience, before using the simulation, after using the simulation, personal, and comments. References to questions are of the form Q1, which means question 1.

Early childhood experience The purpose of these items was to find out whether certain types of prior experience in early childhood by participants would influence their response to the simulation. Q1 asked for the highest level of qualification awarded which has an aspect of early childhood within it. The qualification categories were taken from the application form available on the UCAS website [Uca11]. The categories are: none, below honours degree, and honours degree or above. Specific qualifications were not important, rather the level, so the three categories sufficed. Q2 asked how much time they have spent as a paid employee in an early childhood based role. Q3 asked how many observations of young children's learning they have conducted.

Before using the simulation The purpose of these items was to find out how much familiarity participants had with the child development theory represented within the characters of the simulation *before* using the simulation. There was no attempt to assess acquisition of knowledge in a pre-test, post-test manner, but this would provide contextual data. A pair of questions was asked for each aspect of child development. One question asked about knowledge, which may have been picked up in a book. The other question asked whether the child development had been observed. Q4 and Q5 asked about the six social stages of play. Q6 and Q7 asked about the seven stages of blockplay. Q8 and Q9 asked about egocentrism as defined by Piaget.

After using the simulation The purpose of these items was to find out participants' responses to the simulation *after* they had used it, to determine if they thought their understanding of the three child development areas (and how they are interconnected) had increased. Q10, Q11, Q12 and Q13 were combined to form an 'Understanding Scale' (Section 6.1.4).

The purpose of these items was to find out participants' responses to the abstract appearance of the characters within the simulation and which items from a list, including individual faces, would cause the participants to observe the characters in a different way. Q15 provides an open-ended response to elaborate on any choices made from the list in Q14.

The purpose of these items was to find out the perceived utility of the simulation for the participants. Q16 to Q24 inclusive asked how useful it was to perform some function in the simulation. Seven of these nine questions were combined to form a 'Simulation Utility Scale' (Section 6.1.4).

The purpose of this item was to find out if participants thought that the simulation was an interesting way to explore the behaviours of young children. Q25 asked this question, and was intentionally dichotomous, compelling participants to provide a clear, unequivocal response [CMM07].

The purpose of this item was to find out if the simulation has helped participants to think about how they will conduct early childhood observations in the real-world. Q26 asked this question, and was intentionally dichotomous, compelling participants to provide a clear, unequivocal response [CMM07].

Personal The purpose of these items was to find out some demographic information, unconnected to early childhood, so it was included for completion at the end, once the time and energy had been spent on the rest of the questionnaire [Daw09], and to avoid being too bald very early on [Dav07]. Rather than being optional though, completion was mandatory, as part of the online questionnaire validation.

Q27 asked for the participant's age.

Q28 asked for the participant's sex, and although it was dichotomous, considerable thought was given to this restriction, because compelling participants to provide a clear, unequivocal response [CMM07], may not be appropriate for all people. Consideration was given as to whether the question should ask for the 'sex' (biological, based on reproductive functions) or the 'gender' (based on social and cultural differences) of the participant. In both cases, more than two categories may be possible, and perhaps desirable by some individuals [ALA09]. However, since there seems to be no consensus on categories for either case, the status quo was preserved, and participants were given the choice of sex as 'male' or 'female'.

The purpose of this item was to find out whether playing video games made a difference to participants' attitudes towards the simulation. Q29 asked how many hours per week they spend playing video games (on any platform, e.g. computer, console, handheld device). The type of games was intentionally omitted as this, in itself, is quite complex to define [DAJM07].

Comments The purpose of this item was to find out anything else that could not be expressed by answering any of the previous questions, by inviting participants to reflect upon their experience of using the simulation. Q30 prompted participants to: describe what they got out of using the simulation, report bugs, request features, and to have their say.

6.1.2 Data collection

It would have been entirely possible for any participant to complete an evaluation outside of a formal teaching session and this is exactly what educators have done. However, all the student participants in this research attended formal teaching sessions, for which the various formats are now described.

At the beginning of the second semester of the academic year 2011–2012, two two-hour sessions, on different days, were run at Edge Hill University. The first group of students were on a foundation degree, and the second group of students were on an undergraduate degree. All of the students were female and undertaking a programme with an early childhood education theme. The format of the sessions for both groups was identical. A personal contact at the university, joined the group tutor, and gave an introduction to the session in which the students were told about the research, using the home page of the project website for reference, and making students aware of giving informed consent. Students were invited to participate but, if they did not wish to participate, they could opt to complete an alternative piece of work, which was to read some articles and answer some questions on observation and blockplay, to be completed in the same room. One person chose to complete the alternative piece of work. Participants did the following, within the session: signed up on the project website, accessed supporting materials, downloaded the simulation, completed the activity, and completed the questionnaire.

Also at the beginning of the second semester of the academic year 2011–2012, two two-hour sessions were run simultaneously at Liverpool Hope University. All of the students were female undergraduates at the university and undertaking a programme with an early childhood education theme. A personal contact at the university had recently presented linked material on well-being. The personal contact in one group, and their colleague in the other group, gave an introduction to the session in which the students were told about the research, using the home page of the project website for reference. Similar to the other formal sessions, the students needed to signup to download the software, make use of the supporting materials, and access the activity, but unlike the other formal sessions, students were free to decide if they wished to complete the questionnaire afterwards or leave.

In the main study, the activity was extended (Section C.2) and divided into three parts. In part one, entitled Underpinning Theory, participants were asked to define characters with certain characteristics and add the characters to the world, rather like the pilot study (Section C.1), but without monitoring their well-being. In part two, entitled Creativity, participants were asked to be creative and modify the simulated environment by: defining the terrain shape and textures, adding shelving, and adding some furniture. Also, characters that were added were to be randomly generated. In part three, entitled Balancing Act, participants were asked to monitor and maximise the well-being of individual characters. Participants were asked to activate the experimental credit system which would charge them for objects added, and reward them for sustained high levels of well-being in the characters.

6.1.3 Participant conversion rate

56 people out of the 108 people who signed up to be a participant in the main study did not complete the evaluation. None of the 56 non-evaluators in the main study appear as participants anywhere in Table 3.4.

Of the 56 non-evaluators in the main study, 26 people were students who attended a classroom session at Liverpool Hope University at which they were invited to become participants, and 7 people were students who attended a classroom session at Edge Hill University at which they were invited to become participants. All of these 33 students downloaded the simulation, and were asked to complete the evaluation.

Of the 56 non-evaluators in the main study, 24 people were not students attending classroom sessions at a university. The 24 people were composed of 5 students, 7 educators, and 12 unknown. It is likely that these 24 people responded to calls for participation through either institutions or through professional associations. Of those 24 people, 5 people downloaded the simulation and 1 person did not download the simulation. For 18 of those 24 people, it is not known whether they downloaded the simulation, as the download logging script for the website was not operational when they signed up; what is known, is that they did not download the simulation, in response to evaluation reminders by email, when logging had become operational.

Of the 56 non-evaluators in the main study, 8 people replied to an email reminder to complete the evaluation by unsubscribing as a participant. Of those 8 people, 5 people gave no reason at all, 1 person said that they did not have the time, 1 person said that they could not open the instructions on their computer, and 1 person's response was spam.

Of the 52 evaluations completed in the main study, 2 cases were removed due to incoherent data in the answers that were provided.

Thus, there were 50 evaluations in the main study (44 students, 6 educators) that could be used for analysis.

6.1.4 Reliability and validity of scales developed

The questionnaire in the main study had been designed to include questions that might form two scales. However, before data collection in the main study, there was no way to be sure that the scales would emerge from the data. For one possible scale, there was no representative data from the pilot study because of its size and for the other possible scale, the main study had additional questions to the pilot study. Thus, the two scales developed for this questionnaire were produced after data collection in the main study.

When a scale is used, the reliability of the scale, measured by the internal consistency of the items, should be checked to determine if all the items are measuring the same construct, known as a latent variable. A popular indicator of internal consistency is Cronbach's α coefficient. Values above .7 are considered acceptable, although values above .8 are preferable [Pal10].

Nine items on the online questionnaire were considered as potential items on a summated scale [Spe91] which has been termed the 'Simulation Utility Scale' (SUS), which measures the degree of perceived utility with the 3D interactive simulation. The latent variable in this scale measures simulation utility. The nine items considered for the Simulation Utility Scale appear as items 16 to 23 on the online questionnaire (Section A.2), and are all on the same 5-point Likert scale ranging from strongly disagree to strongly agree. This combination of nine items has a good internal consistency, with a Cronbach's α coefficient (calculated in SPSS) of .87.

In order to determine uni-dimensionality, where the items on the scale all measure a common construct [Gar96], the nine items of the Simulation Utility Scale were subjected to principal components analysis (PCA) using SPSS. Prior to performing PCA, the suitability of data for factor analysis was assessed, and although the sample size ($n = 50$) may be considered rather low, it was decided that it would be worth doing for completeness, using a more liberal approach to sample size, where five cases per item are considered adequate [Pal10]. Inspection of the correlation matrix revealed many coefficients of .3 and above. The Kaiser-Meyer-Olkin value was .8, exceeding the recommended value of .6 [Pal10] and Bartletts Test of Sphericity [Pal10] reached statistical significance, providing support for the factorability of the correlation matrix.

Principal components analysis revealed the presence of two components (Table B.1) with eigenvalues exceeding 1, explaining 51.2%, and 13.9% of the variance respectively. To aid in the interpretation of these two components, Oblimin rotation was performed. The rotated solution revealed the presence of simple structure [Pal10], with both components showing a number of strong loadings and all variables loading substantially on only one component (Table B.2). An inspection of the scree plot, using Catell's scree test [Pal10], revealed one component above the elbow (Figure B.1). This was further supported by the results of Parallel Analysis [Wat00], which showed only one component with an eigenvalue (4.6) exceeding the corresponding criterion value (1.7) for a randomly generated data matrix of the same size (9 variables x 50 subjects). The eigenvalue for the second component (1.3) was less than the corresponding random eigenvalue (1.4).

Fixing the number of factors to be 1 revealed a low communality for the variable 'charged' (.298). Removing the 'charged' variable revealed a low communality for the variable 'shelves' (.291), which was subsequently removed. It was these two variables, 'charged', and 'shelves', that comprised component two. Running the PCA again on the 7 items from the first component, revealed the presence of one component only (Table B.3). The scree plot revealed one component above the elbow (Figure B.2). The one-component solution explained a total of 58.9% of the variance. The final seven-item Simulation Utility Scale developed has a good internal consistency, with a Cronbach's α coefficient (calculated in SPSS) of .88. The items and the corresponding idea for each item are listed in Table 6.1.

The two items in the second PCA component, which did not make it into the SUS were 'shelves' and 'charged'. The first item, 'shelves', represents the adding of shelves and the organisation of objects on them. Shelves are also a reference to the physics simulation, as objects can be placed naturally on the shelves (and on each other), although this was not mentioned explicitly within this or any other questionnaire items. It may be that the idea of shelving was subsumed within 'dress' in the minds of participants anyway. The second item, 'charged', represents a game-based feature of being charged for objects, using a credit system. Although there are some game-based aspects within the simulation, of which 'charged' is an example, a game as such was not really presented to participants, so this perhaps does not fit so well with the other items.

Item	Idea within item
moveAmong	Movement around world and amongst characters
viewpoint	Seeing from various positions
influence	Making a difference to the well-being of characters
define	Creating characters by defining their attributes
random	Creating characters by random generation
terrain	Editing the terrain height and textures
dress	Adding and positioning objects in the environment

Table 6.1: Items within the Simulation Utility Scale.

Four items on the online questionnaire were grouped together to form a summated scale and has been termed the 'Understanding Scale' (US), which measures the degree of increased understanding of the theoretical content with respect to childhood development within the 3D interactive simulation. The latent variable in this scale measures increased understanding. The four items which form the Understanding Scale appear as items 10 to 13 on the online questionnaire (Section A.2), and are all on the same 5-point Likert scale ranging from strongly disagree to strongly agree. The Understanding Scale developed has a good internal consistency, with a Cronbach's α coefficient (calculated in SPSS) of .91.

In order to determine uni-dimensionality, where the items on the scale all measure a common construct [Gar96], the four items of the Understanding Scale were subjected to principal components analysis (PCA) using SPSS. Prior to performing PCA, the suitability of data for factor analysis was assessed, and although the sample size ($n = 50$) may be considered rather low, it was decided that it would be worth doing for completeness, using a more liberal approach to sample size, where five cases are considered adequate [Pal10]. Inspection of the correlation matrix revealed many coefficients of .3 and above. The Kaiser-Meyer-Olkin value was .85, exceeding the recommended value of .6 [Pal10] and Bartletts Test of Sphericity [Pal10] reached statistical significance, providing support for the factorability of the correlation matrix.

Principal components analysis revealed the presence of one component with an eigenvalue exceeding 1, explaining 78.8% of the variance. The component matrix showed a number of strong loadings on only one component (Table B.4). An inspection of the scree plot revealed one component above the elbow (Figure B.3). The items and the corresponding idea for each item are listed in Table 6.2.

Item	Idea within item
social	Increased understanding of social play stages
block	Increased understanding of blockplay stages
egocentrism	Increased understanding of egocentrism
connections	Increased understanding of the connections between social play, blockplay, and egocentrism

Table 6.2: Items within the Understanding Scale.

For both the Simulation Utility Scale and the Understanding Scale, the mean of the item scores is calculated from the summated score because the interpretation of a mean is clearer than the sum of the items, since it is constrained within the original scale of measurement, which, in this case, ranges from 1 to 5. For example, reporting a person's mean Simulation Utility Scale score of 4.4 means that the score is at the upper end of the range of responses, which is clearer than reporting a score of 35 out of 40.

6.1.5 Findings

The descriptive statistics which follow were derived from the online questionnaire (Section A.2), for which the associated question number is provided, e.g. Q1 means question 1.

All 44 students were female (Q28). The students' ages (Q27) ranged from 18 to 33 (M = 19.7, Md = 19, SD = 2.6). The distribution of responses to the highest level of qualification awarded which has an aspect of early childhood within it (Q1) by students was as follows: none = 10, below honours degree = 33, and honours degree or above = 1. The number of months as a paid employee in an early childhood based role (Q2) by students ranged from 0 to 48 (M = 4.1, Md = 0, SD = 10.3). The number of observations of young children's learning conducted by students (Q3) ranged from 0 to 100 (M = 17, Md = 6, SD = 22.2). The number of hours per week students spend playing video games (on any platform, e.g. computer, console, handheld device) (Q29) ranged from 0 to 24 (M = 5, Md = 4, SD = 5.9).

There were 5 female educators and 1 male (Q28). The educators' ages (Q27) ranged from 44 to 58 (M = 52.3, Md = 53, SD = 5.4). The distribution of responses to 'The highest level of qualification awarded which has an aspect of early childhood within it' (Q2) by educators was as follows: none = 0, below honours degree = 1, and honours degree or above = 5. The number of months as a paid employee in an early childhood based role (Q2) by educators ranged from 172 to 298 (M = 232.8, Md = 221.5, SD = 50.8). The number of observations of young children's learning conducted by educators (Q3) ranged from 10 to 10000 (M = 2010, Md = 500, SD = 3931). The number of hours per week educators spend playing video games (on any platform, e.g. computer, console, handheld device) (Q29) ranged from 0 to 20 (M = 4, Md = .5, SD = 7.9).

Area	Students		Educators	
	% PK	% PO	% PK	% PO
Social play stages	50	43	97	89
Blockplay stages	48	44	83	86
Egocentrism	66	25	100	83

Table 6.3: Summary of students' ($n = 44$) and educators' ($n = 6$) prior knowledge (PK) of social play stages, blockplay stages, and egocentrism, and respective prior observations (PO).

A number of groups were identified for comparative purposes (Table 6.4).

There was not a question on the online questionnaire asking whether participants had used Second Life to simulate an early childhood environment as part of their current studies. However, the content analysis of focus group, interview and responses to open-ended items on the online questionnaire, revealed that the undergraduate1 group had indeed had such an experience. By contacting the relevant tutors for the undergraduate2 and foundation groups, it was established that these students had not had any experiences like those of undergraduate1. The two groups priorVeYes and priorVeNo were therefore created to accommodate this extra dimension, although for this particular dataset, priorVeYes is synonymous with undergraduate1.

Group	Description	n	Md
foundation	Foundation students from institution 1	25	4.00
undergraduate1	Undergraduates from institution 1	14	4.29
undergraduate2	Undergraduates from institution 2	5	4.00
undergraduates	Undergraduates from institutions 1 and 2	19	4.14
priorVeYes	Any students who *had* used Second Life to simulate an early childhood environment as part of their current studies (undergraduate1)	14	4.29
priorVeNo	Any students who *had not* used Second Life to simulate an early childhood environment as part of their current studies (foundation and undergraduate2)	30	4.00

Table 6.4: Groups to be compared, showing the sample size and Simulation Utility Scale median score for each group.

Mann-Whitney U tests were conducted using the groups in Table 6.4. Mann-Whitney U tests are used when measures, scores or ratings have been obtained for two independent groups which may be of unequal sizes [Dav07]. The results are presented in Table 6.5, including the approximated r value and effect size using Cohen's criteria (.1 = small, .3 = medium, .5 = large) [Pal10]. The foundation group has a statistically significant different (lower) median Simulation Utility Scale score than both the undergraduate1 group and the undergraduates group. The priorVeNo group has a statistically significant different (lower) median Simulation Utility Scale score than the priorVeYes group.

Group 1	Group 2	U	z	p	r	Effect size
foundation	undergraduate1	87.5	-2.60	.009	-.42	Medium
foundation	undergraduates	150.5	-2.09	.037	-.31	Medium
priorVeNo	priorVeYes	108.5	-2.59	.010	-.39	Medium

Table 6.5: Results from Mann-Whitney U tests, showing statistically significant differences in the Simulation Utility Scale median scores for each group.

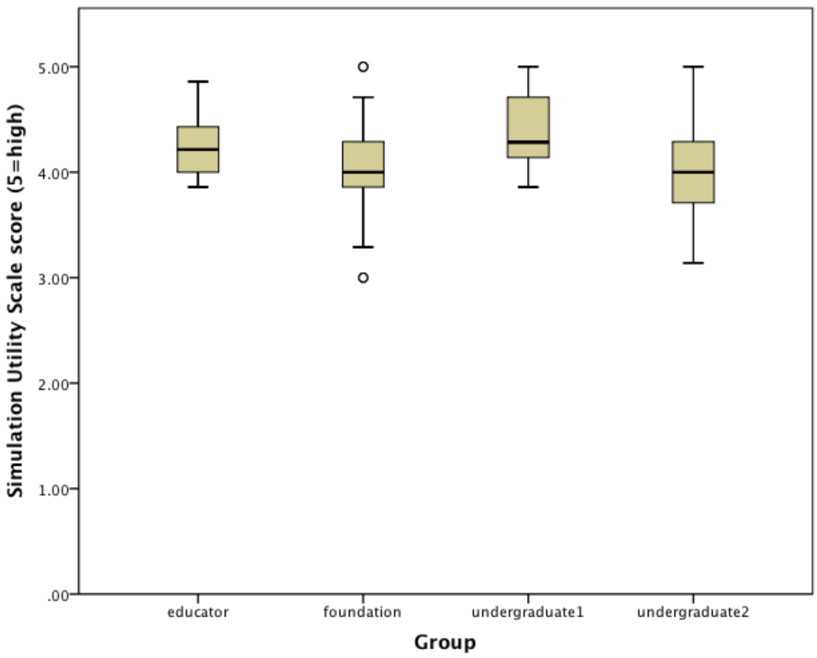


Figure 6.1: Boxplot showing Simulation Utility score against sample sub-group. The undergraduates are split into two groups.

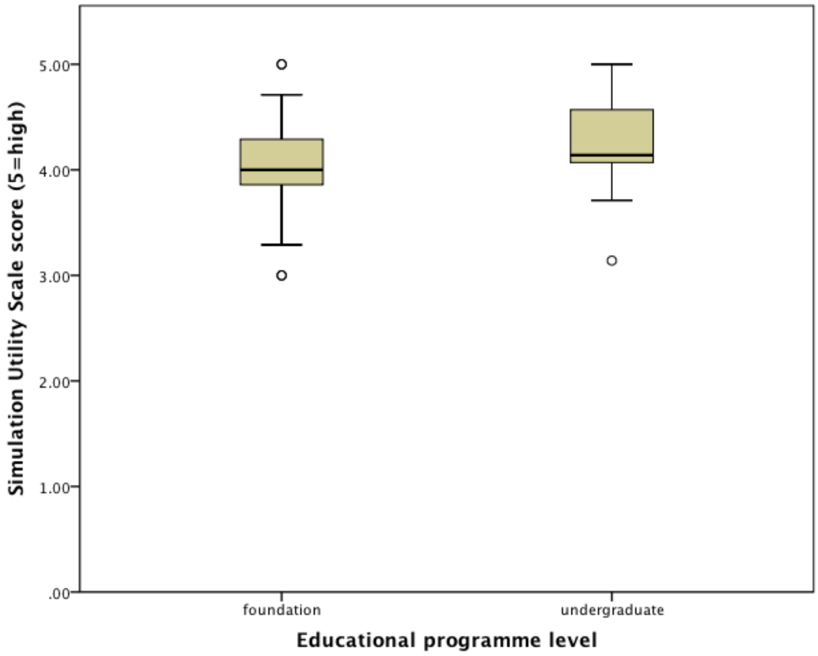


Figure 6.2: Boxplot showing Simulation Utility score against level of student educational programme. The undergraduates are combined into one group.

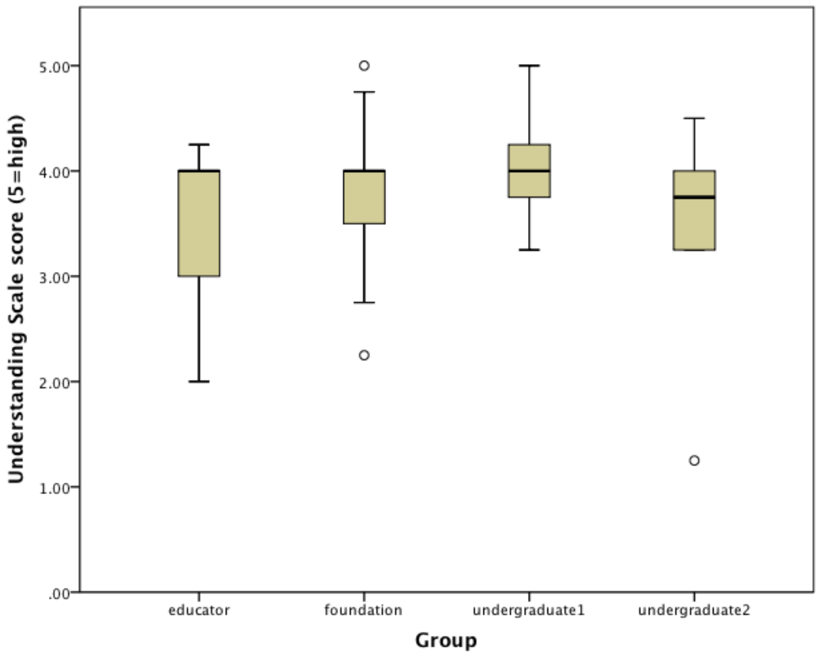


Figure 6.3: Boxplot showing Understanding score against sample group. The undergraduates are split into two groups.

Question 14 in the online questionnaire asked 'Based upon the current character behaviours (social play, blockplay, egocentrism) in the simulation, would the addition of any of the following cause you to observe the characters in a different way?' The findings for both students and educators are in Table 6.6.

Item	Total %	Students $n = 44$	Educators $n = 6$
age	46	20	3
individual faces	40	15	5
gender	38	15	4
clothing	20	8	2
individual body shapes	16	6	2
ethnicity	8	3	1

Table 6.6: Affirmative responses to Q14 in the online questionnaire.

94% ($N = 50$, 41/44 students, 6/6 educators) agreed with the statement 'Using the simulation was an interesting way to explore the behaviours of young children'.

86% ($N = 50$, 37/44 students, 6/6 educators) agreed with the statement 'The simulation has helped me to think about how I will conduct early childhood observations in the real-world'.

56% ($N = 50$, 26/44 students, 2/6 educators) agreed (agree and strongly agree responses combined) with the statement 'It was useful to add shelves'.

52% ($N = 50$, 25/44 students, 1/6 educators) agreed (agree and strongly agree responses combined) with the statement 'It was useful to be charged for objects'.

Correlational analysis was undertaken on the continuous variables in this research. The independent variables are: age (age of participant in years); employment (number of months as a paid employee in an early childhood based role); games (number of hours per week spent playing video games on any platform e.g. computer, console, handheld device); and observations (number of observations of young children's learning conducted). The dependent variables are simulation (Simulation Utility Scale score) and understanding (Understanding Scale score). When looking at correlations between the variables for only the students (Table B.6), there is a significant, high positive correlation (.713) between simulation and understanding (Figure 6.4). There is also a significant, moderate positive correlation (.394) between observations and games. When the educators are included with the students (Table B.5), additional, experience-related correlations emerge. There is a significant, very high positive correlation (.961) between age and employment. There is a significant, high positive correlation (.656) between simulation and understanding. There is a significant, moderate positive correlation (.428) between age and observations. There is a significant, moderate positive correlation (.373) between employment and observations.

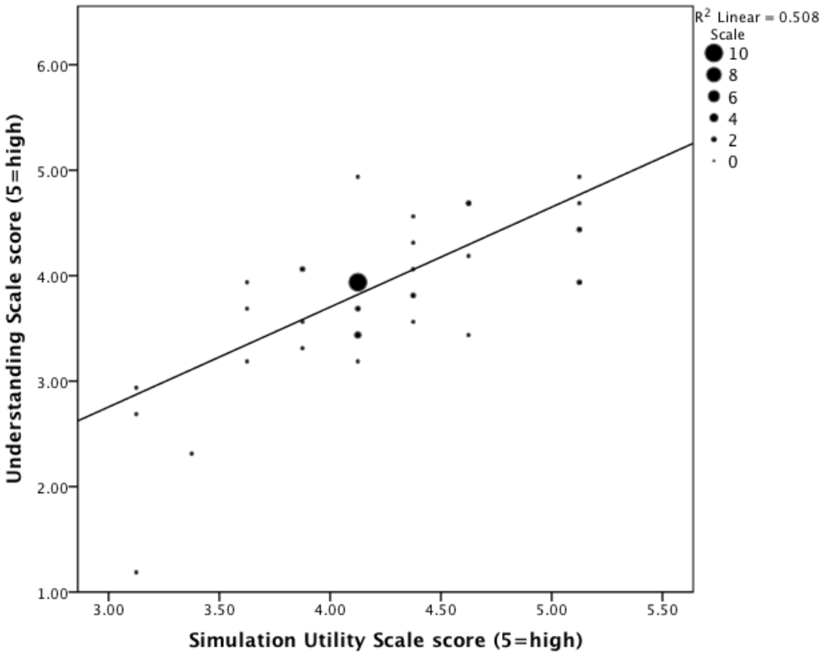


Figure 6.4: Scatter plot showing Understanding score against Simulation Utility score.

There were no significant correlations between any of the independent variables and the dependent variables. This was the case when the entire dataset was used (students and educators) and also when just the students were used. It was therefore not appropriate to perform multiple regression in order to discover how well the set of independent variables could predict any of the dependent variables. Logistic regression was performed to assess the impact of a number of factors on the likelihood that (student) participants would agree with the statement (Q26) ‘The simulation has helped me to think about how I will conduct early childhood observations in the real-world’. The model contained five independent variables: employment (number of months as a paid employee in an early childhood based role); games (number of hours per week spent playing video games on any platform, e.g. computer, console, handheld device); observations (number of observations of young children's learning conducted); education (highest level of qualification awarded which has an aspect of early childhood within it); and level (level of current academic programme). The full model containing all predictors was not statistically significant, χ^2 (5, n = 44) = 9.11, p = .105, indicating that the model was unable to distinguish between participants who agreed and did not agree with the statement 'The simulation has helped me to think about how I will conduct early childhood observations in the real-world'. The model as a whole explained between 18.7% (Cox and Snell R Square) and 32% (Nagelkerke R Square) of the variance in responses to the conducting observations statement, and correctly classified 90.9% of cases. None of the independent variables made a statistically significant contribution to the model (Table B.7). It is likely that the sample was not large enough and, as a consequence, that there was not enough data in the various categories to conclude any relationships between the independent variables and the dependent variable.

6.2 Content analysis study

6.2.1 Data collection

A focus group meeting was held at the beginning of the second semester of the academic year 2011–2012, one week after the formal session. The venue was a teaching room at Edge Hill University. In attendance were four early childhood education students from the university, together with this author. The format was very similar to the focus group with students in the pilot study, except the intention to follow a protocol was announced, which included some ground rules such as: everybody must participate, and there are no right or wrong answers. The session was semi-structured and explored participants' attitudes towards the simulation.

Semi-structured interviews were used with educators, in the main study, to get their perspective not only as a user of the simulation, but also as a professional who works with students in the field of early childhood education, in an academic environment.

Speech was recorded throughout the focus group and interviews on an Olympus WS 760M digital voice recorder.

6.2.2 Development of coding frame

During content analysis, a researcher may already have a list of categories or they may let the categories emerge from the data. Some researchers adopt both approaches [Daw09]. A hierarchical coding frame [Sch08] was developed to code the qualitative data. The coding frame was largely produced using categories derived from the theoretical background of 3D virtual learning environments. Early childhood education concepts were also used to further define the context. Research questions and the data collected also made a contribution to how the categories were defined.

The principal categories are based upon four of the five learning affordances of 3D virtual learning environments identified in [DL10]. These theory-informed categories are used as an analytic lens for coding. The fifth affordance, collaborative learning, was not considered, as collaboration within 3D virtual environments was not under investigation. The principal categories and subcategories are described in Section 6.2.3 and presented in an abridged form in Table 6.8.

One of the more interesting categories from the coding frame's development is now discussed. The Experiential category refers to experiential learning, which is the process of making meaning from direct experience [Iti99]. The category could have potentially been an umbrella term that covered many concepts, so the scope of that experience should be considered. It could be argued that any functionality built into a simulation could constitute experience. Another dimension appears if experimentation with dynamic entities [DL10] is included. Yet another dimension appears if the impractical or impossible nature of the experience [DL10] is included. Examples of potential candidates for this now broad category might be: flying to obtain an overview, being able to add unlimited objects, defining characters, randomly generating characters, speeding up/slowing down/pausing time, editing the terrain, seeing the world through the eyes of a character, and observing. However, if this category is restricted to only include references to tasks that *can* be undertaken, but might be impractical, in the real-world, within the context of early childhood education, this permits further dimensionalising. The Experiential category is now reduced to references about the process of conducting observations, with the other examples finding homes in other categories.

Whilst the coding frame does not code for usability explicitly, there may be allusions to this within the units of analysis, particularly for those codes more concerned with interactive parts of the simulation, e.g. spatial codes.

Units of meaning, based upon a combination of their affective valence and perceived benefit, were divided into those which tended to convey a positive, negative or neutral experience, and recorded as a value for a code. In addition, suggestions for a code were also identified. A suggestion may be an explicit response to a reported positive, negative or neutral experience. Alternatively, a suggestion may have no obvious connection with any other unit of meaning.

6.2.3 The coding frame

The coding categories used in the coding frame are described here in an extended form.

Contextual This category contains three subcategories for statements that refer to the real-life domain (early childhood education) or to theory which forms the basis of early childhood education. There may be comments about the fidelity (realism) of the simulation. **Appearance of character** is for the outward appearance of the character (representing a child): physical features of the body, clothing, and expression of emotion. **Environment** is for the physical space provided, together with objects within that space. There may be references to real-life constraints. **Development of character** is about how the development of a character (representing a child) is represented and any support associated with that development. The development is framed within the generic educational framework known as PIES (Physical Intellectual Emotional Social). There may be comments about making sense of the character's development.

Engagement This category contains three subcategories for statements that refer to the interest shown by users about using/playing the simulation. There may be some reference to other games. **Game** is about the gameplay aspects of the simulation: how a player interacts with it, the game rules, and any sort of challenge. **General** is for interest shown but only in a general way, nothing specific is mentioned. **Personalisation** is about making choices in the simulation and may include: configuring, setting up, and making selections. It is *not* about relating to the characters.

Experiential This category has one subcategory and is for statements that refer to the undertaking of tasks that *can* be performed in real-life but are likely to be impractical. **Observation** is about the process of making observations, the observational method and associated ethics. It is *not* about positioning or viewing within the 3D environment.

Spatial This category contains four subcategories for statements that refer to the spatial aspects of the simulation afforded by a 3D environment. **Manipulate** describes the skillful handling (picking up, placing, arranging) of objects within the scene. **Metaphor** is for graphical items within a scene which represent or symbolise something else, thus providing useful information. **Move** is about changing position and the proximity of things with respect to the user's position. **View** refers to seeing from a specific position.

The coding frame has been developed to assign a unit of meaning to a single category denoted by a code, using a best fit approach based upon the meaning. A unit of meaning may be a phrase, sentence, paragraph, or section of dialogue.

A value must also be assigned to each code in the coding frame. The value indicates the tone of the unit of meaning based upon the language used, unless it is a suggestion. The symbols that represent the values are in Table 6.7.

Symbol	Meaning
`+`	Positive emotive language.
`=`	Neutral, neither positive emotive, nor negative emotive language.
`-`	Negative emotive language.
`!`	Idea for a new feature of simulation or possible use of simulation.

Table 6.7: Symbols representing values assigned to codes.

The format for coding a unit of meaning is `category-subcategory(value)`. This is based on Schneider's coding approach [Sch08] but extended to add suggestions as a value.

Example `E-P(+)` signifies that the category is Engagement, the subcategory is Personalisation, and the value is `+` because the tone of the unit of meaning is positive.

The coding frame is presented in shortened form in Table 6.8.

Category	Code	Subcategory
Contextual		
Reference to real-life domain or domain theory Fidelity	`C-A`	**Appearance of character** Physical features, clothes, emotional expression
	`C-D`	**Development of character** Representation of, support for (using PIES as lens) Make sense of
	`C-E`	**Environment** Physical space, objects Constraints
Engagement		
Show of interest in using/playing simulation Reference to other games	`E-GA`	**Game** Gameplay (player interaction with simulation, game rules, challenge)
	`E-GE`	**General** Non-specific show of interest
	`E-P`	**Personalisation** Choices/selections to achieve individual goals
Experiential		
Undertake impractical real-life task	`EX-O`	**Observation** Notice activity
Spatial		
Spatial knowledge of the explored domain	`S-MA`	**Manipulate** Handle objects skillfully
	`S-ME`	**Metaphor** Symbolic graphical items providing information
	`S-MO`	**Move** Change position Proximity of things to user
	`S-V`	**View** See from a position

Table 6.8: Hierarchical coding frame for qualitative data.

6.2.4 Reliability of coding frame

It is widely known that inter-rater (or intercoder) reliability is a vital component of content analysis. Without it, the data and associated interpretations can never be considered valid [LSDB02].

When multiple researchers code records of behaviour, typically categorising or scoring, it is important that they do so in ways consistent with one another. This is known as reproducibility. To evaluate the consistency across different people an inter-rater reliability statistic can be calculated.

In this research, only one researcher (this author) was responsible for the quality of the coded data using a coding frame developed by this author, specifically for the purpose. It was therefore desirable to determine whether the coding frame devised was free from ambiguity, and capable of producing a consistent reliable coding, by obtaining a measure of the inter-rater reliability using another researcher.

A reliability sample of 10% (25) of the units of meaning identified was prepared. The reliability sample included data from focus group, interview, and online questionnaire open-ended items. The reliability sample covered the full range of measurement within the coding frame (Table 6.8) which contained *a priori* codes. The reliability sample was a subset of the full sample. The reliability here is concerned only with the reliability of the coding categories. There is not a separate reliability calculated for the reliability of segmentation into units of analysis [SMPJ06], which in this case is text forming a unit of meaning, since the segmentation of the reliability sample was conducted solely by this author.

The aid of a colleague (Section 3.3) was enlisted to code the reliability sample, and to serve as a peer debriefer [Spi03] for the purposes of validation. The debriefer was chosen because they have had experience in qualitative research methods, including content analysis. They understand the epistemology of qualitative research and recognise the standards of quality appropriate to the paradigm. The debriefer was also chosen because of where they fall on the continuum of insider to outsider perspectives. Since the nature of the research is inter-disciplinary, including the coding frame, the dual-role of the debriefer was to be an insider with respect to the discipline of early childhood education, and an outsider with respect to 3D virtual learning environments. The insider as debriefer can comprehend what the researcher and research participants say without lengthy explanations and can understand conceptual areas in the field. The outsider as debriefer may challenge the researcher's beliefs and stimulate further examination.

In addition to the reliability sample, the coding frame was provided to the debriefer, plus extended descriptions of the coding categories (Section 6.2.3). No additional training was given. The coding frame was refined over several iterations (Table 6.9) using inter-rater measurements to identify the sources of variability in coding. After the first iteration, one item from the sample was adjusted to match that of the debriefer and the category Observation was moved from being a subcategory of Contextual to being a subcategory of Experiential. After the second iteration, definitions of the coding categories were made more explicit. After the third iteration, definitions of the coding categories were, once more, made more explicit. After the fifth iteration, the suggestion was made to the debriefer to examine the word frequency [Ste01] within the units of meaning. The two codes that were not being identified by the debriefer from iteration four onwards were `S-MA` and `S-V`, which partly reflect the 3D spatial aspects of the simulation, namely manipulating objects and viewing, respectively. After the sixth iteration, the debriefer did not appear to be recognising the inter-disciplinary nature of the coding frame, as the coding was not deviating from their field of expertise, so a rationale was provided for looking through the lens of the researcher (this author). After the seventh iteration, when absolute agreement was reached, the coding frame was considered both a valid and reliable instrument.

Cohen's κ and Krippendorff's α are inter-rater agreement statistics that control for the agreement that would be expected by chance alone. They are preferred over the more intuitive and simple approach of calculating the percentage of agreement between two raters [LSDB02]. The strength of agreement in Table 6.9 for both κ and α is taken from popular interpretive scales [LK77, Kri04, LSDB02]. Cohen's κ and Krippendorff's α were both computed in TAMS Analyzer, and Cohen's κ was additionally computed in SPSS.

The process could have legitimately stopped after the third iteration, since the level of inter-rater reliability was .8 for both Cohen's κ and Krippendorff's α, indicating a high level of agreement (Table 6.9). However, it was important to ensure that the remaining items were classified correctly as they represented important and fundamental aspects of this thesis.

i	N	$=$	%	κ	κ Strength	α	α Strength
1	24	13	54	0.491	Moderate	0.4990	-
2	24	16	67	0.624	Substantial	0.6292	-
3	25	20	80	0.774	Substantial	0.7754	Similar
4	25	23	92	0.910	Almost perfect	0.9113	Similar
5	25	23	92	0.910	Almost perfect	0.9117	Similar
6	25	23	92	0.910	Almost perfect	0.9117	Similar
7	25	25	100	1.000	-	1.0000	-

Table 6.9: Inter-rater reliability statistics over several iterations. Key: i iteration, N opportunities, $=$ agreements, % agreements as percentage.

6.2.5 Findings

A summary of the salient points from the content analysis has been organised under headings formed from the coding frame codes (Table 6.8).

The content is grouped based on the value assigned to the unit of meaning (Table 6.7). In general, the order is positive, neutral, negative, suggestion, although positive and neutral may be combined in some cases. There may not always be content for every value. Quotations are used throughout the text for the purposes of illustration.

Since the participants are a mixture of both students and educators, certain qualifying terms have been used when reporting comments. The term 'student' is used when the point has been made by a student. The term 'educator' is used when the point has been made by an educator. The term 'people' is used when the point has been made by at least one student and at least one educator.

It is not fruitful to place emphasis on statements about quantity as part of a focus group analysis because of the limits of generalisation and because the data collection is neither individual nor standardised [Vic10]. To confound the issue, content from other sources is also present from: open-ended questionnaire items, open-ended participant comments on website, open-ended questionnaire items linked to other questionnaire items, and semi-structured interviews. Whilst all of these complementary sources may be individual, they cannot be said to be standardised collectively.

Rather than report the precise frequency of points made, points are reported when they were made by a single person, or by more than person. When one participant has made a point, this is acknowledged. When two or more unique participants have made a similar point the term 'some' is used. Uniqueness was determined by cross-checking within and between content sources, to ensure that a contribution by an individual making duplicate statements with similar meaning was only included once.

Contextual - Appearance of character One student likened the characters to wooden armatures used in art. One student felt that, in place of facial expressions, it was possible to find out about a character by selecting them.

Some people commented on the adult proportions of the characters' bodies and how more child-like proportions may have helped with the emotional engagement of the player. Some students thought that the characters looked too similar, which made monitoring them difficult. One student felt that the characters looked like robots.

Some people suggested using individual faces to make the characters more individual, and in some cases individual body shapes, for the purposes of identifying the characters and remembering them. Some people thought that faces could be used to express the emotions of the characters. One student thought that, particularly for young children, alternatives to facial expressions could be used to determine feelings, such as characters becoming a certain colour, or the use of emoticons (emotional icons). One student suggested the use of body language. One student suggested using names for the characters. Some students said that the characters could perhaps have hair. Some students said that the characters could perhaps have clothes. One student thought that age and gender would allow the player to picture the characters more in a classroom.

Contextual - Development of character Some people made the connection between the behaviour of the characters and real-life observations they have made. One student said:

> By adding more characters and resources the onlooker character's well-being increased. Often within a placement if a child is the first to arrive they will stand and wait for others before beginning a game or in some cases going near a resource.

One educator said, 'The bridging, and all the different things they were doing with the blocks, that's the kind of thing that you see children doing'. One student thought that the random character generator was more true to real-life than defining characters and said, '... you couldn't know who you'd get in a nursery. Especially us going on to placement. We don't know the children. We get to know them, but we don't know them as soon as we walk in.' Another student remarked that definition is not possible because children change and develop. Some students noticed the link between the well-being and the behaviour of the characters, and either took some action, or expressed a desire to interact with the character. One student said that they would be able to recognise blockplay in the future, and another said that they had experienced the range of blockplay, from simple to advanced. One student said that the simulation had helped them to understand the importance of staff to children ratios. One educator felt that the simulation was an effective way to get students to manage a group of children, and to think about their needs. Another educator said that they often refer to experiences that students have had whilst on placement, so a simulation brings the experience into the classroom.

One student did not understand how egocentrism was defined in the simulation. One educator did not get a sense that the characters needed emotional reassurance.

One student suggested that a physical connection with the characters would be useful, such as the ability to hug, to respond to emotional needs. One student suggested incorporating behavioural problems such as biting or smacking. Some students thought that the addition of fighting or nastiness would be quite realistic, and would also be an interesting situation for adults to handle. Some people said that age (this was the most popular) would be useful as an additional feature for the following reasons: children have different levels of development at different ages, children have different needs at different ages, an adult treats a child differently at different ages, younger children may not understand social play as much as older children, and the age would allow the adult to determine if the child is meeting curriculum stage targets and therefore tailor the activities accordingly. One educator said, about the inclusion of age:

> If part of the intention of the simulation is to get students to recognise different forms of play etc., perhaps an option to set ages (but not stages) could be considered, leaving the student to deduce a character's stage of development from the behaviour exhibited.

Some students suggested that the inclusion of gender in a character would be useful because it would be interesting to see if males and females behave differently, and one student stated that there has been research into behaviour patterns of males and females. One educator suggested that the simulation might be used to stimulate discussion and allow the students to recognise that there's a range of strategies to affect the well-being of a child. Some students suggested the addition of dialogue, with one student suggesting simple phrases, and an educator thought that talking to a character, as an option, may have a bearing on well-being. One student thought that it would be useful for the adult to be able to play with individuals or groups of children.

Contextual - Environment One student liked how it was possible to mimic the environment of their placement. One student liked the ability to make changes to the environment, and said, 'We always say we could have improvements on where we work, whereas in that world you could just change them, so it was good.' Some students liked providing resources for the characters and one student felt a sense of control, similar to being in a classroom. Some students recognised that in a real setting resources would be limited by budgetary constraints. One student was influenced to think about the safety of children with respect to high terrain. One student reflected on how simple objects, such as blocks, can be used in many different ways.

One student stated that the environment doesn't look like a nursery.

Some students thought that it would be useful to create specific learning areas like those found in early childhood settings such as a quiet reading corner. One student would like to introduce covered areas. One student would like to introduce other surfaces such as mud, and perhaps a representation of water. Some students would like to see the addition of balls. One student would like to introduce slides. One student would like to introduce monkey bars. One educator, who teaches resource management, could see the learning potential for students trying to create the richest learning environment possible within a budget.

Engagement - Game Some people became attached to the characters and enjoyed looking after their well-being by providing resources and food, described by one educator as, 'A bit like keeping your Tamagotchi alive.' Some students described the way they catered for the needs of multiple characters simultaneously. Some students were challenged to think about why characters were behaving in a certain way and also what might they, the player, be able to do about it, with one saying, 'Just because it's not real life, you can't shove it to the side.' There was a comparison to The Sims, and a perceived benefit over Second Life where the other characters might be role-playing people. Some students had a sense of satisfaction when the characters were building. One student liked the way that the player must shape the environment, in order to carry on playing. Some students appreciated the uncertainty of the characters' behaviours, with one saying, 'I liked putting the stuff in and seeing which one played' and another saying, 'The free will of the characters shows the natural world, because of the free will we have.'

One student remarked that there was no physical connection, such as hugging, between the adult and child. One student commented that the characters did not use the chairs.

Some students felt that a budget might be useful to put a limit on how much could be spent. Some students suggested an undo feature, and in one case, specifically to avoid making too many characters. An educator saw a great deal of future potential in allowing students to explore and respond to health and safety hazards in an early years environment.

Engagement - General People's comments included, 'lots of fun', 'really enjoyed it', 'really interesting', 'informative', 'cool', 'hooked', and 'really good'. Some students preferred the simulation to Second Life. One student said, 'we ran completely into our lunch. But we just wanted to stay and play with it.'

One educator found the simulation intriguing and could see it being used to introduce elements to challenge students' thinking and to stimulate discussion. They said, 'As a tutor I would definitely consider using this activity with students although they would need some time to simply play with it before I could adapt it to my learning objectives.'

Engagement - Personalisation Some students liked being in control of creating their own world, deciding what goes in and what doesn't, and making different types of flooring for indoor and outdoor areas. Some people liked defining the characters and one educator remarked that in a class, you cannot plan which developmental stages will show themselves, so to be able to select them and compare them was useful. Some students were impressed that the behaviours of the characters on each other's computer screens were quite different, even though they were following the same task sheet.

There was a suggestion from one student to have more objects to add. Another student suggested having a range of clothing with which to dress characters. One educator felt that there was value in both defining and generating random characters, when wanting to bring out particular learning points, and would also appreciate the control of additional features such as age, gender, clothing, or ethnicity.

Experiential - Observation Some students commented that the simulation gave support to, or helped develop their understanding of, observation. One said, 'Found this to be a really interesting medium through which to explore the process of observation.' An educator recognised the benefits of a system that can offer covert observation, similar to an observation with a one-way mirror, without the ethical issues of acting in a covert manner. They said:

> If you then think about covert observation, there's lots of aspects of ethical protocols that have to be taken into account there. About people's knowledge that they are being observed, parental permissions for all of that, as well as the staff being okay with it as a process. Whereas this has the advantage of covert observation [laughs] without all those ethical complications perhaps.

One educator felt that the inclusion of character features such as individual faces, individual body shape, age, gender, ethnicity, and clothing, could be used to stimulate discussion about the process of observing:

> Observers are influenced by characteristics which may be extraneous to the behaviour they are setting out to observe. This may be conscious or unconscious, but there are effects nonetheless supported by literature on interpersonal perception, performance characteristics/expectation, prejudice, stereotyping, non-verbal communication, attribution. All the characteristics listed in the question could trigger certain responses/preconceptions in the observer. The inclusion of such characteristics may therefore open Observation to discussion about 'extraneous variables' and the potentially misleading effects of such things on the process of observing.

One student suggested that monitoring would be easier if characters had more individuality.

Spatial - Manipulate One student liked the interactive editing of the terrain, so that characters who were not previously scaling the steep terrain, would now walk over the less-steep slopes. One student carefully placed separate shelves, with vertical space between them, so that the highest shelf was not higher than the height of the characters.

Some educators used a touchpad, one of which was reported to be on a laptop, rather than a separate mouse, and had difficulties placing objects in the scene and editing the terrain. They also experienced some strange physical behaviours with the objects. One student took some time to get used to using the scroll wheel on a regular mouse for object manipulation and terrain editing.

Spatial - Metaphor One educator appreciated the visualisation of the connection between characters, 'I liked the bar, that linked the ones that were playing together.' Some people could relate to items above the characters' heads, feeling that they were a good indicator of current behaviour and needs, with one reference to a similar representation in The Sims.

Spatial - Move Some people made comments about having a sense of being in amongst the characters, moving around them, and proximity to them. One student said, 'somebody else would walk past you' and 'walking behind you'. Another said, 'it was doing my head in just being so near' and 'where have they gone?'

One educator struggled with having independent moving and viewing controls, which are typical in a gaming environment.

Spatial - View Some people commented on the benefits of the 'flying' view within the simulation, termed in various ways as, 'overview', 'snapshot', 'birds-eye view', and 'aeroplane type view'. It was remarked upon that such a view is not possible in the real world, being described by one educator as a, 'luxurious position' and by one student, 'It's what you'd expect from a game.' Linked to viewing was the benefit of pausing the simulation, which a student said gave them the possibility to, 'look around at the surroundings'. One student commented on the ability to change orientation, 'I kept rotating it so I could see them all'. Some people felt that the 'empathise' view was useful and one student said, 'it helps me to think about being in a child's eyes.' Some students said that flying was familiar to them because they had already used Second Life during their course.

An educator suggested that controlling the view could perhaps be a little more intuitive. The terms used were pan, tilt and zoom (PTZ) functions used by cameras in television production and security.

6.3 Summary

This chapter has reported the findings from the main study, including statistical findings from a questionnaire and findings from a content analysis study. Reliability and validity were demonstrated for the scales developed from the questionnaire and for the coding frame used during the content analysis. The participants in the main study included both educators and students in the field of early childhood education. A high percentage of the participants agreed that the simulation has helped them to think about how they will conduct early childhood observations in the real-world, and a high percentage of the participants agreed that the simulation was an interesting way to explore the behaviours of young children. There were no significant correlations between any of the participant profile variables and the perceived utility of the simulation by participants. However, it emerged that the group of students with the highest perceived utility of the simulation had used the virtual world Second Life to simulate an early childhood environment as part of their current studies.

Chapter 7

Evaluation

This chapter evaluates this work. Two complementary evaluation frameworks for serious games are applied to the simulation Observation. A compare and contrast exercise is performed using a video clip of blockplay and the features of the simulation. Connections are made with the simulations developed in the related work described in Chapter 2. Consideration is given to what extent the research questions have been answered. Certain procedural aspects of the research design are reviewed.

7.1 Evaluation of a serious game

In Observation, the user effectively experiences the world by assuming the role of an adult, a practitioner in the field of early childhood education. Linser [Lin11] reports that the field of role play simulation games is fractured to such an extent that it is very difficult to evaluate the results of the various projects. Some of the factors causing the fracture are: naming convention (e.g. scenario, simulation, role play, role play game, role play simulation, role play simulation game); mode of delivery (e.g. text and images, 3D); and media of delivery (e.g. face-to-face, online, mobile).

However, three frameworks have been identified [UW10] that can be used for serious games developers and teachers to develop and evaluate games. Each emphasises different aspects of serious games. The RETAIN model [GKV08] looks at elements within the game. The four-dimensional framework of De Freitas and Oliver [dFO06] focusses on game selection and integration. The three-component model of Harteveld et al. [HGaMB07] considers the need to balance learning, game, and reality.

Whilst the RETAIN model can be partially applied to the simulation, it appears to have its roots in a didactic philosophy, rather than a constructivist philosophy. In the rubric, the following are examples of phrases that are used: ‘required learning content’, ‘progression’, ‘didactic content’, ‘scaffolded levels of challenge’, ‘previous levels’, ‘increasing level of difficulty’, ‘instructional elements that are introduced in a hierarchical manner’, ‘content sequenced’, ‘unit of gameplay’, and ‘mastery of facts or a particular skill’. If the simulation had been developed with instructional learning material presented in a sequenced, hierarchical fashion, and there was a lot of content, it would have been appropriate to use the RETAIN model to evaluate the simulation. However, the simulation developed is based on an experiential approach, providing a more open-ended experience. The RETAIN model will therefore not be used to evaluate the simulation.

Observation (the simulation) is now evaluated using the four-dimensional framework of De Freitas and Oliver (Section 7.1.1), and the three-component model of Harteveld and colleagues (Section 7.1.2). In a few places, the two frameworks cover a similar concept, so rather than be repetitive, it is addressed once under one framework, and a reference to that is made from the other framework.

7.1.1 Four-dimensional framework

The four dimensions are: Context, Learner specification, Pedagogic principles, and Mode of representation (tools for use). The main questions within each of these dimensions have been used and coded sequentially, to give: C1–C3 (Context), L1–L5 (Learner specification), P1–P7 (Pedagogic principles), and M1–M4 (Mode of representation).

C1. What is the context for learning? (e.g. school, university, home, a combination of several) Observation (the simulation) can be used in a formal learning situation at university by learners, or used by the same learners independently. Observation may also be used by professionals undertaking professional development, in a formal setting, or independently. The context can be found in Section 6.1.2.

C2. Does the context affect learning? (e.g. level of resources, accessibility, technical support) Video tutorials explaining all the main features of

Observation, together with a user manual providing multi-language translation, are available from the software website. Binaries for Observation are available for download from the website, for the following operating systems: Windows, Mac OS X, and Linux. A computer with an implementation of OpenGL is required. A two-button mouse with scroll wheel, and keyboard, gives the best experience for the interactive 3D graphics. The touchpad of a laptop running Windows has been tested and known to work but using the interactive graphics in Observation, particularly when editing terrain, is a little cumbersome (Section 6.2.5, p. 131). Apple's Magic Trackpad is unsupported. In the absence of a mouse with scroll wheel, or any other another method for scrolling, the scroll wheel functionality can also be obtained from the keyboard. Observation has been tested and ran successfully on a number of computers with different configurations: Tiny PC (2 GHz CPU, 1024 MB RAM, 128 MB VRAM, Windows XP Professional SP2 OS); HP mini netbook (1.7 GHz Dual CPU, 1024 MB RAM, 237 MB VRAM, Windows 7 Starter OS); eMachines laptop (2.2 GHz CPU, 3002 MB RAM, 1308 MB VRAM, Windows Vista Home Basic OS, Ubuntu Linux 9.04 Jaunty Jackalope OS); and iMac (2.93 GHz Quad core CPU, 16 GB RAM, 1024 MB VRAM, Mac OS X 10.6.8 Snow Leopard OS, Windows XP Professional SP2 virtual machine OS, Ubuntu Linux 10.10 Maverick Meerkat virtual machine OS).

C3. How can links be made between context and practice? Observation (the simulation) supports the underpinning knowledge of the reflective practitioner, whether they are a learner, or a professional, and provides experiences similar to those found in early childhood settings (Section 6.2.5, pp. 126–128).

L1. Who is the learner? Learners over 18 years of age (Section 6.1.5).

L2. What is their background and learning history? Learners may have no previous qualifications in early childhood, qualifications in early childhood below honours degree, or qualifications in early childhood at or above honours degree level. Learners may have no experience, little experience, or a number of years experience working as a professional within the field of early childhood. Learners may have no experience, little experience, or a number of years experience observing young children in an early childhood educational setting. Learner backgrounds can be found in Section 6.1.5.

L3. What are the learning styles/preferences? A range of differentiated learners with different learning styles can be catered for through the use of the simulation. Learners can engage with the simulation using their own preferences.

L4. Who is the learner group? The simulation can be used by learners on programmes having an early childhood education theme, or used by early childhood education professionals undergoing professional development (Section 6.1.5).

L5. In what ways are the groups working together (e.g. singly, partially in groups) and what collaborative approaches could support this? The simulation can be used by learners working singly (Section 6.1.2) and also in groups.

P1. Which pedagogic models and approaches are being used? Kolbs Experiential learning cycle or other variants of the learning cycle, e.g. plan-do-review, Jonassens constructivist model, Activity theory, and Discovery Learning (Bruner).

P2. What are the curricula objectives? A development-based example from one university programme [Cur11] has these learning objectives: begin to understand significant theories of child development (and reflect upon how theories relate to observations within practice), know and understand some of the influences on development and learning, understand stages of development from birth to 5 years, gain an awareness of the diversity of backgrounds that children bring to their early learning, and understand the need to and means of challenging stereotypical views.

An observation-based example from another university programme [Bea09] has these learning objectives: know and understand the importance of observation and assessment in recognising childrens learning and planning for 'next steps', and know and understand good practice in observation and assessment. Students reflect upon how they currently use observation and assessment in their own work and how they can make improvements.

P3. What are the learning outcomes? Explain the stages of blockplay, the stages of social play, and egocentrism. Locate observational strategies within a continuum of pure observer and pure participant. Show empathy with the learning of others. Give examples of good resource management.

P4. What are the learning activities? Creating the environment for an early childhood setting. Adding characters (representing children) which have been randomly generated or defined manually. Observing the activities of the characters using visual and textual cues. Monitoring the well-being of the characters using visual and textual cues. Providing resources according to the requirements of the characters. The activities used for the pilot study and for the main study can be found in Sections C.1 and C.2, respectively.

P5. How can the learning activities and outcomes be achieved through existing games or simulations? There are currently no existing games or simulations available, of a similar nature.

P6. How can the learning activities and outcomes be achieved through specially developed software (e.g. embedding into lesson plans)? Activities using the simulation can be embedded as a practical session (Section 6.1.2) in the lesson plan of the tutor. The simulation can be used in a whole-class situation (as proposed by an educator in Section 8.4). Activities can be completed by learners independently (Section 5.2.1), outside a formal teaching session.

P7. How can briefing/debriefing be used to reinforce learning outcomes? Learners can be prepared before using the simulation and afterwards (as suggested in Sections 3.10.2 and 3.10.3) engage in reflective consideration of their experience [Nic12].

M1. What level of fidelity needs to be used to support learning activities and outcomes? Observation uses a range of fidelity. *Low*: appearance of the 3D humanoid characters is quite abstract; age of the characters is unspecified, although they are of walking age, evident from their animations; objects are consumed by the character by coming into range of them; unlimited objects when credits system is not on. *Medium*: characters have a simple set of animations; character behaviour is interpreted from research in child development, though limited in scope; character well-being is a simplified version of a concept used in early childhood education; spatial exploration is possible as an observer, and includes impossible viewing from a great height; objects can be carefully manipulated and placed, including at distances from player's viewpoint, and within other objects (the physics simulation resolves this); a character's inventory is based on a personal collection of objects, although it is dimensionless; characters can be randomly generated but also defined manually. *High*: objects are based on real-world objects, e.g. block dimensions; objects are controlled by a physics simulation; characters plan their own activities; characters locate objects by looking for them; characters cannot obtain objects located too high above them; characters cannot spawn (create) new objects; characters cannot be deleted.

M2. What level of interactivity needs to be used to support learning activities and outcomes? There are high levels of interactivity in the simulation, due to the exploratory nature of the software, and particularly because many of the learning activities involve interactive 3D graphics. How characters get defined, where characters are placed, which objects are added to the world and where, and the level of empathy shown by the player with the characters, all have an impact upon the outcomes.

M3.What level of immersion is needed to support learning outcomes? Observation uses a conventional computer monitor to display the visual world, known as Desktop Virtual Reality (VR), or a window on a world [BF92].

M4. How can links be made between the world of the game/simulation and reflection upon learning? Observation provides generic theoretical content based upon early childhood research, which is not tied to any particular curricula. Educators can incorporate the simulation flexibly into learning episodes to bring out specific learning points, and support reflective processes of learning.

7.1.2 Balancing pedagogy

The three components of this model are: Pedagogy, Game elements, and Reality. The criteria within each of these components have been used and coded sequentially, to give: P1–P5 (Pedagogy), G1–G5 (Game elements), and R1–R5 (Reality).

P1. Reflection *Games offer little opportunity for reflection, so inclusion would be valuable.* Reflection is not built into the simulation. It is expected to be stimulated by an instructor.

P2. Experience *Learning-by-doing should be emphasised, not providing extensive amounts of text.* The simulation is very visual, making use of interactive 3D graphics, because the emphasis is on observation. Text is restricted to event log text and basic character information. There are no large bodies of text. There are no descriptions of the development characteristics used (blockplay stage, social play stage, egocentrism) when randomly generating or manually defining characters.

P3. Low resource demanding *Information overload or time pressure can overburden the player and cause them to miss important information.* The graphical user interface can display just the 3D graphical world, or it can also display an event log and character information pane. The event log can be filtered on the currently selected character. There are no explicit time constraints within the simulation, such as a fixed amount of time to complete a task. There are more subtle time-related effects, such as a character's well-being decreasing whilst in a certain state. In addition to using the simulation in real-time, the slowing down, the speeding up, and the pausing of time are built-in features for flexible observation.

P4. Exploration *Players should not be forced to do things, they should just figure it out, with minimal direction.* The simulation provides a nonlinear gameplay experience. It is up to the player to provide an environment for learning, and manage the well-being of any characters they add, but how this is done is up to the player.

P5. Incremental *Learning should be incremental so it is less demanding.* Technical scaffolding is provided for guidance on how to use the simulation, by way of video tutorials, and a user manual (including a web-based multi-lingual option).

G1. Harmony *A game should be a coherent and consistent system.* There are many interdependent components. Physics-based objects can be placed freely by the player, which has real-time planning implications for characters planning a path from one point to another. Certain combinations of developmental attributes for a character are prohibited because they simply do not make sense. For instance, cooperative blockplay can only happen when the character is at a certain social play stage. Cooperative blockplay builders must coordinate the retrieval and placement of blocks for a common construction, and the builders share the objects within the inventories which belong to each of the group members. The well-being of each individual character is constantly updated and presented visually and in textual form (if required). These individual well-being scores are combined to form a population average, which is used as a global feedback mechanism.

G2. Uncertainty *Players should experience challenge and fun from randomness and uncertainty.* There are many examples within the simulation. A character can be generated randomly, whereby they will be given a random colour, assigned a social play stage, assigned a block play stage, and defined as egocentric or not. If a character has a social play stage which is more social, they will be in a group, the size of which is random, and the group leader will randomly allow other characters into the group. Characters randomly select a construction from a bank to be their next one. Block availability for characters constructing will depend upon what the other characters are doing and whether the player has added the requisite blocks, which may depend upon whether they are operating within a budget. Egocentric block builders will take the blocks of others, for their own construction, depending if the blocks are available at the time. This causes characters to abandon their construction and start again. Characters relocate their patch if their adjacency to others is not ideal for their social play stage. Random terrain generation was possible in early versions of the simulation.

G3. Interactivity *Choices made by the player should be interesting and affect the outcomes in the game.* See Interactivity in Section 7.1.1.

G4. Engaging *Entertainment games are fast, motivating, and reward the player's actions.* The simulation happens in real-time, so there is always something happening. A combination of visual and textual information gives feedback to the player on the state of the world and how their actions have made a difference.

G5. Flow *Difficult games are frustrating, easy games are boring. Players should have just enough frustration.* Challenges can emerge in a number of ways depending upon the contents of the world, which is a combination of player choices and randomisation. The simulation becomes more challenging as the player adds more and more characters, which places more demands upon the player, and resources, if the credits system is on, which enforces a budget.

R1. Learning objectives See Learning outcomes in Section 7.1.1.

R2. Target group See Learner, Background, and Learner group in Section 7.1.1.

R3. Challenge The well-being of the characters is the focus and this is the main challenge of the simulation. The player should strive to maintain the highest average well-being possible for the population, and the highest well-being possible for each individual character.

R4. Clients The clients of the simulation are education departments in universities which provide academic programmes in early childhood education.

R5. Organisation The provision on early childhood education programmes will vary at the various universities which provide them. Some learners may be expected to be working already, whilst others may be assigned a placement in an early childhood setting as part of the programme. All learners will receive theoretical instruction from educators, and spend time with young children, observing them and interacting with them, professionally.

7.2 Compare and contrast using video and simulation

Why not just watch a video, instead of using a simulation? To explore this further, a critical analysis is performed using a compare and contrast exercise on a video clip of blockplay and the simulation. The video can be found on an Early Years Foundation Stage CD-ROM [Dep07], which provides support materials as part of a larger pack. The video is set in a nursery school where two children are shown playing cooperatively in building a fortress using blocks (Figure 7.1). At the end of the clip a sign identifies four children that had worked together on the large construction, and their work-in-progress is cordoned off, to respect their achievement.

Figure 7.1: Still from blockplay video in which two boys play co-operatively in building a block fortress. Crown copyright material reproduced with permission.

The compare and contrast exercise is based purely on what is present in the video, and based purely on what has been implemented in the simulation, where there is a correspondence between the video content and a simulation feature. The exercise is not concerned with how video might be used or what could be implemented in the simulation. The exercise is not concerned with other features of the simulation that have no correspondence with the content of the video.

Comparing the video with the simulation gives:

- Cooperative play, working on a shared goal and sharing resources;
- Representational blockplay, incorporating stacking and enclosures;
- Path following around objects (foreground child in video);
- Body positioning within reach of placement point for block;
- Construction takes place on its own patch of floor;
- Unit blocks used in construction;
- Objects have physical properties (collision);
- Shelving has physical properties, for supporting objects;

- Tables have physical properties, which can support objects;
- Floor has physical properties, for supporting objects;
- Wall has physical properties, for containing objects;
- Objects have textural properties;
- Wooden surface on floor;
- Level floor for constructions;
- Lighting which casts shadows;
- Pausing and speeding up of time.

Contrasting the video with the simulation gives the analysis in Table 7.1. The entries in the table are in no particular order and have been grouped thematically.

7.3 Connection to related work

Foley and McAllister [FM05] found that students were able to visualise a real classroom by planning for learning based upon profiles of children, although visualise here means to form a mental image, rather than make visible. Participants found it helpful using a 3D environment to create scenes that resemble learning environments for young children. Foley and McAllister also found that students struggled to create cooperative groups, based upon the diversity of the children. In Observation, simulated children form their own groups, based upon compatible profiles, where group leaders may accept or refuse entry to a group.

Cheong [Che10] found that pre-service teachers could practice teaching skills without a negative impact on (real) students. Similarly, Ferry et al. [FKC+04] found that students felt safe exploring the consequences of their decisions without affecting real children. Observation (the simulation) enables users to explore their role within an environment for young children. One of the participants, an educator, particularly liked having the option of *not* intervening, without detriment to any children.

Gregory et al. [GDC+11] found that using Second Life for role-playing teachers and students, whilst interesting, entertaining, and novel, had technical difficulties, particularly with the display of the 3D world. The authors plan to develop

Video	Simulation
Fixed viewpoint	Variable viewpoint
No spatial depth (2D)	Player can move within scene (3D)
Fixed narrative	Variable narrative (interactivity)
Recorded	Real-time
Edited into several scenes	Continuous
Snapshot of construction process	Entire construction process
Rewind time	No rewind of time
Hollow blocks	No hollow blocks
Large scale construction	Construction within 1 square metre
Stepping over blocks	Walking around blocks
Kneeling whilst building	Standing whilst building
Multiple blocks transported	Single blocks transported
Use of both hands	Use of one hand
Experimenting with balance	No exploration of physical properties
One child builds using blocks fetched by another child	All group members fetch and build
Explicit object passing	Implicit object passing (via inventories)
Four boys had built together, only two shown	All group members visible
Calling child to get their attention	No communication to get attention
Sound of other children's voices	No sound
Sound of blocks on floor	No sound
Facial expressions	No faces
Individual faces, individual body shapes, age, gender, ethnicity, clothing (nursery uniform)	No face, universal body shape, no age, no gender, no ethnicity, no clothing
Fixed environment	Variable environment (interactivity)
Pictures, storage containers, plant	No pictures, no containers, no plants
Visible wall	Invisible wall (physical)

Table 7.1: Contrasting the video with the simulation.

bots to take the part of the children. Mahon et al. [MBBK10] also reported technical issues when using Second Life for role-play, but the big limitation for them was that only one person could play the part of the teacher at a time, and students needed to role-play the same scenarios over and over. Consequently, the authors, who are already using bots, intend to make further use of them to simulate students. Similar technical difficulties were reported by some participants (educators and students) who had also used Second Life for role-playing as part of their studies. Some participants commented that Observation did not suffer from any technical issues whilst being used and was generally easier to use than Second Life. Observation exclusively uses bots to represent young children.

Reeve [Ree11] found that users of Virtual School shared little common ground in gameplay, due to randomisation of the simulation. Despite this underlying randomisation though, the scenarios presented looked and felt very similar. Unlike users of Virtual School, participants commented that it was interesting how they were completing an identical activity to their peers but the activity on each of their screens was quite different. Fischler [Fis06] found that, in an attempt to create varied experiences for users, it was time-consuming for instructors to create the branching content for their simulation, making use of a linear gameplay format. Observation does not use predefined scenarios, it is based on the idea of a more open-ended, emergent gameplay, where the narrative is dynamic, not predefined.

Ferry et al. [FKC+04] found that students could make connections between their simulation, their experience in schools, and the theory behind education. In the comments collected from participants during the main study, including the focus group, students were also contextualising their experiences using the simulation with their placement experience in settings, and making references to more theoretical aspects.

Users of simSchool [Cur10] and some of the participants both wanted to create 'problem' students from their own experience.

Skrødal [Skr10] found that students who are frequent games players are less likely to have a positive reaction to the simulation and suggests that this may be because there was less interactivity than in games. However, there was no correlation found between frequency of game playing and reaction to Observation.

Virtual School is now integrated further into teaching and used in groups for reflection. Fischler [Fis06] found that when the simulation was not used in classes, that in-class discussion was less productive. One of the participants (an educator) also believed that a simulation such as Observation would be well-suited as a stimulus within formal teaching sessions, rather than being used solely as a stand-alone resource.

7.4 Connection to research questions

What is the perceived utility of a real-time 3D graphical simulation of childrens play behaviour? One measure of utility for this central research question is in Table 6.4 and Figure 6.1 which show that the Simulation Utility Scale median score for each group (including educators) was positive.

The following sub-questions provide support for the central research question.

Is the simulation an interesting way to explore the behaviours of young children? 94% ($N = 50$, 41/44 students, 6/6 educators) agreed with the statement 'Using the simulation was an interesting way to explore the behaviours of young children'. These figures suggest that something about the simulation has engaged or excited participants, holding their attention or curiosity. It is encouraging that all of the educators agreed with the statement.

Can the understanding of the theory behind children's play be deepened? Figure 6.3 shows that the Understanding Scale median scores for all the student groups and educator group indicate an increase in understanding of the theory behind children's play (blockplay stages, social play stages, egocentrism, and the connections between these). It is interesting that some educators showed an increase in understanding. This may be because they previously had either none or only a superficial knowledge of some aspects of the theory represented in the simulation. It may be because blockplay, although quite common as an activity in settings, is quite a niche research area, and perhaps not widely known about. When only the students are considered, there is a significant, high positive correlation (.713) between Simulation Utility Scale score and Understanding Scale score (Figure 6.4). This indicates that the more students 'bought into' the simulation, the more their understanding increased.

Can observational skills be developed? 86% ($N = 50$, 37/44 students, 6/6 educators) agreed with the statement 'The simulation has helped me to think about how I will conduct early childhood observations in the real-world'. These statistics would suggest that something about using the simulation has caused participants to reflect upon the process of observation with respect to young children. For both students and educators, it may be that they have not been able to focus on observing play so intently before without distractions. Recording of some kind is usually performed whilst observing (Section 2.5.3), so it may be that exploring a virtual world, by moving around freely, and interacting with the context, without the burden of recording helped to provide that focus. What is particularly interesting is that all of the educators agreed with the statement, including those who have conducted hundreds or thousands of observations. This may be because educators are usually concerned with the education of their students and using the simulation gave them an opportunity to revisit and reflect upon the process of observation on a personal level.

Does professional experience influence the perceived utility of the simulation? There was no statistically significant correlation between the professional experience and the Simulation Utility Scale score of participants. This may suggest that the simulation appeals to a wide audience, with little or no professional experience to those with a great deal of experience.

Does the number of real-life observations conducted of young children influence the perceived utility of the simulation? There was no statistically significant correlation between the number of real observations performed and the Simulation Utility Scale score of participants. This may suggest that the simulation offers more than just an alternative way to observe, and also that it appeals to a wide audience with varying track records of observation.

Does playing video games influence the perceived utility of the simulation? There was no statistically significant correlation between the amount of time spent playing video games and the Simulation Utility Scale score of participants. This may suggest that the simulation appeals to a wide audience with varying interest in playing video games. It should be noted that the specific type of video games was not mentioned in the question. This is partly because there is no definitive system for adequately describing different types of video games [DAJM07] and partly because attempting to isolate particular aspects of video games may be at the expense of other aspects. For instance, many video games now use 3D graphics, which is also becoming increasingly common on mobile devices, but the question did not specifically ask about 3D. What emerged in the main study was that the group which had used Second Life before as part of their studies, where they role-played young children in a virtual environment designed to look like a setting, had the highest median Simulation Utility Scale score out of the three student groups.

What level of abstraction is appropriate for the representation of young children in a play environment? The following statistics, taken from Table 6.6, show how important participants in the main study feel additional features are, when monitoring the characters, based upon the character development as defined by blockplay stage, social play stage, and egocentrism. It is possible however, that participants responded in a more general way, considering an imaginary child, whose development can be represented in all sorts of ways. 46% of all participants would like to see the age of the character added. The age of a child can be useful because this can be used to determine where the child is with respect to developmental norms [Dep08a], and general comments were made from participants to support this. However, it could also be argued that *not* representing the age requires the observer to interpret what they see and deduce what the age might be. 40% of all participants would like to see individual faces on the characters. From the comments, this appears to be mainly to help with identification, especially when there are many characters present simultaneously. 38% of all participants would like to see gender represented in the characters. Perhaps this is because of the research that exists on gender issues, together with practical advice for supporting the learning of both boys and girls [Pou09]. Like age, representing gender might be useful to determine where the child is with respect to developmental norms. However, like age, it could also be argued that *not* representing the gender requires the observer to interpret what they see and deduce what the gender might be. Comments were mainly about seeing if there are any differences in the play behaviour of the genders. 20% of all participants would like to see clothing on characters, which suggests that clothing does not impact greatly on how children are observed. Although none of the participants specifically mentioned this, wearing clothes that are dirty, or that don't keep the child warm or dry, are physical signs of neglect [Nsp10]. It is interesting to note that clothing could, but not necessarily, indicate gender. One of the participants in the focus group mentioned how some children really like to dress up in the clothes traditionally worn by the other gender; clearly a boy does not really become a girl because they put on a dress. 16% of all participants would like to see individual body shapes, which suggests that body shape does not impact greatly on how children are observed. Although none of the participants specifically mentioned this, there may be health concerns if a child has a loss of weight, or is constantly underweight, as these are physical signs of neglect [Nsp10]. 8% of all participants would like to see some representation of ethnicity, which suggests that ethnicity does not impact greatly on how children are observed. Ethnicity was not defined in the questionnaire but was intended to mean ethnic group as used by organisations such as governments when referring to diversity.

7.5 Review of research design

7.5.1 Signup

In order to signup as a research participant, an email address is used as the username, much like most accounts for web-based services, so a confirmation email can be sent to the person, requesting that they authenticate the account request. Using emails generated instantly from events on the web-site, this author could see when participants had entered an invalid email address, which resulted in an undeliverable email, causing a delay in their signup. During the main study, for students in classes, they were sometimes waiting for an email that was never going to arrive. Eventually, participants realised what they had done and either used the correct email address, or used an alternative email address. After the first class of students, the website was modified to inform people before, and remind them afterwards, about the importance of a valid email address during the signup process.

At the beginning of the main study, approximately half of the participants who completed the signup process did not complete an evaluation. For the people who signed up at that time, a multi-stage approach to participation had been presented on the home page of the project website: signup, download, complete activity, and evaluate. Since the expectations of participants was always made very clear, it may be that a combination of being able to withdraw at any time, and a multi-stage approach to participation, contributed to people having a perception that they were initially signing up to get some free software, with no further obligation. The wording of the website was modified to remove the multi-stage description, and explicitly state that the signup process was for people wishing to become a research participant.

7.5.2 Downloads

The simulation was programmed using portable C++ and was compiled, tested, and made available for downloading on the project website for the Windows, Mac OS X, and Linux operating systems. This was to give choice for participants who may be working at an institution or at home. During the pilot study one student made it known to this author that they would download the Mac OS X version to use at home. During the main study there were no known, intentional downloads of either Mac OS X or Linux versions of the simulation, although it is possible that some people downloaded these before the download logging system was in place. During the main study, at one university, several students mistakenly downloaded the Mac OS X and/or Linux version during a classroom session in which they were using computers running Windows, which caused delays for those students getting started.

Some students in the main study downloaded the software multiple times during a classroom session. The file downloaded from the website is an archive which unpacks to a folder, so, speculating, it is possible that the students closed the program and could not locate that folder again.

7.5.3 Class time constraints

In a class situation, after an introduction from a tutor, students needed to read about informed consent, signup, familiarise themselves with the software via video tutorials and manual, complete an activity, and complete a questionnaire. There were comments in the focus group that this was a lot to do in one session. It is possible that some students may have been overwhelmed by the amount that had to be done and may not have given sufficient time to one or more aspects of the session.

7.5.4 Generation of research data

During the main study, despite the positive response (Section 3.8.2) from some of the 59 institutions emailed to participate, this approach did not generate any research data.

During the pilot study, of the students that attended a classroom session and were asked to complete an evaluation in their own time, less than half did so.

During the main study, of the students that attended a classroom session where it was left up to students to decide whether to complete an evaluation, only three of the thirty-plus students completed the evaluation, and a further three only after several email reminders.

During the main study, the most successful format was where the nature of the classroom session was presented clearly as a combination of exploratory learning using novel technology, and reflective evaluation. In addition, these students were offered an alternative learning task, if they wished to opt out of this one-off session. All students but one who attended these two one-off sessions completed the evaluation within the session.

7.5.5 Activity completion

An activity was included with the simulation so that participants would have a similar experience when using the software, ignoring the creative aspects of the activity.

The questionnaire is supposed to be completed after the activity but does completion of the questionnaire imply total completion of the activity? Was enough time spent on the various parts of the activity? Does the time between downloading the software and completing the questionnaire provide an indication of whether the activity has been completed adequately?

Participants were not explicitly asked to comment on the quality of the supporting materials (video tutorials and manual) for the simulation, or to comment on the instructions for the activity. Although there were no comments about either of them, it is possible that participants may have had difficulties following the supporting materials and/or the activity.

7.5.6 Collecting comments

During the main study, a personal contact that had been at the first student session, reported that students had made verbal comments during the session, but this author noticed that these particular comments had not been recorded in the comments section at the end of the questionnaire. In addition, comments in general tended to be quite brief or non-existent. This seemed like a missed opportunity, so a free-text 'Post a comment' web form was implemented inside the members area of the website, enabling participants to have their thoughts recorded (in a MySQL database) as they think of them. It would not matter if they then chose not to make any comments later. The next student session produced some very thoughtful comments through this system. In some cases, when a student was heard making a comment, they were encouraged to 'Post a comment', and soon they did it automatically.

7.6 Summary

In this chapter the simulation was treated as a serious game and two complementary evaluation frameworks were used to critically examine the simulation as a game within a learning context. Video recordings were recognised as being the default technological medium through which visual observations are made within learning contexts, and therefore a compare and contrast exercise was performed using a video clip and Observation. The following were presented: how this work relates to the work of others in the field attempting to simulate the learning environments of children, how the findings in this work support the research questions, and a review of some aspects of the research design.

Chapter 8

Conclusion

This concluding Chapter looks at the limitations of this research, provides some recommendations for future work based upon some of the main omissions from Observation, and considers the implications of the findings.

8.1 Limitations of the research

8.1.1 Scope

Each of the statements which specified the scope of this work in Chapter 1 are now considered.

This research is not about academic performance as a result of an intervention. An attempt has not been made to investigate the change in performance of students as a result of using a simulation, the use of which was not integrated into any academic programmes, making any genuine assessment difficult, including any longitudinal studies. It therefore cannot be known whether a simulation affects the academic performance of its users.

This research is not about comparative task performance. For various reasons discussed in Section 3.4.1, an experimental approach was not taken in this research which makes comparisons difficult. However, even if an experimental approach was taken, it is challenging finding a sensible basis for any comparisons to be made. It may have been possible to use recognition as the basis, treating the stages of child development as scientific facts (Table 3.1). However, if it had been desirable to use nature and a simulation to investigate the changes in students' conceptions [Skr10] about certain aspects of child development, this would have meant, for every participant, being in the same room as one or more children exhibiting play behaviours identical to the play behaviours in Observation. It is anticipated that this would have been rather hit-and miss and that it would be a case of being in the right place at the right time, since children are not predictable, unlike moon phases. For example, a personal contact has reported, when conducting observations in a setting, on multiple occasions, that there was no blockplay taking place, which may have been a result of the setting's infrastructure, or the interests and personalities of the children (Table 3.1).

This research is not about the usability of a developed simulation. The findings from the content analysis were presented through the lens of a coding frame, which was largely produced using categories based upon the theoretical background of 3D virtual learning environments, plus early childhood education concepts. Within the content analysis there may be comments that reflect the participants' perceptions of usability, which may include ease of use, learnability, efficiency or elegance. However, participants were not asked about usability, and no attempt has been made to classify comments as such within the text.

This research is not about investigating which aspects of a 3D experience may be beneficial for learners. The user is not embodied in Observation. The user is not represented as an avatar within the world and has no volume. The user does not have an arm, typical of First Person Shooter (FPS) games, which grips an object at the bottom of the screen. However, Observation does provide interactive graphics, allowing the user to manipulate an object within the scene, during which a hand icon is shown gripping the object. Whether this lack of embodiment affects the sense of presence [LD97], is not considered.

Sound has not been used, so it is not possible to investigate whether spatial audio feedback gives a greater sense of presence.

A physics simulation has been integrated into Observation. The assumption was made that this would increase the fidelity of the environment, especially when users manipulate objects. However, the implications of using physics for the users has not been explored.

This research is not about developing new techniques in computer graphics. The application of the computer graphics techniques was considered by this author to be appropriate for the various areas within the simulation. By taking a bottom-up approach, essential aspects were implemented, attempting to create reusable code wherever possible. However, no novel computer graphics techniques were presented.

8.1.2 Research design

Purposive sampling was deliberately used in this research to target early childhood education professionals, using carefully chosen institutions, and professional networks, since the content of the simulation was clearly aimed at early childhood education professionals. The recruitment effort was a national one, by contacting named individuals (where available) at all HEIs providing early childhood education programmes in the United Kingdom, using a website to promote and support participants. However, the resulting take-up and conversion meant that participants were largely taken from two universities in the North West of England, although there was some variety in the educational programmes on which the student participants were embarked at the two institutions. Even if participant data had been collected from around the United Kingdom, participants were self-selecting volunteers, who may be more motivated, which introduces a self-selection bias. Whilst it can be said that participants were carefully targeted, the sampling approach was nonprobabilistic, so it is not possible to generalise statistically beyond the sample.

8.2 Recommendations for future work

The characters do not really have any explicit emotions encoded in them. They do have a level of 'well-being' encoded as a continuous number, and reported to the user as one of five items on a scale, or as grey-scale on their upper torso, which resembles a vest (Section 4.2.4). The well-being representation is very much a simplification, and does not take into account indicators such as body posture and facial expression, which are used in the Leuven scale (Section 2.5.1). There were suggestions from some of the participants regarding emotion, such as giving the characters a face to display expressions, being able to demonstrate a physical act such as a hug (in response to emotion), and having an abstract representation of emotional expression. The representation of emotion may therefore be an interesting avenue to explore. However, it should be noted that the use of faces introduces another interesting problem of how much similarity is acceptable [ACH09]. It should also be said that emotion researchers do not agree on how to define emotions or how to measure them [SK11].

Observation tends to give the user an experience as more of a non-participant observer than as a participant observer (Section 2.4). There is some indirect interaction with the characters in Observation, such as supplying blocks or food, but there is no direct interaction. The participant observer experience could be explored, by providing direct interaction, which might include communication in some form. It may be that the user's sense of presence increases by providing the ability to interact with the characters. It also opens up possibilities for building up a profile of how an educator intervenes in the learning process (Section 4.4.3).

Observation does not represent the specific age of a character. The height, at one metre, is typical of a three- to four-year-old child. The characters use walk animations to move about, so there is an impression given that the children are of walking age. However, there is deliberately no attempt to create body proportions of any particular age (Section 4.2.3). There were comments from some participants (in the pilot study and the main study) that the characters' body proportions resembled those of an adult. There is no sense of age in any of the developmental areas represented in the characters, although there are constraints to prevent non-sensical combinations (Section 4.2.2). Incorporating the age into the characters was the most popular character feature chosen (from a list) by participants (Table 6.6) for several reasons (Section 6.2.5). It would appear to be sensible to represent the age for the characters but there are many implications for this. Even with an abstract representation, decisions would need to be made about how unique to make the characters' physical appearance. A straightforward approach could be taken whereby skeletal dimensions and associated body shapes could all be the same for a given age. Alternatively, plausible individuals could be generated using age-appropriate constraints, though not necessarily using large anthropometric databases [SYCGMT02]. Another physical implication is that animations would also be needed to represent age-appropriate movement, such as a very young child crawling. In terms of representing the development norms for a child, this could be informed by developmental theories and curricula guidance for early childhood practitioners [Dep08a].

8.3 Summary of findings

These findings are for the entire sample of early childhood education professionals, which included students and educators.

The perceived utility of a real-time 3D graphical simulation of children's play behaviour is demonstrated by the findings from sub-questions which show that: the simulation is an interesting way to explore the behaviours of young children; by using the simulation, the theoretical understanding behind children's play can be deepened; and by using the simulation, observational skills can be developed.

The perceived utility of the simulation is not influenced by: professional experience, number of real-life observations conducted of young children, or how much video games are played.

However, the student group that had undertaken role play based on early childhood using a 3D virtual world, as part of their studies, did report a higher perceived utility of the simulation.

The representation of a character's age is considered to be the most important character feature that was omitted from the abstract character in the simulation.

8.4 Implications of findings

These implications are for the entire sample of early childhood professionals, which included students and educators.

Utility It has been shown that a real-time 3D graphical simulation of children's play behaviour does have utility.

Firstly, it has been shown that the simulation is an interesting way to explore the behaviours of young children.

Secondly, it has been shown that by using the simulation, the theoretical understanding behind children's play can be deepened. The simulation implemented an interpretation of several aspects of child development including social play stage, blockplay stage, and egocentrism. This may indicate that further aspects of development could be implemented to give the characters a wider repertoire of behaviour. This view is supported by one educator who said during an interview:

> We could look at different theorists' approaches. You could look at a Piagetian model, or a Vygotsky, or a Bruner model. Perhaps look at comparisons but be doing that in the classroom in front of the students, or allowing them to experience it from those different perspectives. It's got a lot of potential.

Thirdly, it has been shown that using the simulation helps users to think about how they will conduct early childhood observations in the real-world.

The utility of the simulation may be influenced by several factors, including the element of novelty. However, the thesis of this work is that a combination of a real-time serious game with interactive 3D graphics, emergent gameplay, a physical environment, and characters with behaviour based on developmental theory, all help to provide a meaningful context, providing a bridge between theory and practice.

It is therefore possible that there may be place for such a simulation, to support curricula objectives on programmes of learning (Section 7.1.1) where theories of child development and the importance of observation are examined.

Wide appeal It has been shown that neither professional experience, nor the number of real-life observations conducted of young children, have any correlation with the utility of the simulation. This would suggest that the simulation appeals to a range of individuals, with varying prior experience of working with young children. It has been shown that there is no correlation between playing video games and the utility of the simulation. This would suggest that users of the simulation are not expected to be avid gamers. However, the highest utility was reported by a group who had used a 3D virtual world before, to simulate an early childhood environment, as part of their studies. This may suggest that users with prior experience of 3D virtual environments in an early childhood context are already 'tuned in' to such an experience.

The role of abstraction The representation of a character as an abstract universal figure is somewhat of a double-edged sword.

The abstraction of physical appearance reduces the amount of visual information, giving the ability to focus on other aspects of the character, such as the development which is represented as stages (social play and blockplay) and as behaviour (egocentrism), which are not explicitly associated with specific ages or age ranges in the characters.

However, it was shown that a character's age is considered to be the most important feature that was omitted from the abstract characters. This is in keeping with the EYFS [Dep08a] which sets out ages and developmental norms, to give practitioners guidelines for their practice. When defining characters or randomly generating them, incompatible combinations are built into, and enforced by Observation. These combinations are based upon stages though, rather than ages. However, as more aspects of development are added, the complexity grows, and, it is anticipated that there is likely to be a combinatorial explosion of plausible developmental profiles. Therefore, if age was added to characters, an important consideration is *how* age should be used to determine the development of the characters, and to a lesser extent, their physical appearance. The representation of age becomes even more interesting when the developmental timetables of children are accelerated or delayed causing a discord with their chronological age [Gul04].

8.5 Final remarks

There has been limited research in the area of simulations which represent children in their learning environments, and even less where those children are autonomous characters. Until this research, there had been no simulations where there was a representation of young children in their play-based learning environments. It is generally accepted that people are complex, which makes them challenging to simulate, but selective aspects *can* be represented, and used for the purposes of analysis. The characters in Observation may be gross simplifications in many ways, but they are designed to mirror the observations and subsequent models developed from early childhood research. For reflective practitioners that perform observations, such a simulation offers a novel way for bridging theory and practice.

Bibliography

[ACH09] Adrian Albin-Clark and Toby Howard. Automatically Generating Virtual Humans using Evolutionary Algorithms. In *Proceedings of Theory and Practice of Computer Graphics*, pages 61–64, Cardiff, June 2009. Eurographics. [15, 69, 155]

[ACHA11a] A. Albin-Clark, T. L. J. Howard, and B. Anderson. Real-time computer graphics simulation of blockplay in early childhood. *Computers & Education*, 57(4):2496–2504, December 2011. [52]

[ACHA11b] Adrian Albin-Clark, T. L. J. Howard, and B. Anderson. Visualisation of Blockplay in Early Childhood. In *Proceedings of Theory and Practice of Computer Graphics*, pages 53–60, Warwick, September 2011. Eurographics. [52]

[ACHA12] A. Albin-Clark, T. L. J. Howard, and B. Anderson. Simulating characters for observation. In *Proceedings of Computer Graphics Theory and Applications*, pages 501–502, Rome, Italy, February 2012. Springer. [52]

[Adv02] Advanced Interfaces Group. *MAVERIK version 6.2 (virtual reality system)*. Available from: http://aig.cs.man.ac.uk/maverik/maverik.php. Accessed: 12 April 2009, 2002. [61]

[ALA09] ALA Connect. *Asking the "gender" question*. Available from: http://connect.ala.org/node/80754. Accessed: 25 September 2011, 2009. [105]

[Ale09] Robin Alexander, editor. *Children, their World, their Education: Final report and recommendations of the Cambridge Primary Review*. Routledge, London, October 2009. [36]

[AN07] John B. Ahlquist and Jeannie Novak. *Game Development Essentials: Game Artificial Intelligence.* Thomson Delmar Learning, Clifton Park, NY, July 2007. [71]

[Ang09] Edward Angel. *Interactive Computer Graphics: A Top-Down Approach Using OpenGL.* Addison-Wesley, Boston, MA, fifth edition, 2009. [69]

[ANM96] Andrea L. Ames, David R. Nadeau, and John L. Moreland. *The VRML Sourcebook.* John Wiley & Sons, New York, 1996. [86]

[Bea09] Liana Beattie. FDE 2103 Managing Transitions and Other Practitioners to Deliver the Early Years Curriculum and Assessment Module Handbook 2009-2010, Foundation Degree in Early Years Practice, Edge Hill University. 2009. [136]

[Ber96] Anthony D. Bertram. *Effective early childhood educators: developing a methodology for improvement Volume 1.* PhD thesis, Coventry University, Unpublished, July 1996. [93]

[BF92] Gary Bishop and Henry Fuchs. Research Directions in Virtual Environments: Report of an NSF Invitational Workshop, March 23-24, 1992, University of North Carolina at Chapel Hill. *Computer Graphics*, 26(3):153–177, August 1992. [138]

[BF10] Jonathan Belman and Mary Flanagan. Designing Games to Foster Empathy. *Cognitive Technology*, 14(2):1–15, 2010. [93]

[Ble08] Blender Foundation. *Blender version 2.48a (3D content creation suite).* Available from: http://blender.org/. Accessed: 3 December 2008, Amsterdam, Netherlands, 2008. [70]

[Bli04] Blizzard Entertainment. *World of Warcraft (massively multiplayer online role-playing game).* Author, Versailles, France, November 2004. [25]

[BM06] Tina Bruce and Carolyn Meggitt. *Child Care & Education.* Hodder Arnold, London, fourth edition, May 2006. [41, 90]

[Boe08] Tom Boellstorff. *Coming of Age in Second Life: An Anthropologist Explores the Virtually Human.* Princeton University Press, Princeton, NJ, April 2008. [15]

[BP02] Tony Bertram and Chris Pascal. *Early Years Education: An International Perspective.* Qualifications and Curriculum Authority, London, July 2002. [36]

[Bri02] British Broadcasting Corporation. *Virtual School.* Available from: http://devvirtualschool.ncsl.org.uk/. Accessed: 16 October 2011, 2002. [35]

[Bru01] Tina Bruce. *Learning through play: Babies, Toddlers and the Foundation Years.* Hodder Arnold, London, 2001. [40]

[Brynda] Alan E. Bryman. Multimethod Research. In *Encyclopedia of Social Science Research Methods.* Available from: http://www.referenceworld.com/sage/socialscience/mmr.pdf. Accessed: 3 November 2011, n.d. [50]

[Bryndb] Alan E. Bryman. Triangulation. In *Encyclopedia of Social Science Research Methods.* Available from: http://referenceworld.com/sage/socialscience/triangulation.pdf. Accessed: 3 November 2011, n.d. [50]

[BS04] David M. Bourg and Glenn Seemann. *AI for Game Developers.* O'Reilly Media, Sebastopol, CA, July 2004. [76]

[Car09] Carnegie Mellon Entertainment Technology Center. *Panda3D (game engine).* Available from: http://www.panda3d.org/. Accessed: 19 May 2009, 2009. [62]

[CDS07] Robbie Cooper, Julian Dibbell, and Tracy Spaight. *Alter Ego: Avatars and their Creators.* Chris Boot, London, May 2007. [69]

[Ces08] Cessen. *Biped rig.* Available from: http://blenderartists.org/forum/showthread.php?131079-Simple-biped-rig-free-to-use. Accessed: 1 December 2009, 2008. [70]

[Che10] Donguk Cheong. The effects of practice teaching sessions in second life on the change in pre-service teachers' teaching efficacy. *Computers & Education*, 55(2):868–880, September 2010. [29, 35, 143]

[CMM07] Louis Cohen, Lawrence Manion, and Keith Morrison. *Research Methods in Education*. Routledge, Oxford, sixth edition, April 2007. [105]

[Com06] Community Playthings. *Spaces: Room layout for early childhood education*. Author, Robertsbridge, England, 2006. [82]

[Com10] Community Playthings. *2011 Catalogue*. Author, Robertsbridge, England, 2010. [64]

[Cou10] Erwin Coumans. *Bullet version 2.76 (physics library)*. Available from: http://bulletphysics.org/. Accessed: 14 May 2010, 2010. [64]

[Cry09] Crystal Space Team. *Crystal Space (3D engine)*. Available from: http://crystalspace3d.org/. Accessed: 19 May 2009, 2009. [62]

[Cur10] CurveShift Inc. *simSchool (classroom simulation software)*. Available from: http://www.simschool.net/. Accessed: 10 December 2010, 2010. [31, 35, 145]

[Cur11] Ian Currie. EYL 1001 A Unique Child Module Handbook 2011-2012, BA (Hons) Professional Practice and Leadership in Early Years, Edge Hill University. 2011. [136]

[DAJM07] Damien Djaouti, Julian Alvarez, Jean-Pierre Jessel, and Gilles Methel. Play, Game, World: Anatomy of a Videogame. In *Proceedings of Computer Games: AI, Animation, Mobile, Educational & Serious Games*, La Rochelle, France, November 2007. [106, 148]

[Dav07] Martin B. Davies. *Doing a Successful Research Project: Using Qualitative or Quantitative Methods*. Palgrave Macmillan, Basingstoke, England, February 2007. [46, 58, 98, 105, 113]

[Daw09] Catherine Dawson. *Introduction to Research Methods: A practical guide for anyone undertaking a research project.* How To Books, Oxford, fourth edition, 2009. [46, 50, 51, 56, 57, 105, 119]

[Del09] Delta3D Team. *Delta3D (game and simulation engine).* Available from: http://delta3d.org/. Accessed: 19 May 2009, 2009. [62]

[Dep07] Department for Education and Skills. *The Early Years Foundation Stage (CD-ROM).* Author, Nottingham, 2007. [141]

[Dep08a] Department for Children, Schools and Families. *Practice Guidance for the Early Years Foundation Stage.* Author, Nottingham, May 2008. [40, 148, 156, 158]

[Dep08b] Department for Children, Schools and Families. *Statutory Framework for the Early Years Foundation Stage: Setting the Standards for Learning, Development and Care for children from birth to five.* Author, Nottingham, May 2008. [36]

[dFO06] Sara de Freitas and Martin Oliver. How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? *Computers & Education*, 46(3):249–264, April 2006. [133]

[DL10] Barney Dalgarno and Mark J. W. Lee. What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology*, 41(1):10–32, January 2010. [17, 25, 119]

[DR76] Mary E. Durrett and Phyllis Richards. Computer-Based Simulation for Observing Child Behavior. *Home Economics Research Journal*, 5(2):88–91, December 1976. [26, 34, 35]

[Dub12] Jan Dubiel. In the process. In *Nursery World*, pages 14–18. Haymarket, London, February 2012. [37]

[Edg04] Margaret Edgington. *The Foundation Stage Teacher in Action: Teaching 3, 4 and 5 year olds.* Sage, London, third edition, October 2004. [37, 38, 41]

[Ele10] Electronic Arts. *Skate version 3 (video game)*. Author, Geneva, Switzerland, 2010. [69]

[Fac11] Facepunch Studios. *Garry's Mod version 10 (video game)*. Valve, Bellevue, WA, 2011. [23]

[Fal09] F. V. Falaye. Issues in Mounting Randomized Experiments in Educational Research and Evaluation. *Global Journal of Educational Research*, 8(1&2):21–27, 2009. [47]

[Fil09] FileFormat.Info. *Wavefront OBJ (file format summary)*. Available from: http://fileformat.info/format/wavefrontobj/. Accessed: 14 November 2011, 2009. [64]

[Fis06] Robert B. Fischler. *SimTeacher: Simulation-Based Learning in Teacher Education*. PhD thesis, Indiana University, April 2006. [31, 35, 145]

[FJMM79] Carol A. Falender, Maryalice Jordan-Marsh, and Robert Murar. The Simulation Model for Child Care Programs: Expanding Staff-Child-Parent Development. *Child and Youth Care Forum*, 8(2):113–125, June 1979. [27, 34, 35]

[FKC+04] Brian Ferry, Lisa Kervin, Brian Cambourne, Jan Turbill, Sarah Puglisi, Jonassen David, and John Hedberg. Online classroom simulation: The next wave for pre-service teacher education? In *Proceedings of Australasian Society for Computers in Learning in Tertiary Education*, pages 294–302, Perth, Western Australia, December 2004. ASCILITE. [30, 35, 143, 145]

[FM05] Jean A. Foley and Gretchen McAllister. Making it Real: SimSchool© a Backdrop for Contextualizing Teacher Preparation. *AACE Journal*, 13(2):159–177, April 2005. [28, 35, 143]

[G3D09] G3D Team. *G3D (3D engine)*. Available from: http://g3d.sourceforge.net/. Accessed: 19 May 2009, 2009. [61]

[Gar96] Paul L. Gardner. The dimensionality of attitude scales: a widely misunderstood idea. *International Journal of Science Education*, 18(8):913–919, December 1996. [109, 111]

[GD75] Cathy S. Greenblat and Richard D. Duke. *Gaming Simulation: Rationale, Design and Applications*. John Wiley & Sons, New York, 1975. [21, 22]

[GDC+11] Sue Gregory, Barney Dalgarno, Matthew Campbell, Torsten Reiners, Vicki Knox, and Yvonne Masters. Changing directions through VirtualPREX: engaging pre-service teachers in virtual professional experience. In *Proceedings of Australasian Society for Computers in Learning in Tertiary Education*, pages 491–501, Hobart, Tasmania, December 2011. ASCILITE. [29, 35, 143]

[GF92] Pat Gura and Froebel Blockplay Research Group, editors. *Exploring Learning: Young Children and Blockplay*. Paul Chapman, London, April 1992. [64, 65]

[GG06] Mark Girod and Gerald Girod. Exploring the Efficacy of the Cook School District Simulation. *Journal of Teacher Education*, 57(5):481–497, November 2006. [31, 35]

[GKV08] Glenda A. Gunter, Robert F. Kenny, and Erik H. Vick. Taking educational games seriously: using the RETAIN model to design endogenous fantasy into standalone educational games. *Educational Technology Research and Development*, 56(5):511–537, December 2008. [133]

[Gul04] Dominic F. Gullo. *Understanding Assessment and Evaluation in Early Childhood Education*. Teachers College Press, New York, second edition, November 2004. [34, 159]

[HCB+02] Piet Hut, Adrienne Cool, Charles Bailyn, Steve McMillan, Mario Livio, and Mike Shara. Panel Discussion on Observing Simulations and Simulating Observations. In *Stellar Collisions, Mergers and their Consequences*, volume 263 of *Astronomical Society of the Pacific*, pages 405–411, 2002. [44]

[HGaMB07] Casper Harteveld, Rui Guimarães, Igor Mayer, and Rafael Bidarra. Balancing pedagogy, game and reality components within a unique serious game for training levee inspection. In *Proceedings of Technologies for e-learning and digital entertainment*, pages 128–139, Hong Kong, China, 2007. Springer-Verlag. [133]

[Hir84] Elisabeth S. Hirsch, editor. *The Block Book*. National Association for the Education of Young Children, Washington, D.C., revised edition, 1984. [64, 65]

[Ibm10] Ibm. *SPSS Statistics version 19 (statistics)*. Author, Armonk, NY, 2010. [57]

[Inf09] Infinity Ward. *Call of Duty version Modern Warfare 2 (video game)*. Activision, Santa Monica, CA, 2009. [69]

[Irr09] Irrlicht Team. *Irrlicht (3D engine)*. Available from: http://irrlicht.sourceforge.net/. Accessed: 19 May 2009, 2009. [62]

[Isb06] Katherine Isbister. *Better Game Characters by Design: A Psychological Approach*. Interactive 3D Technology. Morgan Kaufmann, San Francisco, CA, June 2006. [69]

[Iti99] Christian M. Itin. Reasserting the philosophy of experiential education as a vehicle for change in the 21st century. *Experiential Education*, 22(2):91–98, 1999. [119]

[JD09] Joint Health Surveys Unit, National Centre for Social Research and Department of Epidermiology and Public Health, UCL Medical School. *Health Survey for England 2008: Trend tables*. The NHS Information Centre for health and social care, Leeds, England, 2009. [88]

[Kee09] Gerard Keegan. *The Observational Method*. Available from: http://gerardkeegan.co.uk/resource/observationalmeth1.htm. Accessed: 17th May 2012, 2009. [38, 39]

[KM11] Thomas Kesselring and Ulrich Müller. The concept of egocentrism in the context of Piaget's theory. *New Ideas in Psychology*, 29(3):327–345, December 2011. [67]

[Kri04] Klaus Krippendorff. Reliability in Content Analysis: Some Common Misconceptions and Recommendations. *Human Communication Research*, 30(3):411–433, 2004. [124]

[LC08] Kyunghwa Lee and Ikseon Choi. Learning Classroom Management Through Web-Based Case Instruction: Implications for Early Childhood Teacher Education. *Early Childhood Education Journal*, 35(6):495–503, June 2008. [28, 34, 35]

[LD97] Matthew Lombard and Theresa Ditton. At the Heart of It All: The Concept of Presence. *Journal of Computer-Mediated Communication*, 3(2), September 1997. [154]

[Lin10] Linden Research, Inc. *Second Life BVH animations.* Available from: http://static.secondlife.com/downloads/avatar/bvh_files.zip. Accessed: 9 December 2010, 2010. [15]

[Lin11] Ron Linser. What can we learn from the last 20 years of Role Based E-learning? Analysis and critique. In *Proceedings of Society for Information Technology & Teacher Education*, pages 2153–2158, Chesapeake, Virginia, 2011. Association for the Advancement of Computing in Education. [133]

[LK77] J. Richard Landis and Gary G. Koch. The Measurement of Observer Agreement for Categorical Data. *Biometrics*, 33(1):159–174, March 1977. [124]

[LSDB02] Matthew Lombard, Jennifer Snyder-Duch, and Cheryl C. Bracken. Content Analysis in Mass Communication: Assessment and Reporting of Intercoder Reliability. *Human Communication Research*, 28(4):587–604, October 2002. [123, 124]

[LVKD02] F. Laevers, E. Vandenbussche, M. Kog, and L. Depondt. *A Process-Oriented Child Monitoring System for Young Children.* Experiential Education. Centre for Experiential Education, Leuven, Belgium, 2002. [40, 80]

[MAM02] Janet Moyles, Siân Adams, and Alison Musgrove. *SPEEL Study of Pedagogical Effectiveness in Early Learning.* The Department for Education and Skills, Crown copyright, London, June 2002. [36]

[MBBK10] Jennifer Mahon, Bobby Bryant, Ben Brown, and Miran Kim. Using Second Life to enhance classroom management practice in teacher education. *Educational Media International*, 47(2):121–134, June 2010. [33, 35, 145]

[McC94] Scott McCloud. *Understanding Comics: The Invisible Art.* HarperPerennial, New York, May 1994. [69]

[Moj11] Mojang. *Minecraft version 1 (video game).* Author, Stockholm, Sweden, 2011. [69]

[MP62] Maurice Merleau-Ponty. *Phenomenology of Perception.* Routledge & Kegan Paul, London, 1962. [69]

[Nat12] NaturalMotion. *Endorphin version 2.7.1 learning edition (animation tool).* Author, Oxford, 2012. [69]

[Nic07] Janni Nicol. *Bringing the Steiner Waldorf Approach to your Early Years Practice.* David Fulton, London, May 2007. [69]

[Nic12] Scott Nicholson. Completing the Experience: Debriefing in Experiential Educational Games. In *Proceedings of Society and Information Technologies*, pages 117–121, Winter Garden, FL, 2012. International Institute of Informatics and Systemics. [56, 57, 137]

[Nok10] Nokia. *Qt version 4.7 (application and user interface framework).* Available from: http://qt.nokia.com/. Accessed: 15 December 2010, Espoo, Finland, 2010. [64, 90]

[Nsp10] Nspcc. *Child protection fact sheet: The definitions and signs of child abuse.* NSPCC, London, June 2010. [149]

[Ogr09] Ogre Team. *Ogre (3D engine).* Available from: http://ogre3d.org/. Accessed: 2 April 2009, 2009. [62]

[Ope09] Open Scene Graph Team. *Open Scene Graph (3D engine).* Available from: http://www.openscenegraph.org/. Accessed: 19 May 2009, 2009. [61]

[Pal10] Julie Pallant. *SPSS Survival Manual: A step by step guide to data analysis using SPSS.* Open University Press, Maidenhead, England, fourth edition, November 2010. [108, 109, 111, 113]

[Par32] Mildred B. Parten. Social participation among pre-school children. *The Journal of Abnormal & Social Psychology*, 27(3):243–269, October 1932. [65]

[Pou09] Linda Pound. *How children learn 3: contemporary thinking and theorists.* Practical Pre-School Books, London, September 2009. [148]

[PPM+03] Michal Ponder, George Papagiannakis, Tom Molet, Nadia Magnenat-Thalmann, and Daniel Thalmann. VHD++ Development Framework: Towards Extendible, Component Based VR/AR Simulation Engine Featuring Advanced Virtual Character Technologies. In *Proceedings of Computer Graphics International*, pages 96–104, Tokyo, Japan, 2003. IEEE Computer Society. [62]

[Pre02] Marc Prensky. *Why NOT simulation?* Available from: http://www.marcprensky.com/writing/. Accessed: 14 May 2011, 2002. [64]

[Pre04] Marc Prensky. *Interactive Pretending: An Overview of Simulation.* Available from: http://www.marcprensky.com/writing/. Accessed: 14 May 2011, 2004. [23, 24]

[QAv10] QAvimator Team. *QAvimator version January 2010 (BVH animation editor).* Available from: http://qavimator.org/. Accessed: 8 December 2010, 2010. [79]

[Rad07] Paul Rademacher. *GLUI version 2.36 (user interface library).* Available from: http://sourceforge.net/projects/glui/. Accessed: 19 July 2010, 2007. [63]

[Ran08] Justus J. Randolph. *Multidisciplinary Methods in Educational Technology Research and Development*. HAMK University of Applied Sciences, Hämeenlinna, Finland, December 2008. [46, 57]

[Ree11] Carlton Reeve. Simulating Failure: Why Simulations Don't Always Work. In *Proceedings of Games+Learning+Society*, pages 191–199, Madison, WI, 2011. ETC Press. [30, 145]

[Rob00] Nate Robins. *GLM (Wavefront OBJ model file format manipulation library)*. Available from: http://xmission.com/~nate/tutors.html. Accessed: 1 December 2009, 2000. [64, 70]

[Sch08] Daniel K. Schneider. *Methodology tutorial - qualitative data analysis*. Available from: http://edutechwiki.unige.ch/en/Methodology_tutorial_-_qualitative_data_analysis#Code-book_creation_according_to_theory. Accessed: 4 March 2012, October 2008. [119, 121]

[SGG07] Joan Santer, Carol Griffiths, and Deborah Goodall. *Free Play in Early Childhood*. National Children's Bureau, London, 2007. [36]

[She06] Allen Sherrod. *Ultimate 3D Game Engine Design & Architecture*. Game Development. Charles River Media, Boston, MA, December 2006. [62]

[sim08] simSchool blog. *Field Research Report Spring*. Available from: http://simschool.org/simblog. Accessed: 17 April 2012, 2008. [32]

[SK11] Michelle Shiota and James W. Kalat. *Emotion*. Wadsworth Cengage Learning, Belmont, CA, second edition, January 2011. [155]

[Skr10] Simon Skrødal. *Virtual Classroom Simulation: Design and Trial in a Preservice Teacher Education Program*. PhD thesis, The University of Adelaide, June 2010. [32, 35, 48, 145, 153]

[Smi97] Mark K. Smith. *Participant observation and informal education*. Available from: http://www.infed.org/research/participant_observation.htm/. Accessed: 19 October 2011, 1997. [91]

[SMPJ06] Jan-Willem Strijbos, Rob L. Martens, Frans J. Prins, and Wim M. G. Jochems. Content analysis: What are they talking about? *Computers & Education*, 46(1):29–48, January 2006. [123]

[Spe91] Paul E. Spector. *Summated Rating Scale Construction: An Introduction*. Quantitative Applications in the Social Sciences. Sage, Newbury Park, CA, November 1991. [108]

[Spi03] Marydee A. Spillett. Peer debriefing: who, what, when, why, how. *Academic Exchange Quarterly*, 7(3):36–41, September 2003. [45, 123]

[Sta00] Statistical & Technical Team. *A Practical Guide to Sampling*. National Audit Office, London, 2000. [47]

[Ste01] Steve Stemler. An overview of content analysis. *Practical Assessment, Research & Evaluation*, 7(17), 2001. [124]

[SW05] Penelope Sweetser and Janet Wiles. Scripting versus emergence: issues for game developers and players in game environment design. *International Journal of Intelligent Games and Simulations*, 4(1):1–9, 2005. [24]

[SYCGMT02] Hyewon Seo, Lydia Yahia-Cherif, Taro Goto, and Nadia Magnenat-Thalmann. GENESIS: Generation of E-Population Based on Statistical Information. In *Proceedings of Computer Animation*, pages 81–85, Geneva, Switzerland, 2002. IEEE Computer Society. [156]

[TB10] Kathy C. Trundle and Randy L. Bell. The use of a computer simulation to promote conceptual change: A quasi-experimental study. *Computers & Education*, 54(4):1078–1088, May 2010. [47]

[TM02] Daniel Thalmann and Jean-Sébastien Monzani. Behavioural Animation of Virtual Humans: What Kind of Laws and Rules? In *Proceedings of Computer Animation*, pages 144–153, Geneva, Switzerland, 2002. IEEE Computer Society. [70]

[Tro06] William M. K. Trochim. Nonprobability Sampling. In *Research Methods Knowledge Base*. Available from:

http://www.socialresearchmethods.net/kb/sampnon.php. Accessed: 4 November 2011, 2006. [52]

[Uca11] Ucas. *UCAS*. Available from: http://www.ucas.ac.uk/. Accessed: 28 September 2011, 2011. [104]

[Uni09] Unity Technologies. *Unity (game development tool)*. Available from: http://unity3d.com/. Accessed: 19 May 2009, 2009. [62]

[UW10] Mary Ulicsak and Martha Wright. *Games in Education: Serious Games*. Futurelab, Bristol, England, June 2010. [25, 133]

[Val09] Valve. *Left for Dead version 2 (video game)*. Author, Bellevue, WA, 2009. [69]

[Vic10] Lilla Vicsek. Issues in the Analysis of Focus Groups: Generalisability, Quantifiability, Treatment of Context and Quotations. *The Qualitative Report*, 15(1), January 2010. [125]

[Wat00] Marley W. Watkins. *Monte Carlo PCA for Parallel Analysis (statistics)*. Ed & Psych Associates, State College, PA, 2000. [109]

[Wei11] Matthew Weinstein. *TAMS Analyzer version 4.15b1h (qualitative research tool)*. Available from: http://tamsys.sourceforge.net/. Accessed: 3 October 2011, 2011. [58]

[WK00] Karyn Wellhousen and Judith Kieff. *A Constructivist Approach to Block Play in Early Childhood*. Wadsworth, Belmont, CA, December 2000. [64, 65]

[Wri04] Will Wright. Sculpting Possibility Space (audio presentation). In *Accelerating Change*, Stanford University, Palo Alto, CA, November 2004. Available from: http://itc.conversationsnetwork.org/shows/detail376.html. Accessed: 17 July 2012. [64]

Appendix A

Data collection

A.1 Institution call for participation

* denotes wildcard for institution name.

University of * Bedfordshire, Birmingham, Bolton, Chester, Chichester, Cumbria, Derby, East Anglia, East London, Edinburgh, Exeter, Glasgow, Gloucestershire, Greenwich, Hertfordshire, Huddersfield, Hull, London (Goldsmiths), London (Institute of Education), Oxford, Reading, Sheffield, Stirling, Sunderland, the West of England, the West of Scotland, Wales (Newport), Wales (Trinity Saint David), Warwick, Winchester, Wolverhampton, Worcester.

*** University** Anglia Ruskin, Bangor, Bath Spa, Birmingham City, Canterbury Christ Church, Cardiff, Edge Hill, Glyndwr, Leeds Metropolitan, Liverpool John Moores, London Metropolitan, Manchester Metropolitan, Middlesex, Nottingham Trent, Open, Oxford Brookes, Plymouth, Roehampton, Teesside.

University * Campus Suffolk.

University College * Birmingham, Plymouth St Mark & St John.

*** University College** Bishop Grosseteste, Newman, St Mary's (Belfast), Stranmillis.

Research Base Pen Green.

A.2 Questionnaire items

Early childhood experience

1 What has been your highest level of qualification awarded which has an aspect of early childhood within it? (multiple-choice)

2 How much time have you spent as a paid employee in an early childhood based role? (metric years, metric months)

3 Approximately how many observations of young children's learning have you done? (free-response)

Before using the simulation

4 Before using the simulation, which stages of play in young children did you know about? Tick all that apply. (multiple-response)

5 Before using the simulation, which stages of play in young children had you observed? Tick all that apply. (multiple-response)

6 Before using the simulation, which stages of blockplay in young children did you know about? Tick all that apply. (multiple-response)

7 Before using the simulation, which stages of blockplay in young children had you observed? Tick all that apply. (multiple-response)

8 Before using the simulation, did you know about egocentrism as defined by Piaget? (multiple-choice)

9 Before using the simulation, had you observed egocentrism as defined by Piaget? (multiple-choice)

After using the simulation

10 The simulation has increased my understanding of social play stages. (5-point Likert-scale)

11 The simulation has increased my understanding of blockplay stages. (5-point Likert-scale)

12 The simulation has increased my understanding of egocentrism. (5-point Likert-scale)

13 The simulation has increased my understanding of the connections between social play, blockplay, and egocentrism. (5-point Likert-scale)

14 Based upon the current character behaviours (social play, blockplay, egocentrism) in the simulation, would the addition of any of the following cause you to observe the characters in a different way? Tick all that apply. (multiple-response)

15 If you have ticked any of the options in question 14, why did you do so? (free-response)

16 It was useful to move among the characters. (5-point Likert-scale)

17 It was useful to change my viewing position. (5-point Likert-scale)

18 It was useful to influence the well-being of the characters. (5-point Likert-scale)

19 It was useful to define the behaviour of the characters. (5-point Likert-scale)

20 It was useful to add characters with random behaviours. (5-point Likert-scale)

21 It was useful to modify the terrain. (5-point Likert-scale)

22 It was useful to dress the scene by adding furniture, e.g. tables, chairs. (5-point Likert-scale)

23 It was useful to add shelves. (5-point Likert-scale)

24 It was useful to be charged for objects. (5-point Likert-scale)

25 Using the simulation was an interesting way to explore the behaviours of young children. (multiple-choice)

26 The simulation has helped me to think about how I will conduct early childhood observations in the real-world. (multiple-choice)

Personal

27 My age is . . . (free-response)

28 My sex is . . . (multiple-choice)

29 How many hours per week do you spend playing video games (on any platform, e.g. computer, console, handheld device)? (free-response)

Comments

30 Help us to improve Observation by telling us about your experiences. Report bugs, Request features, Have your say. (free-response)

A.3 Focus group transcription sample

Q = researcher, A to D = participants.

> *Q:* Were you able to make sense of the behaviours, by observing them?
>
> *B:* At the end, yeah. At the beginning I was like, “I have not a clue what these were” [laughs]. I learnt from the characters that, “Oh, I can match that to that without even clicking on the characters.”

A: Yeah.

B: And to see the thing above his head.

A: Yeah. The apple. I thought that was a good indicator ... "I need to feed you." [laughs]

B: Yeah. Or the things they've played with above their heads. You can see what the character was, and what the child's behaviour was, without clicking on them.

C: I was completely confused at first because my second character was an observer. It was just dead sad because it had nothing to observe [laughs] and it was just stood there. I said, "Why is he stood there?" 'Cause I was wanting that one to be happy, before I made any more, but not realising that I had to make more, to make it happy. It was really frustrating 'cause I could see it stood there looking sad and following this other person around. I thought it was dead sad.

Q: What did you do about that?

C: I realised what I needed to do and it needed something to observe. I made a few more characters and put the blocks in so it had something to watch. I understood that it needed to observe, and I knew there was another character in there with it. I was like, "Why isn't it looking at that one?" and I realised that that one was hungry, so that was why it wasn't doing anything. [laughs]

Q: Could you make sense of the different blockplay that they were doing, and the social play that was set up, and the egocentrism that I put in, a brief mention of that?

C: It was good because when you had a few characters playing with the blocks and you had quite a few blocks there you could definitely see one character building with things, or moving them, and the other person taking them.

B: I was really happy when I saw that ...

C: Yeah.

B: ... when children were actually building something.

C: [laughs] And then the other one taking them away and putting them somewhere else.

Q: Did you see someone pinch them?

C: Yeah.

D: My one started making himself, didn't he? Out of the blocks ...

B: Yeah. It started making a person.

D: ... it was building the legs of a person and it was getting up to a body. It was showing how he was watching, or seeing everything, and creating it from there. He had a higher level of building than some of the other kids.

B: Yeah, got the whole difference in blockplay, didn't we? Simple, then it was advanced blockplay.

C: The other one pinching it and taking it into the other part. [laughs]

D: Someone knocked it over. It came over innocent [laughs].

Q: Did you prefer to define the characters or have them totally randomised?

B: I like defining them.

A: Yeah. I preferred to have them defined because you knew what they needed then. Like the ones that needed the blocks, there was a stacking one. You obviously knew that you needed to put some shelves in and some things for them, or shelves on the floor to make them stack. You knew what they needed. If you didn't know and they didn't have labels, you'd be a bit confused. It would be harder to find.

B: I didn't realise which one was which when I made up the characters. I liked putting the stuff in and seeing which one played, rather than catering for that child. I liked catering for the community of children.

A: Yeah.

D: I suppose that's what you do in real life anyway isn't it? You can't define someone 'cause they change and develop anyway.

C: On my first go I done them defined and on my second go, I done them randomised, so that I could cater for the children. Because you couldn't know who you'd get in a nursery. Especially us going on to placement. We don't know the children. We get to know them, but we don't know them as soon as we walk in. We can't walk in and say, "You're egocentric. You're this. You're that." It just doesn't work like that.

A.4 Interview transcription sample

Q = researcher, A = participant.

A: Yeah. I enjoyed it. I'm a bit of a geek so I like that kind of thing.

Q: OK.

A: I enjoyed having a play about with it and because I don't tend to read the instructions, I had a play with it first, and then, when I didn't really understand what I was doing, I went back and read the instructions and did it again properly, and that was much better. Yeah, I thought it was really interesting. I'd seen [person1] playing on Sims, years ago, she loved The Sims and was obsessed with it, so I had a little bit of an idea about the things over the head. But I thought it was really interesting and a good tool for maybe students like [person2] to be looking for different schemas and things, and unpicking them, and talking about that.

Q: I noticed that on your survey you ticked that you've had experience in all the things I was asking about.

A: Yeah.

Q: I wondered what difference that made to you as a person using it. Did you get anything from the content of the simulation?

A: Yeah, I knew about the concepts involved . . .

Q: Yeah.

A: . . . already, but it was interesting to see. Obviously in a class of children, you'll get children with certain schemas, but you can't necessarily plan for which ones will show themselves, so it was nice to be able to compare the different stages of development and to have that all at my disposal. And I enjoyed having a play, at picking out different levels of development, and different schemas and seeing how they played alongside each other. That was really good. And not something you can simulate in everyday life, you know what I mean?

Q: Yeah.

Q: Can you relate what you saw to things that you've seen yourself, in the real world?

A: Yeah, the things the children were doing, and, once I got a handle on what was going on, once I read it properly, and I realised what was happening, yeah I definitely could. The bridging, and all the different things they were doing with the blocks, that's the kind of thing that you see children doing, and ...

Q: Yeah.

A: ... the moving stuff around. Yeah, it definitely reflected what you would see children doing.

A.5 Confidentiality

Online questionnaire data was collected through a PHP/MySQL web application hosted by secure servers in the School of Computer Science at the university. An 8-digit activation code (e.g. 93369852) was generated and stored for each new user that registered in order to download the software. The activation code was used when a genuine user replies to an automated email requesting that they activate their account. This activation code provided anonymous unique identification for any data that was collected during the completion of online questionnaires and subsequently downloaded later using phpMyAdmin for offline processing. The anonymous activation code and email address were only kept together in one place, in the secure MySQL web server database in the School of Computer Science on ramen.cs.man.ac.uk. Data was stored anonymously and securely on a single desktop computer at a secure location used only by this author using 256-bit AES encryption on a Mac OS X Snow Leopard disk image with an encryption password of strength Excellent.

The encrypted data comprises: questionnaire data (raw and processed), data on voice recorder from focus groups and transcriptions, and data on voice recorder from interviews and transcriptions.

Any hand-written notes taken during focus groups and interviews were stored at a secure location used only by this author.

Appendix B

Data analysis

B.1 Likert scale validity

B.1.1 Simulation Utility Scale

Item	Component coefficients	
	Component 1	Component 2
moveAmong	.809	
dress	.804	
terrain	.767	
define	.758	
random	.740	
influence	.739	
viewpoint	.637	
shelves	.590	.590
charged	.546	.734

Table B.1: Component matrix for PCA of potential Simulation Utility Scale items.

Item	Pattern coefficients		Structure coefficients		Communalities
	C1	C2	C1	C2	
moveAmong	**.925**	-.118	**.877**	.265	.780
define	**.834**	-.062	**.808**	.283	.656
influence	**.809**	-.054	**.786**	.281	.621
dress	**.736**	.151	**.798**	.455	.656
viewpoint	**.683**	-.026	**.672**	.256	.452
random	**.541**	.336	**.680**	.560	.557
terrain	**.538**	.382	**.696**	.604	.605
charged	-.079	**.944**	.312	**.912**	.836
shelves	.062	**.807**	.396	**.833**	.696

Table B.2: Pattern and structure matrix for PCA with Oblimin rotation of two factor solution of potential Simulation Utility Scale items. Major loadings are shown in bold. C1 = Component 1.

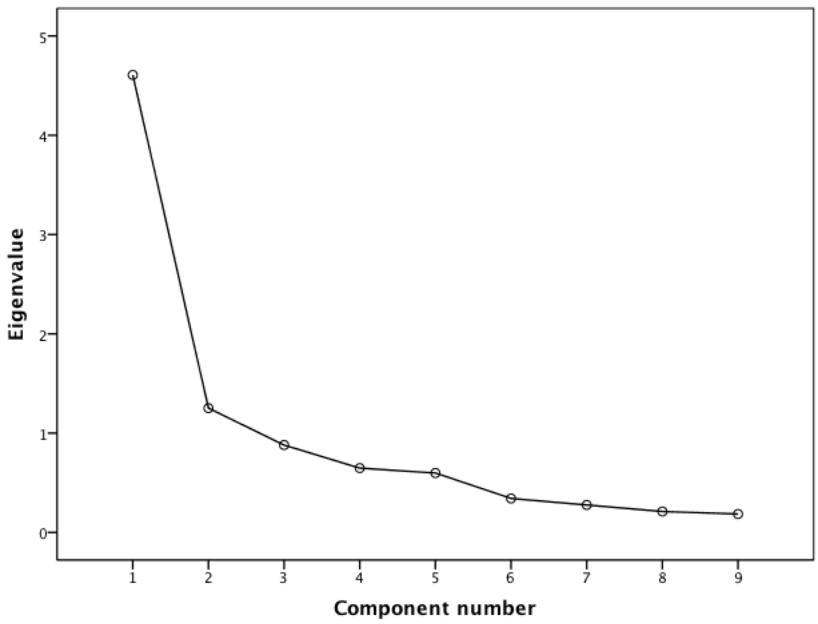


Figure B.1: Scree plot of potential Simulation Utility Scale items showing one component above the elbow.

Item	Component coefficients
	Component 1
moveAmong	.849
dress	.811
define	.797
influence	.766
terrain	.752
random	.724
viewpoint	.656

Table B.3: Component matrix for PCA of final Simulation Utility Scale items.

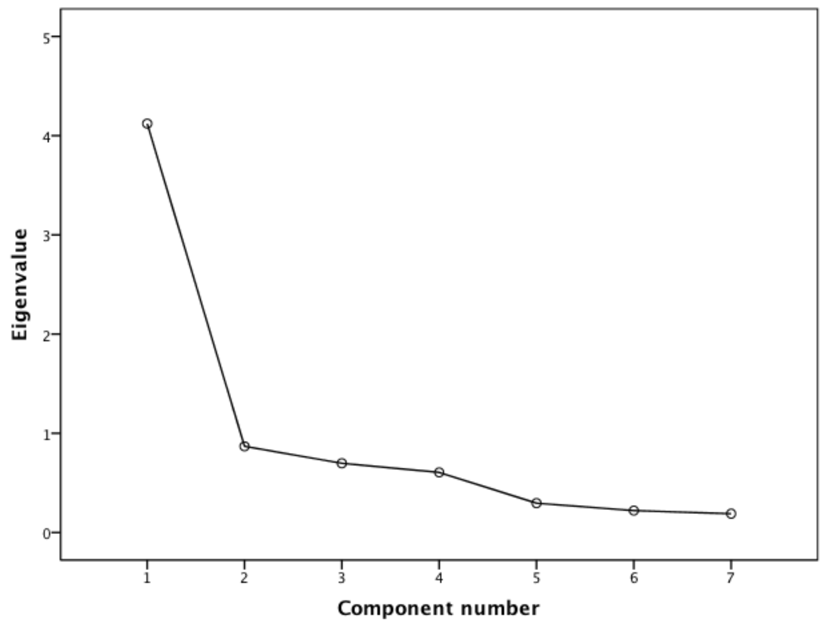


Figure B.2: Scree plot of final Simulation Utility Scale items showing one component above the elbow.

B.1.2 Understanding Scale

Item	Component coefficients
	Component 1
block	.910
connections	.910
egocentrism	.871
social	.858

Table B.4: Component matrix for PCA of Understanding Scale items.

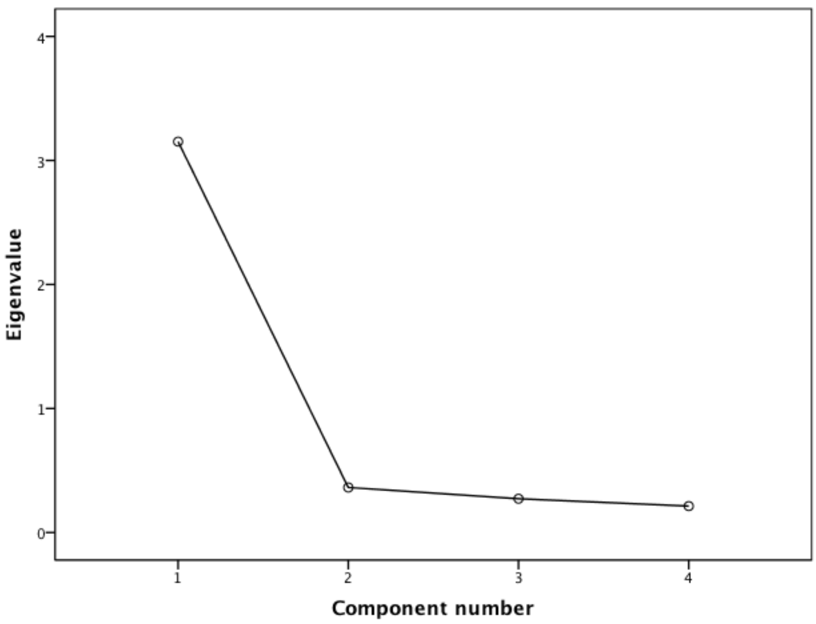


Figure B.3: Scree plot of Understanding Scale items showing one component above the elbow.

B.2 Correlations

		a	e	g	o	s	u
age	Correlation	1	**.961**	-.038	**.428**	.053	-.164
	Sig.		.000	.795	.002	.714	.256
employment	Correlation		1	-.015	**.373**	.029	-.155
	Sig.			.919	.008	.839	.283
games	Correlation			1	-.129	-.193	.071
	Sig.				.371	.179	.624
observations	Correlation				1	.203	.008
	Sig.					.158	.955
simulation	Correlation					1	**.656**
	Sig.						.000
understanding	Correlation						1
	Sig.						

Table B.5: Correlations between variables for entire dataset (students $n = 44$, educators $n = 6$). Horizontal variables are abbreviated. Significant correlation (Pearson, 2-tailed) at the .001 level is shown in bold.

		a	e	g	o	s	u
age	Correlation	1	.232	-0.88	.082	.018	.019
	Sig.		.130	.569	.596	.907	.905
employment	Correlation		1	-.163	.078	-.045	.001
	Sig.			.290	.615	.772	.993
games	Correlation			1	**.394**	-.149	.002
	Sig.				.008	.335	.987
observations	Correlation				1	-.145	.031
	Sig.					.347	.844
simulation	Correlation					1	**.713**
	Sig.						.000
understanding	Correlation						1
	Sig.						

Table B.6: Correlations between variables for students (n = 44). Horizontal variables are abbreviated. Significant correlation (Pearson, 2-tailed) at the .001 level is shown in bold.

B.3 Inferential statistics

	B	S.E.	Wald	df	Sig.	Odds ratio	95% C.I. for odds ratio Lower	Upper
observations	.027	.028	.976	1	.323	1.028	.973	1.085
employment	-.066	.047	1.947	1	.163	.936	.854	1.027
games	-.144	.096	2.276	1	.131	.866	.718	1.044
education	-2.607	1.859	1.967	1	.161	.074	.002	2.818
level	2.063	1.221	2.855	1	.091	7.872	.719	86.206
Constant	4.074	2.034	4.011	1	.045	58.799		

Table B.7: Logistic regression predicting likelihood of students ($n = 44$) being influenced in how they will conduct future real-life observations.

Appendix C

Activity

C.1 Pilot study version

This document was originally created in a word processor. It has been converted to LaTeX for inclusion and differs from its original appearance.

C.1.1 Prerequisites

If you havent done so already, familiarise yourself with Observation's interface, how to add characters and objects, how to get around the world, and how to monitor what is going on. You may wish to refer to the user manual.

C.1.2 Task description

You are going to observe some characters at play, monitor them, and make interventions in order to maximise the well-being of every individual. You will need to use both visual and textual information to monitor events; Table C.1 summarises this for you.

Tip: You may find it easier to pause the simulation when selecting characters and monitoring.

Tip: Make use of the walk/fly/follow features plus mouse/keyboard to move around within the world.

Before you start

Ensure Observation has a blank 10x10 map (this is the default at startup). If not, make a new one.

Complete 1–11 in Table C.2 **in order**.

Where to look	Information
Characters in the world	Well-being vest, what they are doing, goal object above their head, connections to other characters
Character information pane	Well-being, current action, object in which they are interested, egocentric, play stage, blockplay stage
Event log	Population events, events filtered on a selected character
Status bar	Population size, population well-being

Table C.1: Monitoring character events.

It is now time to complete the online questionnaire.

Item	Instructions
1	Add a character with the following: Social play stage - None, Egocentric - No Monitor the population/intervene
2	Add a character with the following: Social play stage - Unoccupied Monitor the population/intervene
3	Add a character with the following: Social play stage - Onlooker Monitor the population/intervene
4	Add a character with the following: Social play stage - Solitary, Blockplay stage - Stacking, Egocentric - No Monitor the population/intervene
5	Add a character with the following: Social play stage - Parallel, Blockplay stage - Bridging Monitor the population/intervene
6	Add a character with the following: Social play stage - Solitary, Blockplay stage - Stacking, Egocentric - Yes Monitor the population/intervene
7	Add a character with the following: Social play stage - Solitary, Blockplay stage - Enclosures, Egocentric - Yes Monitor the population/intervene
8	Add **2** characters with the following: Social play stage - Associative Monitor the population/intervene Look out for inventory sharing and comments in event log
9	Add a character with the following: Social play stage - Parallel, Blockplay stage - Patterns and Symmetry Monitor the population/intervene
10	Add **3** characters with the following: Social play stage - Cooperative Monitor the population/intervene Look out for inventory sharing in event log
11	Add a character with the following: Social play stage - Solitary, Blockplay stage - Stacking, Egocentric - No Monitor the population/intervene

Table C.2: Defining and adding characters.

C.2 Main study version

This document was originally created in a word processor. It has been converted to LaTeX for inclusion and differs from its original appearance.

C.2.1 Part 1 Underpinning theory

Prerequisites Define and add characters, choose and add objects, get around the world, monitor characters.

You are going to look carefully at:

- the blockplay being undertaken by the various characters
- how social the characters are
- the effects of egocentrism.

Make interventions where necessary by adding blocks required by the characters.

Before you start

- Ensure Observation has a blank 10x10 map (default at startup). If not, make a new one.
- In Options, select the Character tab, and in Objects **un**check the Credits Active option.

Complete 1–11 in Table C.3 **in order**.

C.2.2 Part 2 Creativity

Prerequisites Add random characters, choose and add objects, manipulate objects, get around the world, monitor characters, edit terrain.

You are now going to be creative by modifying the environment. You will also be adding randomly generated characters rather than defining them yourself. Make interventions where necessary by adding blocks required by the characters.

Before you start

- Make a new map to be whatever size you like, by adjusting the two sliders.
- Set characters to random.

Item	Instructions
1	Add a character with the following: Social play stage - None, Egocentric - No
2	Add a character with the following: Social play stage - Unoccupied
3	Add a character with the following: Social play stage - Onlooker
4	Add a character with the following: Social play stage - Solitary, Blockplay stage - Stacking, Egocentric - No
5	Add a character with the following: Social play stage - Parallel, Blockplay stage - Bridging
6	Add a character with the following: Social play stage - Solitary, Blockplay stage - Stacking, Egocentric - Yes
7	Add a character with the following: Social play stage - Solitary, Blockplay stage - Enclosures, Egocentric - Yes
8	Add **2** characters with the following: Social play stage - Associative Look out for inventory sharing and comments in event log
9	Add a character with the following: Social play stage - Parallel, Blockplay stage - Patterns and Symmetry
10	Add **3** characters with the following: Social play stage - Cooperative Look out for inventory sharing in event log
11	Add a character with the following: Social play stage - Solitary, Blockplay stage - Stacking, Egocentric - No

Table C.3: Defining and adding characters.

- In Options, select the Character tab, and in Objects **un**check the Credits Active option.

Complete 1–5 in Table C.4 **in any order**.

Item	Instructions
1	Change the shape of the terrain, by grabbing the terrain handles
2	Texture the terrain
3	Add some chairs and tables
4	Add some shelves (they will appear to float) and place different types of blocks onto them
5	Add as many (random) characters as you wish

Table C.4: Creativity instructions.

C.2.3 Part 3 Balancing act

Prerequisites Define and add characters, choose and add objects, get around the world, monitor characters, empathise with characters, activate credit system, monitor credits you have left.

You are going to try and maximise the well-being of every individual. You can do this by:

- adding objects that characters require
- supplying food (apples)
- empathising with a character for a while.

You are also going to be using Observation with **credits** turned on. You will be charged for objects that are added to the scene, so you may run out of credits if you add too many objects! Credits from deleted objects cannot be recouped. Bonus credits can be achieved by sustaining an extremely high level of well-being for the population as a whole.

Before you start

- Ensure Observation has a blank 10x10 map (default at startup). If not, make a new one.

- In Options, select the Character tab, and in Objects check the Credits Active option.

Complete 1–3 in Table C.5 **in any order**.

Item	Instructions
1	Add **2** characters with the following: Social play stage - Solitary, Blockplay stage - Stacking, Egocentric - No
2	Add **2** characters with the following: Social play stage - Parallel, Blockplay stage - Bridging
3	Add **2** characters with the following: Social play stage - Solitary, Blockplay stage - Enclosures, Egocentric - Yes

Table C.5: Balancing act instructions.

It is now time to complete the online questionnaire.